## NSW Roads and Maritime Services

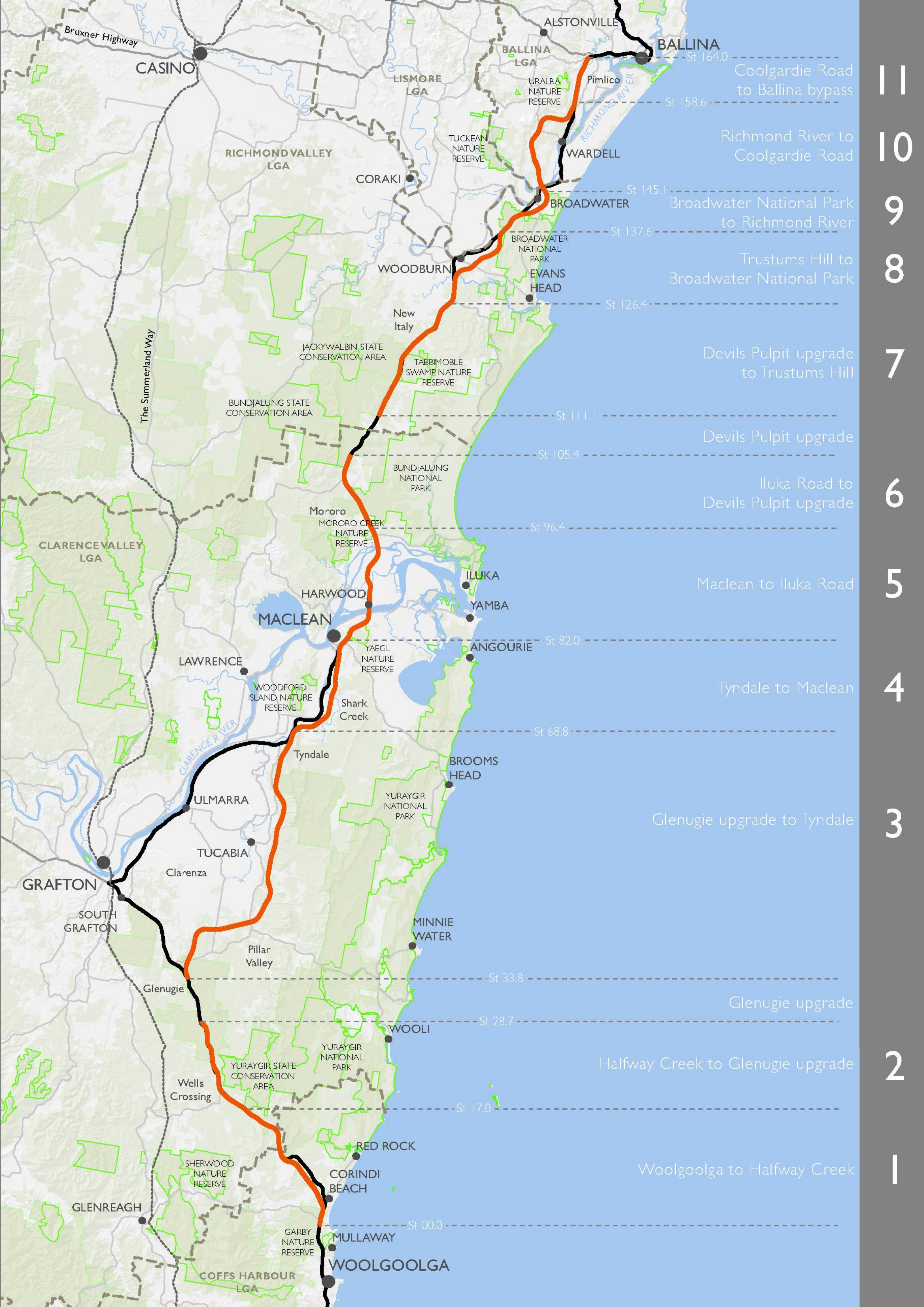
### WOOLGOOLGA TO BALLINA | PACIFIC HIGHWAY UPGRADE

# THREATENED GLIDER MANAGEMENT PLAN

**Version 1.0**

**November 2013**

**Prepared by: NSW Roads and Maritime Services, Aurecon and Sinclair Knight Merz**



ALSTONVILLE
BALLINA
St 164.0
Coolgardie Road to Ballina bypass
11
Bruxner Highway
CASINO
BALLINA LGA
LISMORE LGA
URALBA NATURE RESERVE
Pimlico
RICHMOND RIVER
St 158.6
Richmond River to Coolgardie Road
10
TUCKEAN NATURE RESERVE
WARDELL
RICHMOND VALLEY LGA
CORAKI
St 145.1
BROADWATER
Broadwater National Park to Richmond River
9
St 137.6
BROADWATER NATIONAL PARK
Trustums Hill to Broadwater National Park
8
WOODBURN
EVANS HEAD
St 126.4
New Italy
JACKYWALBIN STATE CONSERVATION AREA
TABBIMOBLE SWAMP NATURE RESERVE
Devils Pulpit upgrade to Trustums Hill
7
The Summerland Way
BUNDJALUNG STATE CONSERVATION AREA
St 111.1
Devils Pulpit upgrade
St 105.4
BUNDJALUNG NATIONAL PARK
Iluka Road to Devils Pulpit upgrade
6
Mororo
MORORO CREEK NATURE RESERVE
St 96.4
CLARENCE VALLEY LGA
ILUKA
Maclean to Iluka Road
5
HARWOOD
YAMBA
MACLEAN
St 82.0
YAEGL NATURE RESERVE
ANGOURIE
LAWRENCE
WOODFORD ISLAND NATURE RESERVE
Tyndale to Maclean
4
Shark Creek
CLARENCE RIVER
St 68.8
Tyndale
BROOMS HEAD
ULMARRA
YURAYGIR NATIONAL PARK
Glenugie upgrade to Tyndale
3
TUCABIA
Clarenza
GRAFTON
SOUTH GRAFTON
MINNIE WATER
Pillar Valley
St 33.8
Glenugie
Glenugie upgrade
St 28.7
WOOLI
YURAYGIR NATIONAL PARK
YURAYGIR STATE CONSERVATION AREA
Halfway Creek to Glenugie upgrade
2
Wells Crossing
St 17.0
RED ROCK
SHERWOOD NATURE RESERVE
CORINDI BEACH
Woolgoolga to Halfway Creek
1
GLENREAGH
St 00.0
GARBY NATURE RESERVE
MULLAWAY
WOOLGOOLGA
COFFS HARBOUR LGA

# Contents

# 1. Introduction

## 1.1 Project overview

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval for the Woolgoolga to Ballina (W2B) Pacific Highway upgrade project (the project / the action), on the NSW North Coast. The approval is sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The location of the project is shown in the figure above.

Since 1996, both the Australian and NSW governments have contributed funds to the upgrade of the 664-kilometre section of the Pacific Highway between Hexham and the Queensland border, as part of the Pacific Highway Upgrade Program.

Both governments have a shared commitment to finish upgrading the highway to a four-lane divided road as soon as possible. For the purposes of the EIS, the NSW Government has nominated the end of 2016 as the planning horizon for a four-lane divided road for the project. However, the actual timing of construction, opening to traffic and completion is dependent on funding negotiations between the Australian and NSW governments. Assessments would be adjusted accordingly based on actual opening dates, for example noise and traffic predictions.

The project would upgrade around 155 kilometres of highway and represents the last priority (known as ‘Priority 3’ in the upgrade program) in achieving a four-lane divided road between Hexham and the NSW/Queensland Border. The project therefore forms a major part of the overall upgrade program and when constructed, would complete the four-lane divided road program.

The project is estimated to cost $4.2 billion (in 2010 dollars) based on an opening by the end of 2016. It would be jointly funded by the NSW and Australian governments.

The project does not include the Pacific Highway upgrades at Glenugie and Devils Pulpit, which are located between Woolgoolga and Ballina. These are separate projects, with Glenugie now complete and Devils Pulpit under construction. Altogether, these three projects would upgrade 164 kilometres of the Pacific Highway. The project does include a partial upgrade of the existing dual carriageways at Halfway Creek.

A more detailed description of the Woolgoolga to Ballina Pacific Highway upgrade is found in the Pacific Highway upgrade: Woolgoolga to Ballina Environmental Impact Statement prepared by Roads and Maritime in December 2012.

## 1.2 Purpose and objectives

This threatened glider management plan addresses impacts of the upgrade and proposed mitigation on populations of the threatened Squirrel Glider (*Petaurus norfolcensis*) and Yellow-bellied Glider (*Petaurus australis*) and identifies the most appropriate management actions to be undertaken to ensure the long-term survival of these species in the area of the project.

Collectively, these species have been referred to as ‘threatened gliders’ in the remainder of the management plan.

The objectives of the plan include providing:

- An overview of the habitat and ecology information available for the threatened gliders.
- A summary of the locations where threatened gliders may be impacted by the project and guidance on further survey locations to inform management decisions.
- Suitable management and mitigation measures to be implemented during construction and operation to minimise impacts on the threatened gliders.
- An overarching monitoring program to be implemented pre-construction and during construction and operation of the project to assess the effectiveness of mitigation measures and to indicate

where changes to the management approach would be required to support the ongoing survival of the threatened gliders in localities impacted by the project.

- Outline an adaptive management framework based on specific goals for mitigation, appropriate monitoring of the performance of these measures against the goals and the identification and implementation of corrective actions to improve mitigation where required. Where shortfalls from the mitigation and adaptive management are identified appropriate provisional and offset measures would be implemented.

## 1.3 Management structure and plan updates

### Management structure

This species management plan provides a framework for any part of the proposed upgrade between Woolgoolga to Ballina. This plan would be updated during detailed design or pre-construction stage of any proposal that may affect threatened species relevant to this plan. The final management plan would be specific to the project section, stage, program of works or singular element of infrastructure which makes-up the overall Woolgoolga to Ballina upgrade. The plan would operate in conjunction with the Construction Environmental Management Plan (CEMP) and project specific flora and fauna management plan (FFMP), or may be incorporated into a wider framework that includes such plans.

Roads and Maritime would finalise this plan in consultation with the NSW Department of Planning and Infrastructure (DP&I) and NSW Office of Environment and Heritage (OEH).

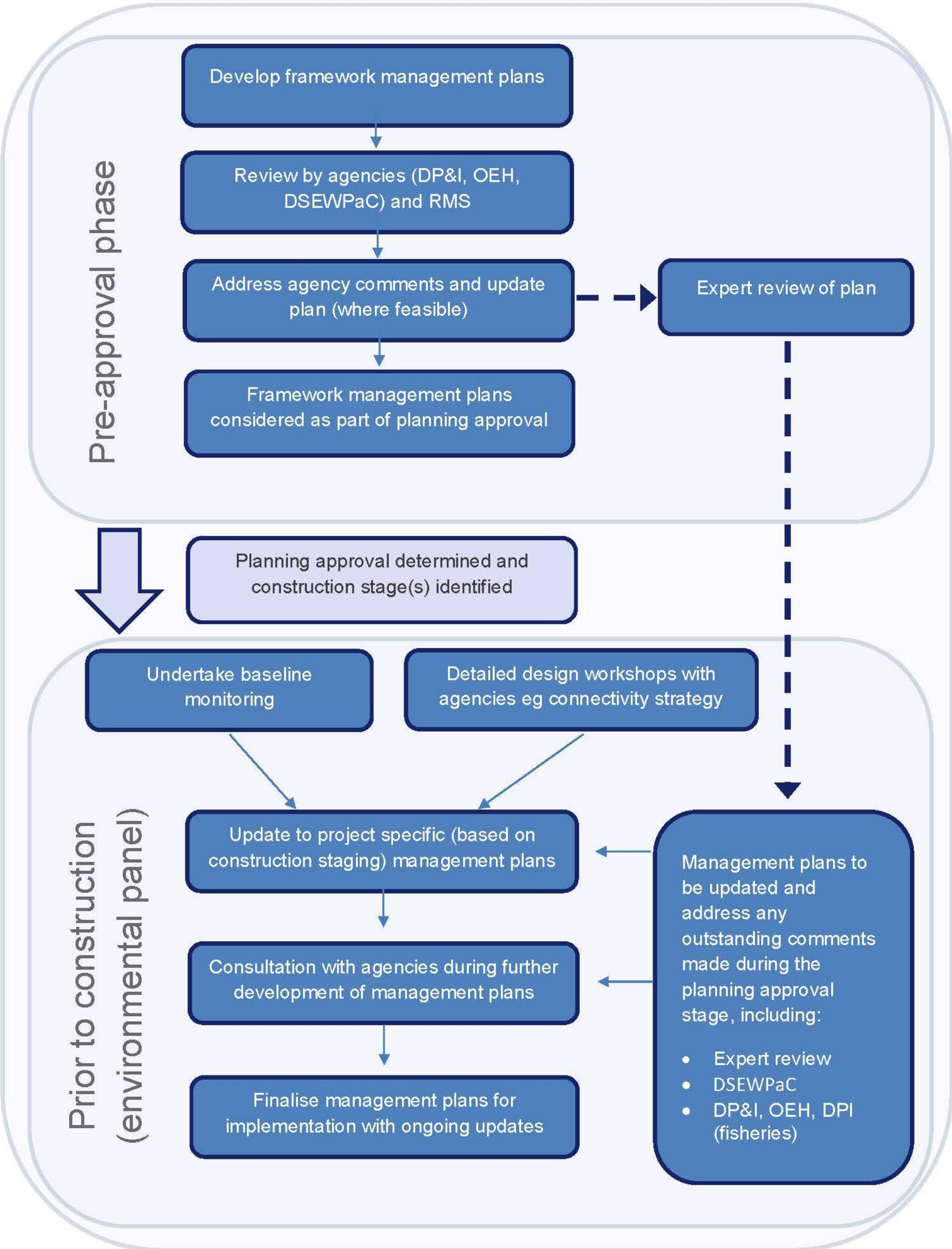
General responsibilities for environmental management would be outlined in the CEMP and FFMP. Responsibilities for implementation of this plan have been described throughout and summarised in Chapter 8. Following approval of the plan, the construction contractor and the contractors ecologist engaged for the relevant project sections would be responsible to oversee implementation of the plan

### Plan updates

The plan is intended to be a dynamic document subject to continual improvement. The management plan would be updated as required to meet the mitigation and management measures committed to in the EIS and PIR reports and any Condition of Approval (CoA) for the project. Prior to implementation, the plan would be updated following independent expert review to incorporate any necessary changes that arise from that review. The process for the update of the plan is illustrated in **Figure 1-1** below.

This plan identifies the general locations proposed for conducting monitoring and the methods, variables and timing of the proposed monitoring program. Details have been provided on the parameters for the selection of the final monitoring sites, both impact and control sites. It is not possible to pre-select the monitoring sites at this point in the planning and design process, as this requires consultation with affected landowners. The final selection of monitoring sites would be subject to further interrogation through the implementation of targeted surveys (refer to **section 4.3.1**) and confirmation of landowner access and would be presented in the first annual monitoring report with the intention of repeated sampling to be conducted at these locations.

**Figure 1-1 Process to develop management plan**



## 1.4 Plan authors and expert review

### Authors

This management plan was prepared by Chris Thomson and Valerie Hagger of Sinclair Knight Merz (SKM).

Chris is a group practice leader for ecology with a Bachelor of Applied Science and Graduate Certificate in Natural Resources and seventeen years professional experience managing biodiversity assessments and scientific reporting. He is a highly experienced field ecologist with extensive experience on major road projects with the Roads and Maritime, having worked widely throughout NSW as the technical lead on a range of environmental assessments including several Pacific Highway upgrades, the Hume Highway, Great Western Highway, Princes Highway and New England Highway along with numerous large and small arterial road projects including the M5, M4, Westlink M7 and Westconnex.

Chris has comprehensive knowledge of Commonwealth and NSW threatened species legislation, policies and guidelines and has extensive experience in the design of avoidance and mitigation measures for minimising impacts on threatened species with a high level of experience on infrastructure projects including the development of compensatory habitat and offset strategies, biodiversity connectivity strategies, mitigation and monitoring strategies and threatened species management plans. Valerie Hagger is a Senior Ecologist with ten years environmental consulting experience specialising in ecological survey, assessment and monitoring and environmental impact assessment (EIA). She has successfully project managed numerous biodiversity and environmental projects in Australia and the United Kingdom, and has been the ecology technical lead for several EIS projects.

Valerie is competent in conducting baseline flora and fauna surveys, vegetation surveys and mapping, assessing impacts on ecological values, developing mitigation measures, management plans and monitoring strategies for threatened species and ecological communities and developing offsets strategies.

### Expert review

An expert review of the plan was undertaken in August 2013 by Dr Rodney van der Ree. Dr van der Ree is currently the Deputy Director and Manager, Ecological Sciences: Australian Research Centre for Urban Ecology (ARCUE) and responsible for conducting high quality scientific research on the impacts of human activities on wildlife. His current research projects are diverse, and broadly cover the effects of habitat loss and fragmentation due to the construction of cities and towns as well as other infrastructures, such as roads, and agricultural activities.

Rodney has successfully undertaken consultancy projects for a range of clients in Victoria and New South Wales, including the New South Wales National Parks and Wildlife Service, VicRoads, and the Albury-Wodonga Development Corporation. His research has included studies of the distribution and abundance of Squirrel Gliders in New South Wales and Victoria, particularly in networks of linear remnants and also the development of mitigation measures to facilitate the crossing of major roads by Squirrel Gliders.

Rodney has ten peer reviewed scientific journal articles on gliders and many more on small mammals and road interactions. He has also supervised postdoctoral fellows and students researching gliders.

Rodney has is an active member a number of professional organisations and has been invited to sit on a number of expert scientific committees across Australia. In addition, he has published more than 60 reports and popular articles, given in excess of 70 presentations at conferences, workshops, community groups and more than 20 media appearances, including TV, radio, and newspaper.

A curriculum vitae for Dr Rodney van der Ree is provided in **Appendix A** and a copy of his review is provided as Appendix B. The recommendations provided in this review have been summarised in **Table 1-1.** The table also identifies how each of the recommendations have been addressed. Recommendations have been addressed in one of three ways:

- Adopted - plan updated.
- Adopted - plan to be updated prior to implementation.

- To be reviewed - recommendation to be reviewed further by Roads and Maritime prior to implementation.

### Table 1-1 Summary of recommendations for the expert review and how addressed in this plan

| ID No | Recommendation | How recommendation is to be addressed |
|---|---|---|
| TGMP1 | The goals for mitigation need to be clearly articulated. They should include general goals (e.g. maintain connectivity for daily movements or maintain natural rates of gene flow across the road) and specific goals that are measurable (i.e. using the SMART approach). | Adopted- plan to be updated prior to implementation |
| TGMP2 | Daily movements should be a goal of mitigation, there for one major goal of mitigation must be to allow regular movement of gliders. | Adopted- plan to be updated prior to implementation |
| TGMP3 | I recommend that the objectives and methods of the monitoring program for threatened gliders be further developed through a workshop with glider experts and monitoring design experts in order to develop a monitoring program that answers the most important and necessary questions. The current monitoring program will conclude: yes, squirrel gliders use crossing structures and yes/no – YBG use crossing structures. | To be reviewed |
| TGMP4 | Developing and finalising a comprehensive, scientifically robust and useful monitoring program can not be completed before the goals for mitigation are revised and the targeted surveys are finalised. I recommend that the monitoring program be developed with relevant experts, as per RECC 3. | Adopted- plan to be updated prior to implementation |
| TGMP5 | "Monitoring will continue until mitigation is proven effective" revise this based on the recommendations above. | Adopted- plan to be updated prior to implementation |
| TGMP6 | Ensure that the effects of mortality and reduced connectivity are clearly differentiated in the TGMP and ensure that the mitigation measures are appropriate for the impact. | Adopted- plan to be updated prior to implementation |
| TGMP7 | A greater number of crossing structures for gliders will be required. | To be reviewed prior to implementation |
| TGMP8 | There is confusion around pre-clearing surveys, Clarify the role / purpose of the different surveys. | To be reviewed prior to implementation |
| TGMP9 | To what extent is this plan a stand-alone document; please Clarify how this plan is to be used in the introduction section. | Adopted- plan to be updated prior to implementation |
| TGMP10 | Acknowledge in the TGMP that the only way to funnel gliders is with strategic tree planting and that gliders are likely to attempt to cross the highway wherever there are trees on both sides of the road, including in places where trees are too distant to successfully make the glide | Adopted- plan to be updated prior to implementation |
| TGMP11 | Ensure glide angle calculations are completed for every set of glider poles and for treed medians and that minimum clearances can be achieved. | Adopted- plan to be updated prior to implementation |
| TGMP12 | There is no detail of amount of time available before construction. The amount of time required for pre-clearing baseline surveys will depend on the goals of monitoring and the monitoring questions being asked. 12 months would likely be the minimum time required, but this should be reviewed when the monitoring program is properly finalised. | To be reviewed prior to implementation |
| TGMP13 | There is insufficient acknowledgment of gliders in fragmented areas. The mitigation proposed for highly cleared and fragmented areas be reviewed for adequacy. | To be reviewed prior to implementation |
| TGMP14 | Use crossing zones with multiple crossing structures when crossings are few and far between. If crossings are spaced at shorter distances (e.g. one per average home range length), then crossing zones are not required. | To be reviewed prior to implementation |

# 2. Glider populations

## 2.1 Background

The Squirrel Glider and Yellow-bellied Glider are currently listed as Vulnerable in NSW under the *Threatened Species Conservation Act 1995* (TSC Act).

## 2.2 Existing knowledge

### 2.2.1 Habitat requirements and populations within the project

Threatened gliders require a landscape mosaic of old growth trees and plant species diversity which meet both foraging and sheltering needs throughout the seasons.

#### Squirrel Glider

The distribution of the Squirrel Glider throughout the North Coast Bioregion is widespread within coastal sclerophyll forests and swamp forests, extending into drier forests and woodlands of the tablelands in the northern regions. There are 603 Squirrel Glider sightings in the Atlas of NSW Wildlife for the NSW North Coast Bioregion, with the bulk of these records from the eastern areas of the bioregion (OEH 2013).

They frequent habitats with an abundant and varied supply of nectar and arthropods (Kavanagh 1984). Access to winter flowering species and species with abundant nectar producing qualities is optimal. They are also dependent on tree hollows for shelter and breeding which limits their distribution to older growth vegetation which may occur wholly across the landscape or may occur patchily in riparian areas in combination with managed production forests.

Refer to Section 4.3.2 (pp 365-366 and 312-313) of the Biodiversity Working Paper (Roads and Maritime 2012) for a detailed description of habitat requirements.

Within the project Squirrel Glider populations are associated with mature dry and moist sclerophyll forests. They rely primarily on a diversity of eucalypt species in the canopy and in some locations, nectar supply from Banksia and Melaleuca species.

Squirrel Gliders have been recorded throughout the project in all sections (1-10). The Atlas of NSW Wildlife shows 144 Squirrel Glider records within 10 kilometres of the project (OEH 2013). The three broad locations of Squirrel Glider population intersected by the project include:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Sections 1 and 2 of the project).
- The slopes of the Summervale Range from Pillar Valley to Gulmarrad and Tyndale (Section 3).
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7 of the project).

#### Yellow-bellied Glider

The Yellow-bellied Glider inhabits tall, mature dry and moist sclerophyll forests on nutrient rich soils. They rely primarily on plant and insect exudates, including nectar, sap, honeydew and manna with pollen and insects providing protein. The species is very mobile and require large home ranges to access seasonally variable food resources (Goldingay and Kavanagh 1991). Extensive areas of mixed forest are required and they are also dependent on tree hollows for shelter and breeding which limits their distribution to older growth vegetation. This habitat may occur wholly across the landscape or may occur patchily in riparian areas in combination with managed production forests.

Refer to Section 4.3.2 (pp 365-366) of the Biodiversity Working Paper (Roads and Maritime 2012) for a detailed description of habitat requirements.

The distribution of the Yellow-bellied Glider is widespread across the slopes, ranges and coastal areas of the North Coast Bioregion in large key habitats and corridors. It is generally absent from the heavily fragmented alluvial floodplains, wetlands and north of the Richmond River in the coastal heath and floodplains. There are 4,802 Yellow-bellied Glider records in the Atlas of NSW Wildlife for the NSW North Coast Bioregion (OEH 2013).

The Atlas of NSW Wildlife shows 288 records within 10 kilometres of the project (OEH 2013). Yellow-bellied Gliders have been recorded in Sections 1 to3 and 6 to 8 of the project. The location of populations of Yellow-bellied Glider and Squirrel Glider from Woolgoolga to Wells Crossing (Sections 1 and 2 of the project), Tabbimoble (Section 6 and 7 of the project) and Broadwater National Park (Section 9 of the project) have been determined through ecological surveys undertaken from 2006 to 2012, review of NSW Atlas data identifying broad population hotspots and consultation with the OEH.

There are several records for the species in the Halfway Creek area (Section 2 of the project) which is considered a hotspot for this species. The two main locations of Yellow-bellied Glider population intersected by the project include:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Sections 1 and 2 of the project).
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7 of the project).

## 2.3 Key threats

Key threatening processes listed under the TSC Act that impact on threatened gliders include:

- Loss of habitat and fragmentation of habitat from the clearing of native vegetation.
- Competition from feral honey bees.
- High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition.
- Loss of hollow bearing trees.
- Removal of dead wood and dead trees.

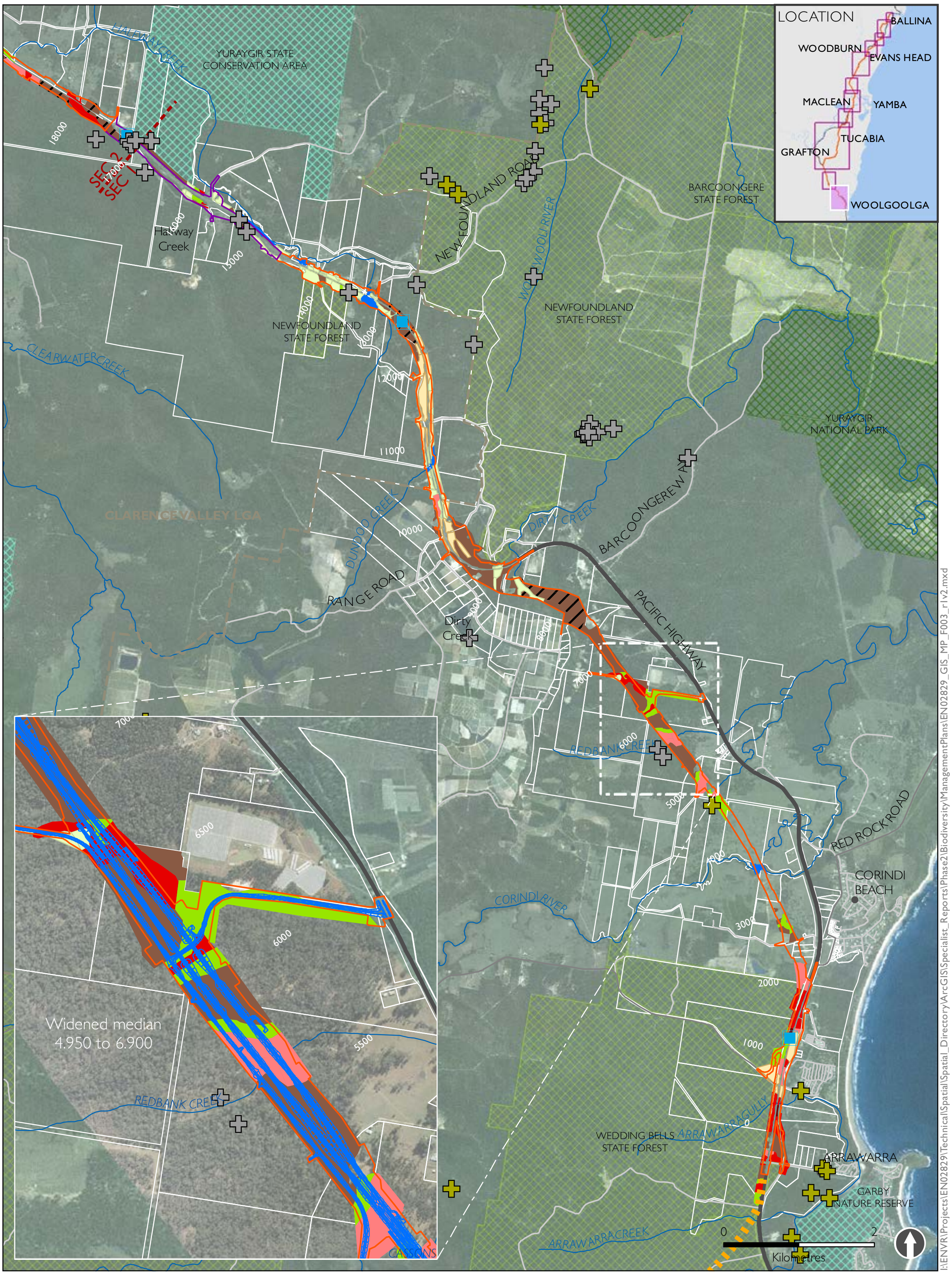
The Action Plan for Australian Marsupials and Mammals (DSEWPaC 1996) lists the following current threats for Squirrel Glider including:

- Loss of habitat due to timber clearing for forestry, agriculture and mining.
- Lack of suitable hollows.
- Lack of regeneration of trees and shrubs due to grazing by stock, rabbits and macropods.
- Inappropriate fire regimes.
- Outbreaks of lerp (leaf-skeletonising caterpillars) in riverine forests.
- Coastal development in NSW and south-east Qld.

In addition, the Action Plan attributes the lack of conservation of intact, extensive areas of forest to the decline of the Yellow-bellied Glider due to their requirement for a variety of feed trees and hollows over a large home range.

Figures 2-1 to 2-11 show the location of the threatened glider records, predicted habitat and connectivity structures.

Figure 2 -1 Threatened glider records, predicted habitat and connectivity structures (section 1)




The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Dedicated Arboreal

Dedicated Overpass

Non-flying mammal

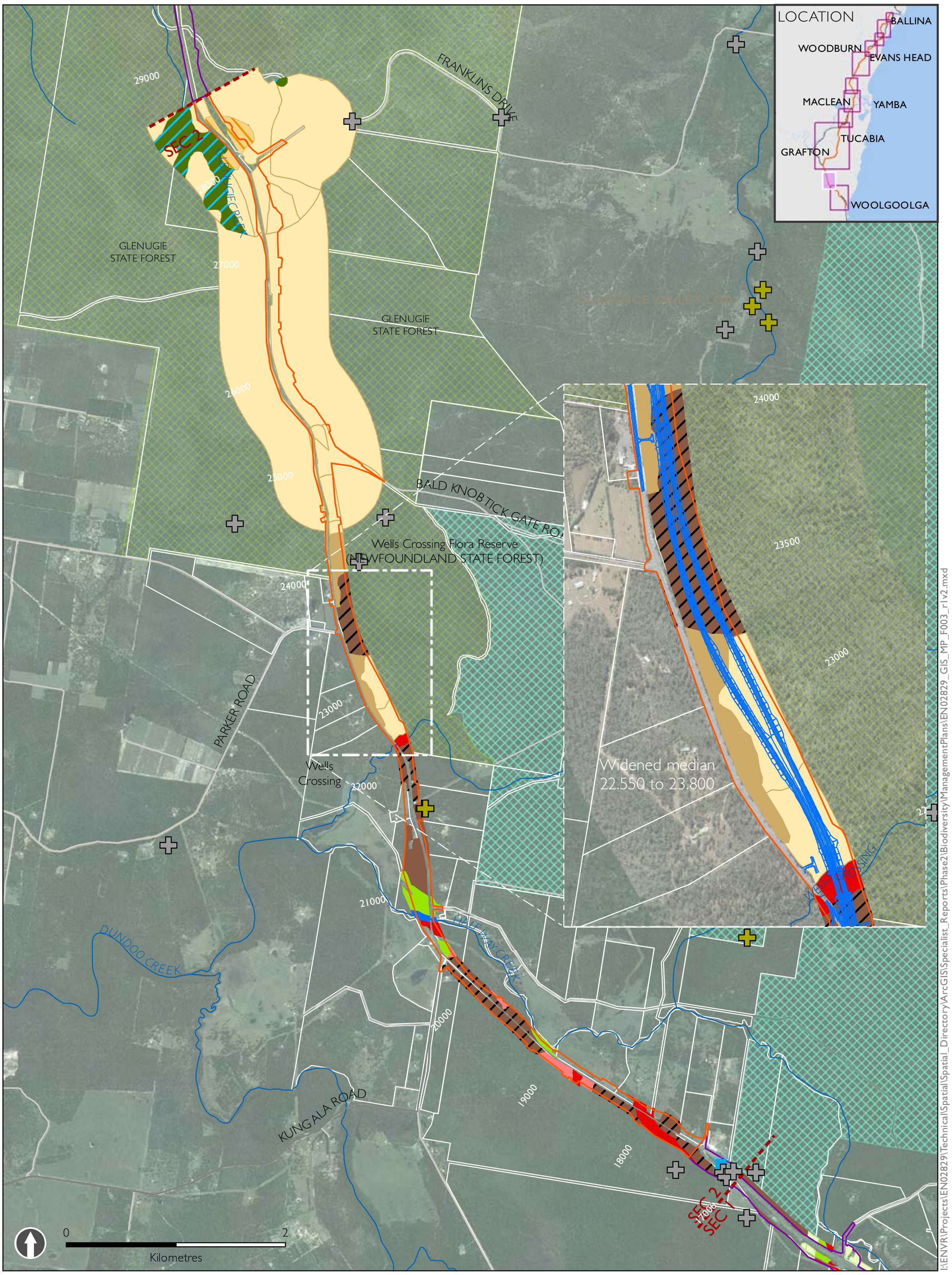
Squirrel Glider

Yellow-bellied Glider

Vegetation communities

- Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
- Blackbutt grassy open forest of the lower Clarence Valley of the North Coast
- Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
- Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
- Swamp Box swamp forest of the coastal lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast

Figure 2 -2 Threatened glider records, predicted habitat and connectivity structures (section 2)



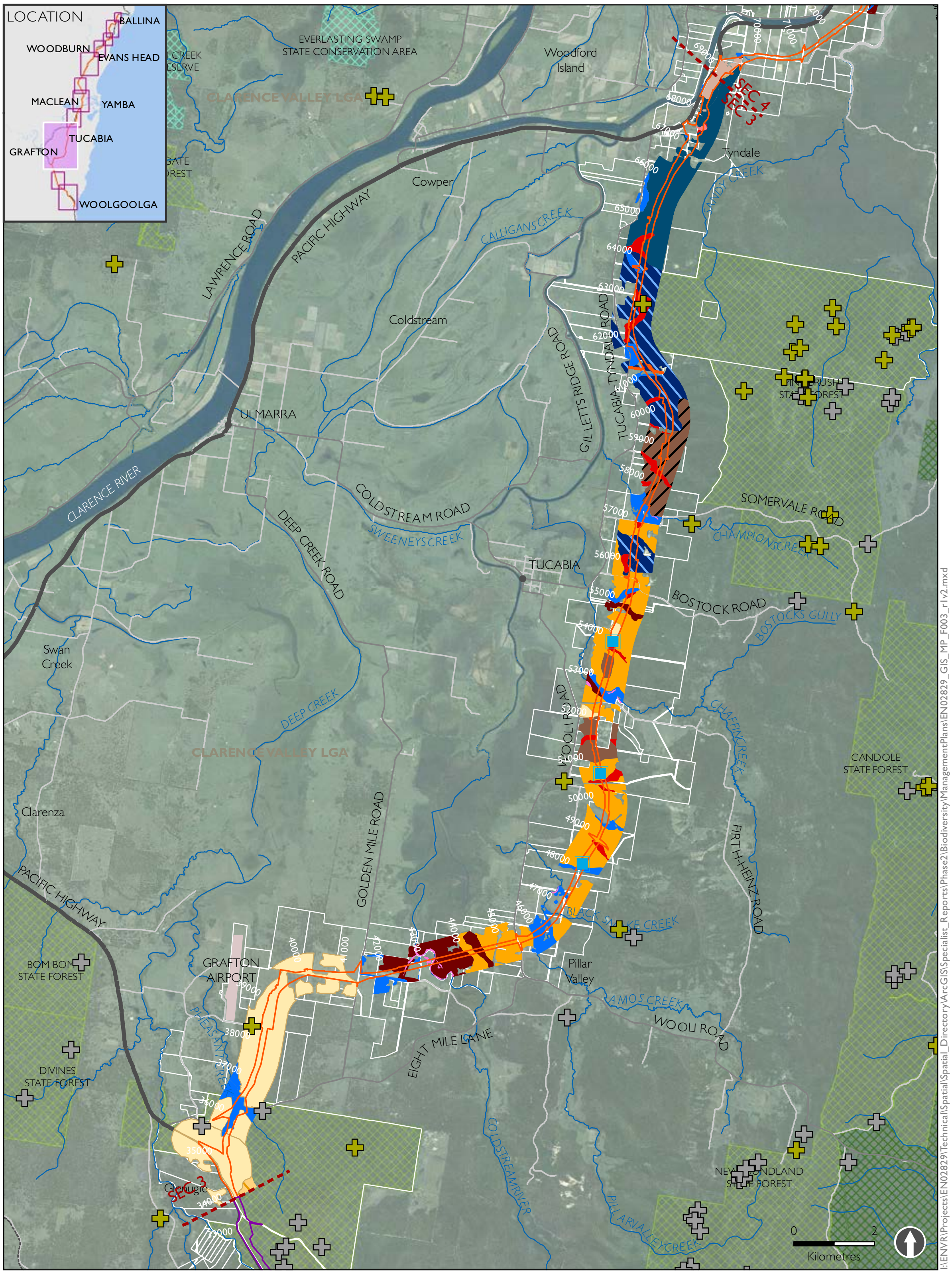

The project
Upgrade completed to dual carriageway
Upgrade under construction

Fauna connectivity structures
Dedicated Arboreal
Dedicated Overpass

Non-flying mammal
Squirrel Glider
Yellow-bellied Glider

Vegetation communities
Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
Blackbutt grassy open forest of the lower Clarence Valley of the North Coast
Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
Narrow-leaved Red Gum woodlands of the lowlands of the North Coast
Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast
Orange Gum (Eucalyptus bancroftii) open forest of the North Coast
Paperbark swamp forest of the coastal lowlands of the North Coast
Spotted Gum - Grey Box - Grey Ironbark dry open forest of the Clarence Valley lowlands of the North Coast
Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
Swamp Box swamp forest of the coastal lowlands of the North Coast
Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Figure 2 -3 Threatened glider records, predicted habitat and connectivity structures (section 3)




The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Dedicated Arboreal

Dedicated Overpass

Non-flying mammal

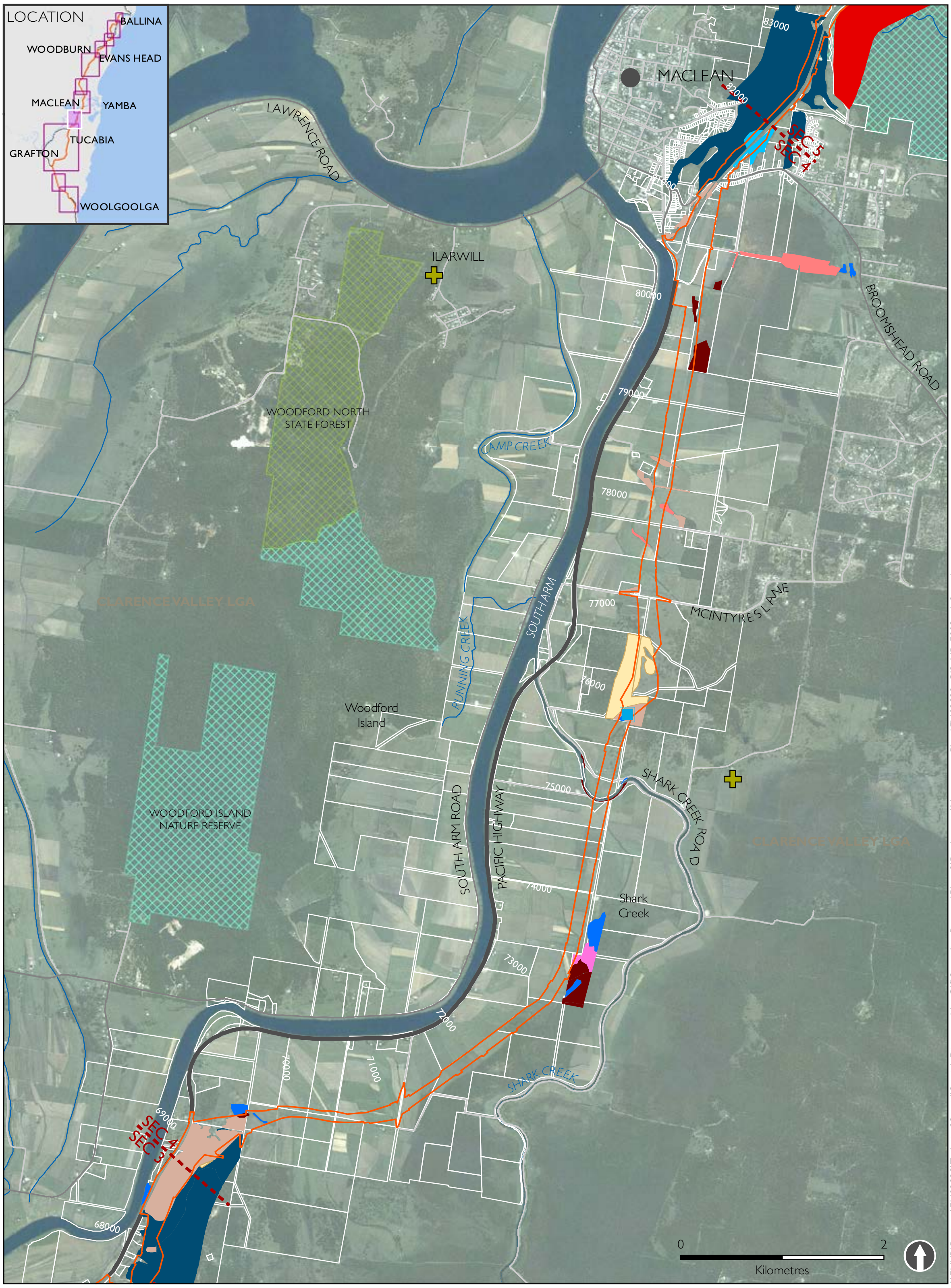
Squirrel Glider

Yellow-bellied Glider

Vegetation communities

- Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
- Coastal floodplain sedgelands, rushlands, and forblands
- Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
- Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast
- Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast
- Spotted Gum - Grey Box - Grey Ironbark dry open forest of the Clarence Valley lowlands of the North Coast
- Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast
- Tallowwood dry grassy forest of the far northern ranges of the North Coast
- Turpentine moist open forest of the coastal hills and ranges of the North Coast

Figure 2 -4 Threatened glider records, predicted habitat and connectivity structures (section 4)

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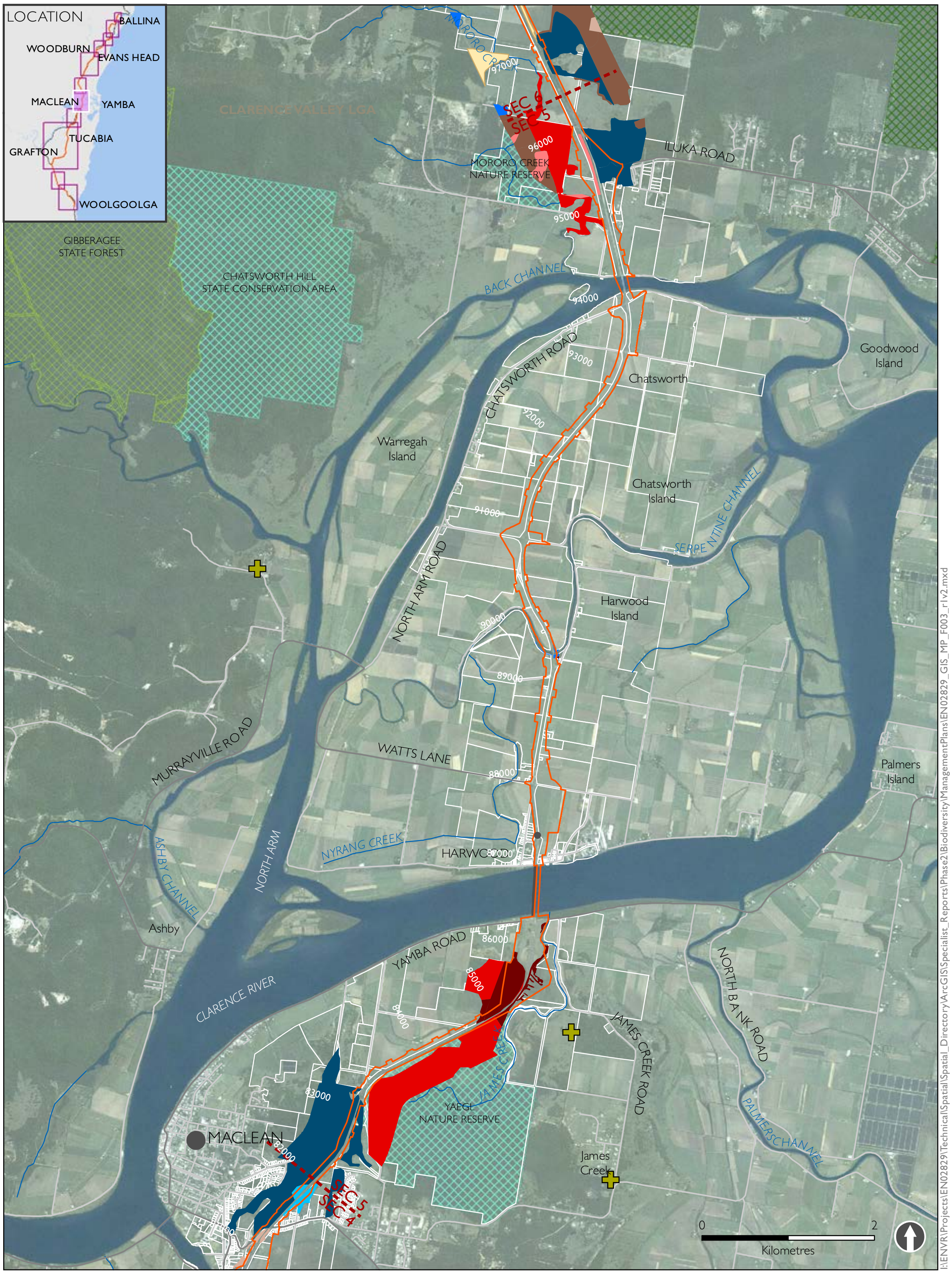
The project
Upgrade completed to dual carriageway
Upgrade under construction

Fauna connectivity structures
Dedicated Arboreal
Dedicated Overpass

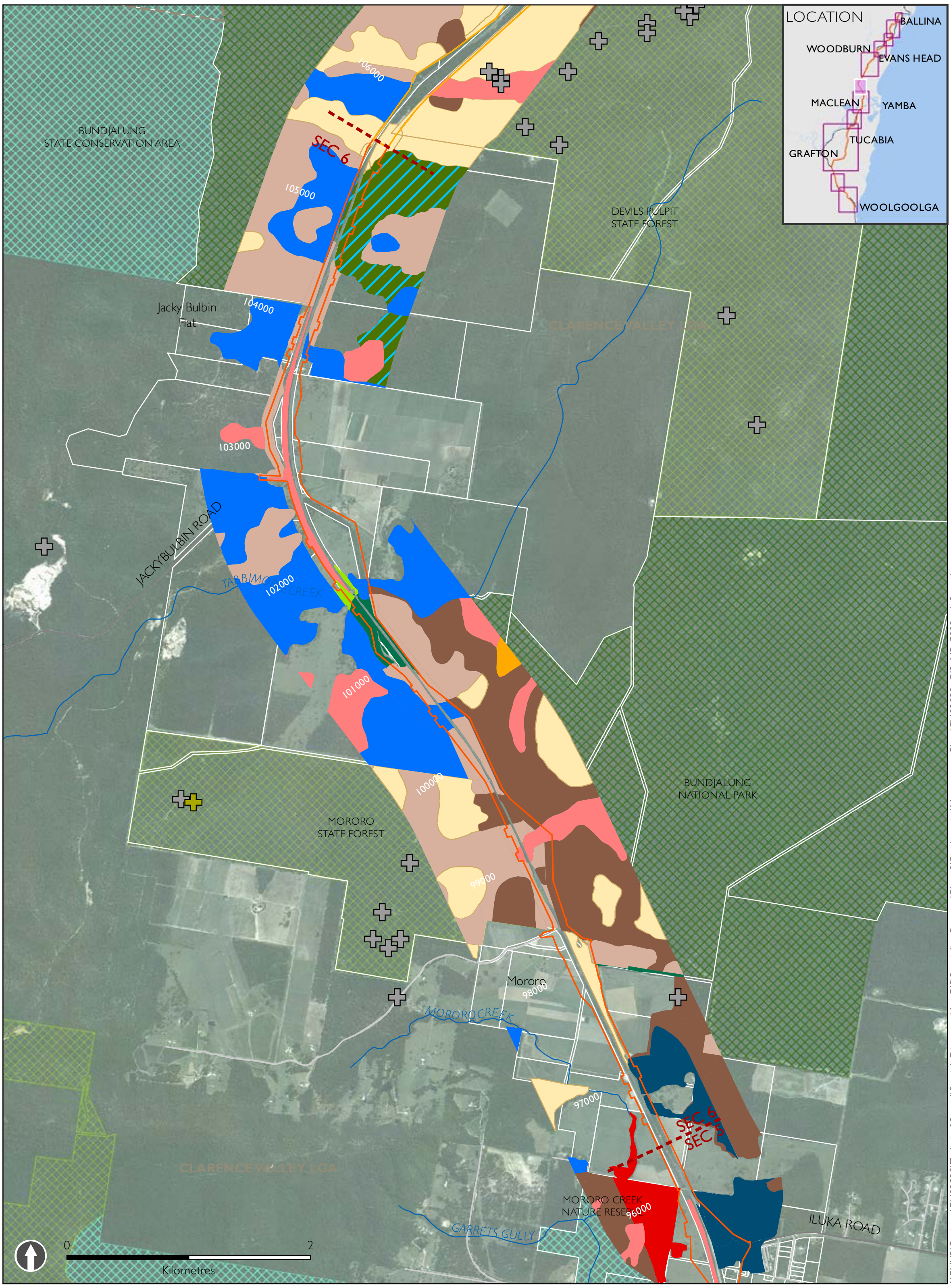
Non-flying mammal
Squirrel Glider
Yellow-bellied Glider

Vegetation communities
- Coastal floodplain sedgelands, rushlands, and forblands
- Flooded Gum - Tallowwood - Brush Box Moist Open Forest of the Coastal Ranges of the North Coast
- Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
- Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast
- Tallowwood dry grassy forest of the far northern ranges of the North Coast

## Figure 2 -5 Threatened glider records, predicted habitat and connectivity structures (section 5)



## Figure 2 -6 Threatened glider records, predicted habitat and connectivity structures (section 6)

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The project

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Upgrade under construction

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Dedicated Arboreal

Dedicated Overpass

Non-flying mammal

Squirrel Glider

Yellow-bellied Glider

Vegetation communities

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Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast

Narrow-leaved Red Gum woodlands of the lowlands of the North Coast

Paperbark swamp forest of the coastal lowlands of the North Coast

Red Mahogany open forest of the coastal lowlands of the North Coast

Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast

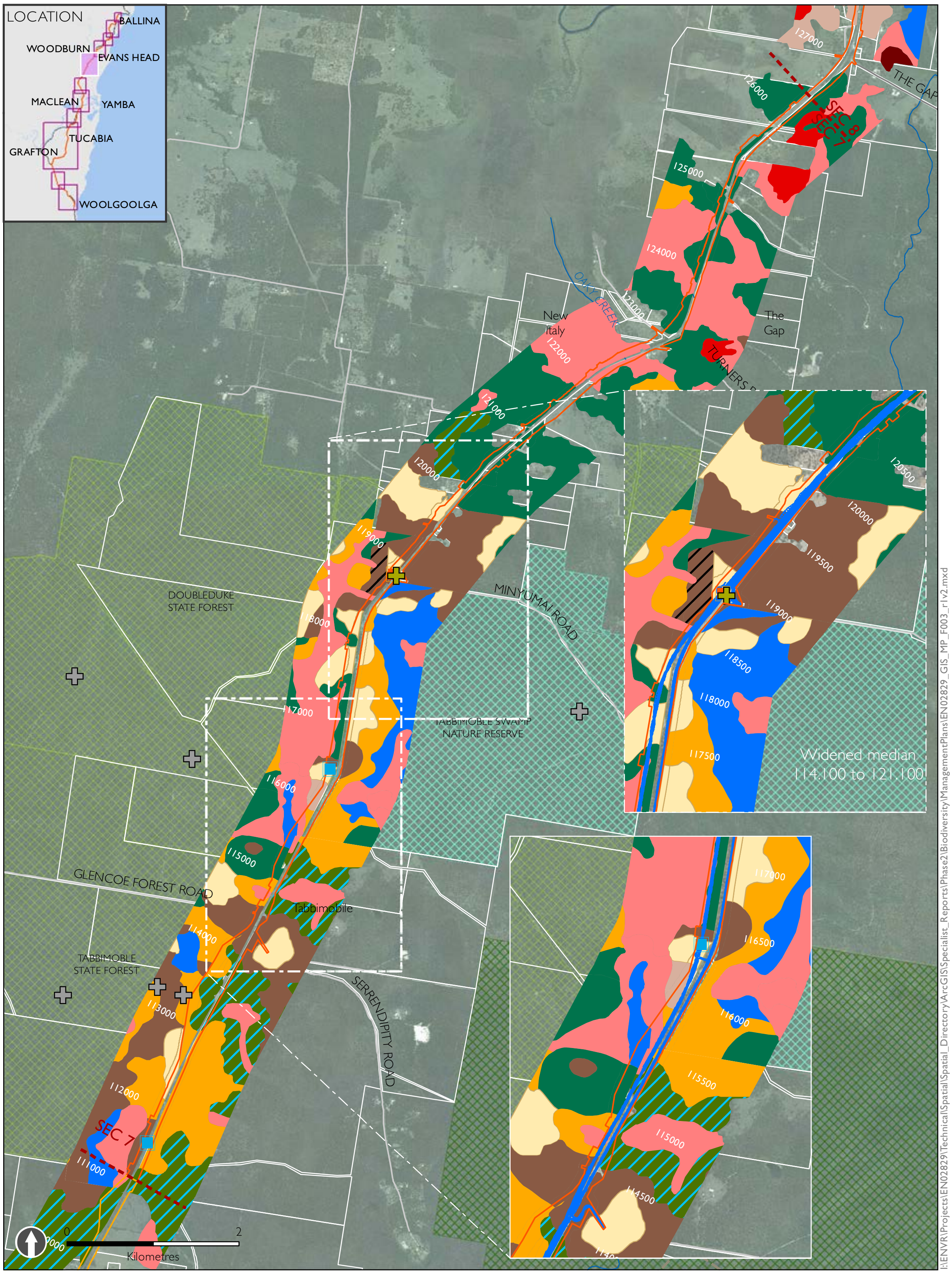
Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast

Swamp Box swamp forest of the coastal lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Tallowwood dry grassy forest of the far northern ranges of the North Coast

Figure 2 -7 Threatened glider records, predicted habitat and connectivity structures (section 7)




The project
Upgrade completed to dual carriageway
Upgrade under construction

Fauna connectivity structures
Dedicated Arboreal
Dedicated Overpass

Non-flying mammal
Squirrel Glider
Yellow-bellied Glider

Vegetation communities
- Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
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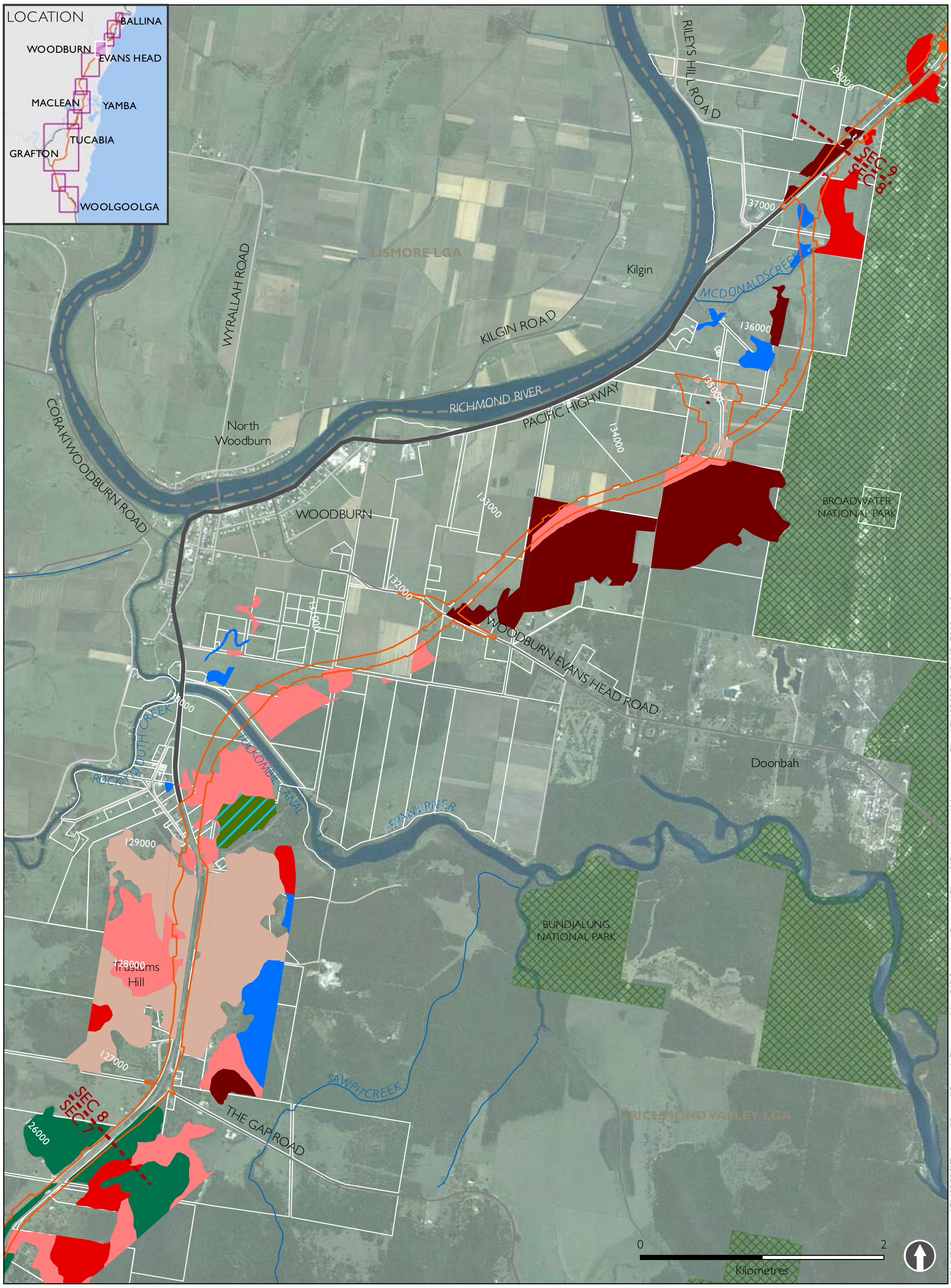
- Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast
- Narrow-leaved Red Gum woodlands of the lowlands of the North Coast
- Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Red Mahogany open forest of the coastal lowlands of the North Coast
- Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast
- Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast

Figure 2 -8 Threatened glider records, predicted habitat and connectivity structures (section 8)

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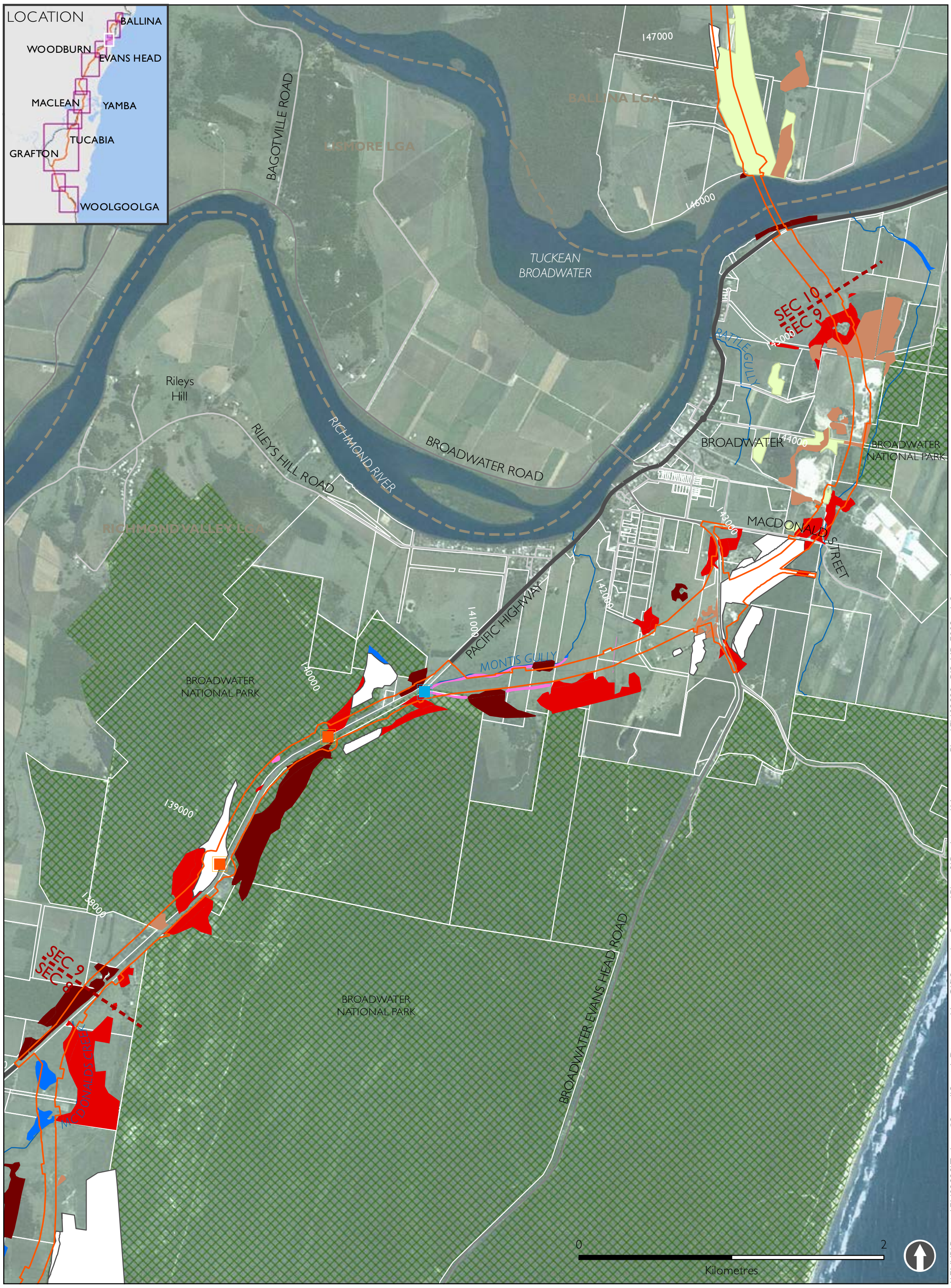
The project
Upgrade completed to dual carriageway
Upgrade under construction

Fauna connectivity structures
Dedicated Arboreal
Dedicated Overpass

Non-flying mammal
Squirrel Glider
Yellow-bellied Glider

Vegetation communities
- Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
- Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
- Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast
- Narrow-leaved Red Gum woodlands of the lowlands of the North Coast
- Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Red Mahogany open forest of the coastal lowlands of the North Coast
- Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast
- Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast

## Figure 2 -9 Threatened glider records, predicted habitat and connectivity structures (section 9)




The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

Dedicated Arboreal

Dedicated Overpass

Non-flying mammal

Squirrel Glider

Yellow-bellied Glider

Vegetation communities

Blackbutt grassy open forest of the lower Clarence Valley of the North Coast

Coast Cypress Pine shrubby open forest of the North Coast Bioregion

Coastal floodplain sedgelands, rushlands, and forblands

Coastal heath on sands of the North Coast

Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast

Swamp Mahogany swamp forest of the coastal lowlands of the North Coast

Swamp Oak swamp forest of the coastal lowlands of the North Coast

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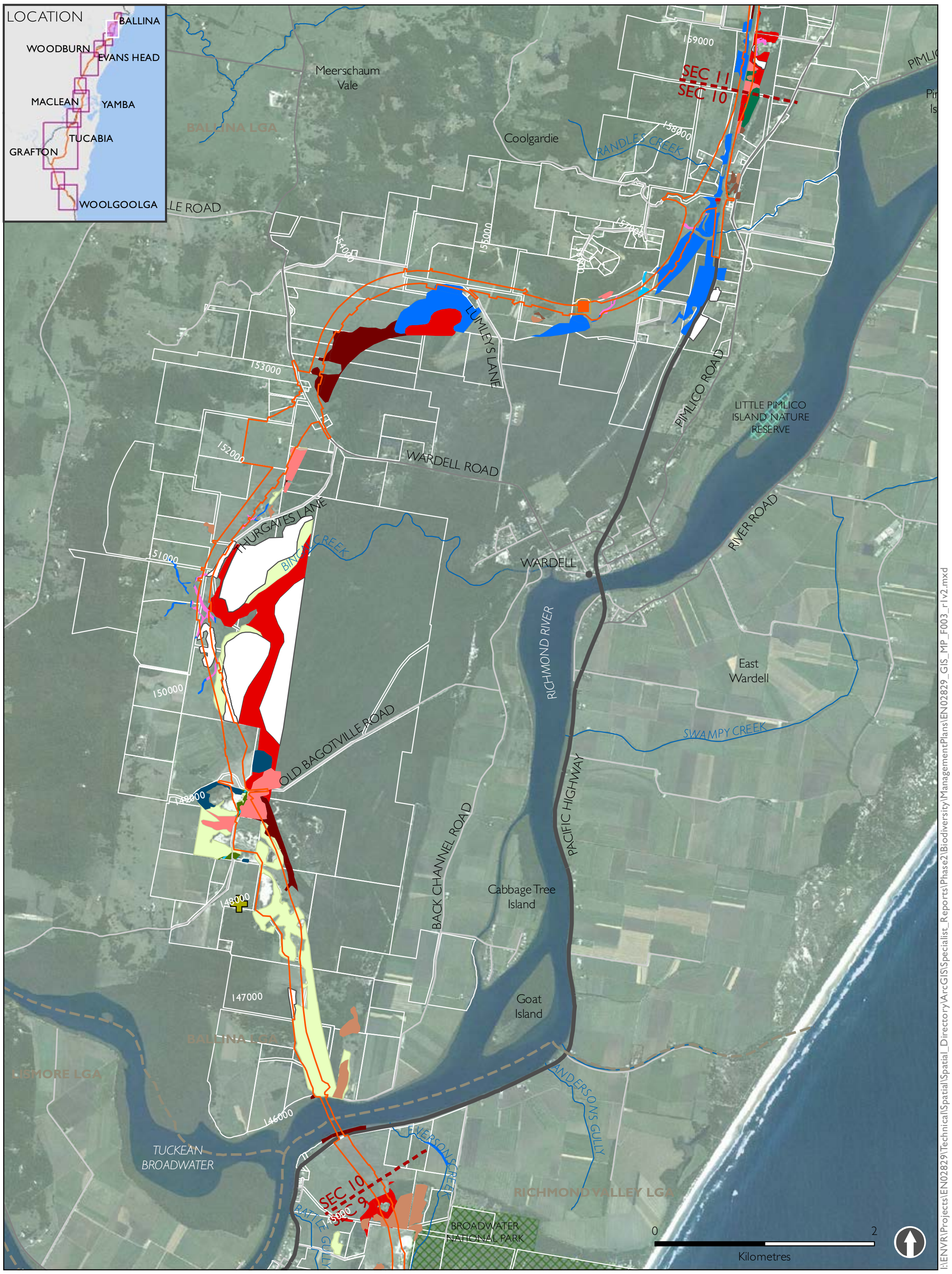
Figure 2 -10 Threatened glider records, predicted habitat and connectivity structures (section 10)



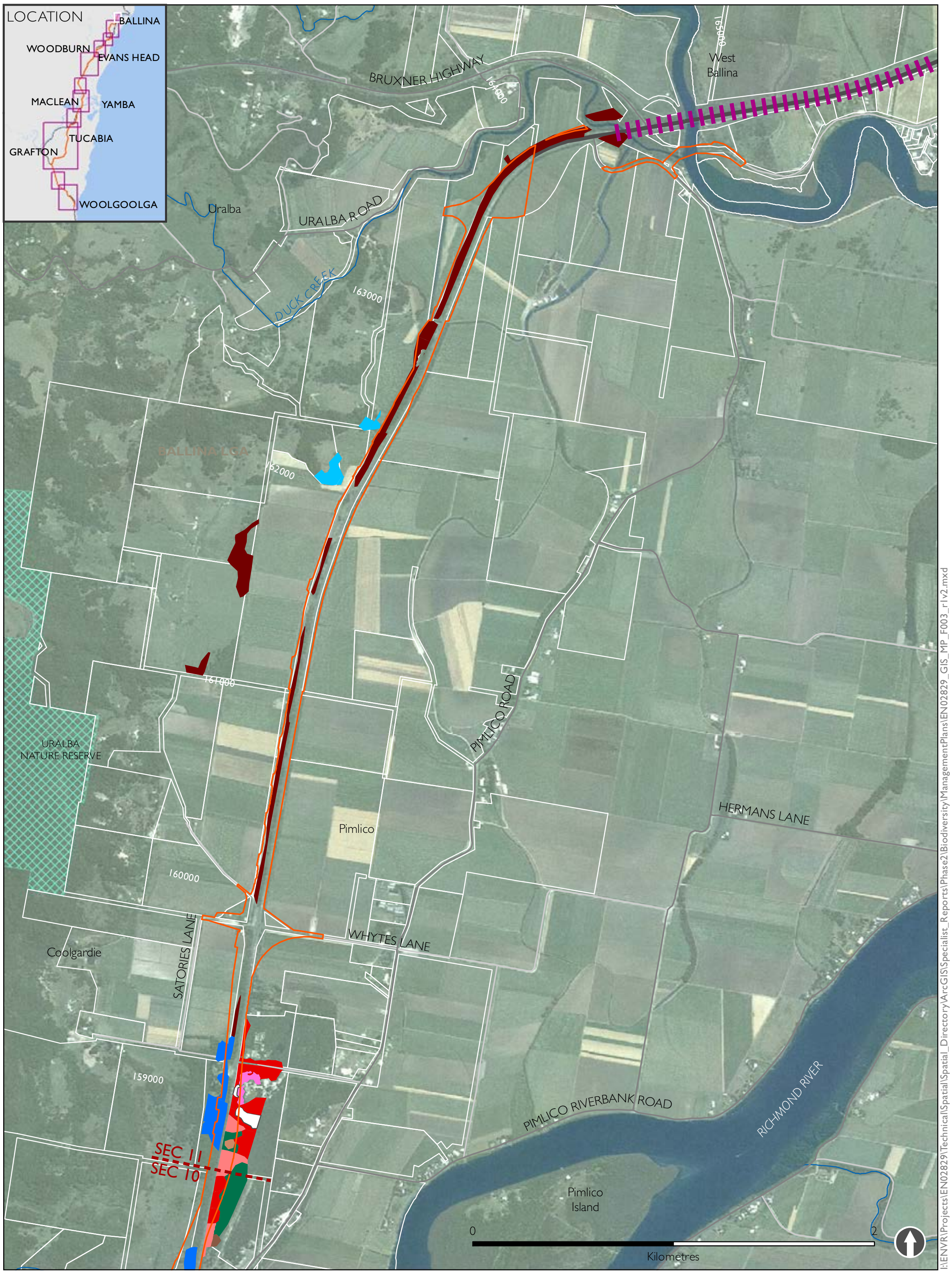

The project
Upgrade completed to dual carriageway
Upgrade under construction

Fauna connectivity structures
Dedicated Arboreal
Dedicated Overpass

Non-flying mammal
Squirrel Glider
Yellow-bellied Glider

Vegetation communities
- Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
- Blackbutt grassy open forest of the lower Clarence Valley of the North Coast
- Coast Cypress Pine shrubby open forest of the North Coast Bioregion
- Coastal floodplain sedgelands, rushlands, and forblands
- Coastal heath on sands of the North Coast
- Flooded Gum - Tallowwood - Brush Box Moist Open Forest of the Coastal Ranges of the North Coast
- Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
- Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast
- Narrow-leaved Red Gum woodlands of the lowlands of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Red Mahogany open forest of the coastal lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast
- Tallowwood dry grassy forest of the far northern ranges of the North Coast

Figure 2 -11 Threatened glider records, predicted habitat and connectivity structures (section 11)




The project

Upgrade completed to dual carriageway

Upgrade under construction

Fauna connectivity structures

- Dedicated Arboreal
- Dedicated Overpass

Non-flying mammal

- Squirrel Glider
- Yellow-bellied Glider

Vegetation communities

- Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast
- Coast Cypress Pine shrubby open forest of the North Coast Bioregion
- Coastal floodplain sedgelands, rushlands, and forblands
- Coastal heath on sands of the North Coast
- Flooded Gum - Tallowwood - Brush Box Moist Open Forest of the Coastal Ranges of the North Coast
- Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast
- Paperbark swamp forest of the coastal lowlands of the North Coast
- Red Mahogany open forest of the coastal lowlands of the North Coast
- Swamp Mahogany swamp forest of the coastal lowlands of the North Coast
- Swamp Oak swamp forest of the coastal lowlands of the North Coast

# 3. Potential impacts and management approach

The following chapter provides a brief overview of the potential impacts to the threatened glider populations with reference to the more detailed impact assessment presented in the Biodiversity Working Paper (Roads and Maritime 2012). It describes the potential impacts to the species at specific locations along the project and during the pre-construction, construction and post-construction (operational) stages of the project. The mitigation approach presented in the EIS and documented in Chapters 4-6 of the management plan target the predicted impacts.

## 3.1 Potential impacts associated with the project

The severity of the impact on a regional scale would be moderate, as the threatened gliders are widespread over a large portion of the bioregion. However impacts on local populations would be high.

### Mortality due to vehicle strike during both the construction and operational phase

Some diurnal and mobile species such as birds and large reptiles may be able to move away from the path of construction tree-clearing. However, other species that are less mobile such as those that are nocturnal or those that have smaller home ranges are less likely to move rapidly away or disperse large distances from this kind of activity. This reduced mobility applies to species such as threatened gliders.

Threatened fauna that have the greatest potential to be negatively affected by vehicle strike over the length of the project are based on published known threats and a review of roadkill databases (Roads and Maritime and WIRES). These include the Squirrel Glider (Claridge and van der Ree 2004), and Yellow-bellied Glider.

### Loss of habitat including loss of potential den sites and foraging opportunities

The loss of hollow-bearing trees is listed as a key threatening process under the TSC Act. Hollow bearing trees are a critical habitat feature for a number of threatened species (Gibbons and Lindenmayer 2002), providing breeding and/or sheltering habitat. Hollow-bearing trees are present in all habitat types and project sections that are proposed to be cleared. Threatened gliders have been identified in the Biodiversity Working Paper (Roads and Maritime 2012) as being impacted by the loss of hollow-bearing trees.

The direct loss of foraging resources can be in the form of foliage, nectar and sap exudates. Foliage and nectar foraging resources are present in multiple strata including the upper canopy, mid to lower and ground level strata. Threatened species potentially impacted at the patch scale are forest dependent species such as threatened gliders.

Known feed tree species for Squirrel Glider have been listed in Appendix B. Feed tree species for Yellow-bellied Glider from the Approved Recovery Plan for the Yellow-bellied Glider (NSW NPWS 2003) are listed in Appendix C.

A number of threatened species require winter flowering foraging resources to supply food year-round, or to coincide with dispersal movements. As such, the presence of reliable annually winter-flowering species is considered a limiting factor in the distribution of a number of threatened species, including threatened gliders. Threatened gliders rely on a tree species composition providing year-round continuity of nectar and pollen. Of the habitats impacted by the project, at least four of those are dominated by winter-flowering species (including Swamp Mahogany (*Eucalyptus robusta*), Forest Red Gum (*E. tereticornis*), Grey Ironbark (*E. siderophloia*) and Broad-leaved Paperbark (*Melaleuca quinquenervia*)).

### Fragmentation of habitat

The project has potential to isolate remnant vegetation patches and create barriers to the movement of small ground-dwelling mammals, reptiles and amphibians and potentially discrete arboreal mammal populations on a both a patch and landscape scale. It is noted, however, that large areas of habitat would remain in state forests and reserved habitats for the longer-terms viability of these species.

The project would be such that the existing barrier effect of the highway would be substantially increased. Sections of the project that deviate substantially from the existing highway would create a new barrier effect (e.g. Sections 3 to 4 and 9 to 10). A barrier effect may also result from a behavioural aversion to a road. Squirrel Gliders regularly crossed a high-volume two-lane highway, whereas female Squirrel Gliders appeared to be inhibited from crossing a high-volume four-lane highway with a median strip (van der Ree 2006).

Species relying on complex social structures for breeding and feeding are also more sensitive to fragmentation than predominantly solitary species during non-breeding lifecycle events. The Squirrel Glider is one such species reliant on social structure. Hollow-dependent fauna, such as threatened gliders, are more vulnerable to fragmentation.

### Loss of ecological connectivity leading to increased isolation of family groups and reduced genetic diversity

The loss of connectivity has potential to impact on populations of several listed fauna species as determined by ecological surveys undertaken 2006 to 2012, review of NSW Atlas data identifying broad population hotspots and through consultation with OEH (OEH 2013). This includes threatened gliders - important populations exist from Woolgoolga to Wells Crossing (Sections 1 and 2 of the project), at Tabbimoble (Section 6 and 7 of the project) and Broadwater National Park (Section 9 of the project).

Loss of connectivity between smaller habitat patches can cause the loss of genetic diversity in populations (Forman *et al.* 2002). As fragmentation proceeds, stochastic forces add to potential declines caused by a dwindling supply of habitat. Some species would be more at risk in fragmented landscapes than others and this relates to the biological characteristics of the species. In this regard species that share similar adaptations to habitat niches and similar life-cycle traits are assumed to be impacted in a similar way, for example threatened gliders.

### Edge effects such as altered light levels and noise from construction and general traffic

In respect to potential impacts on edge areas from noise and light, there would be two sources, firstly construction noise which would be associated with vehicles and machinery such as pile drivers and gravel crushing and secondly general traffic noise and road lighting associated with road operation. Lighting from vehicles and roadside lighting would mainly be an operational issue, however, there would only be limited roadside lighting (the project being mostly unlit except for at interchange roundabouts, major bridges and merge and diverge traffic lanes). However, some out of hours construction work would be required for health/safety and engineering reasons and would require lighting.

Edge effects would be greatest where the project deviates substantially from the existing Pacific Highway. While portions of the habitat in these sections are already fragmented and edge affected, substantial clearing and creation of a new edge would occur in Section 3 of the project along the western foothills of the Summervale Range from Pillar Valley to Tyndale. Large sections of open forest habitat in moderate to high condition would be exposed to edge effects particularly on the eastern edge of the highway. The Squirrel Glider would be susceptible to edge effects.

## 3.2 Detailed design considerations

A number of factors were considered in identifying the key connectivity zones for threatened gliders and the locations of crossing structures incorporated into the concept design stage, with the aim of developing these further at the detailed design stage. The factors considered in locating the structures included:

- The known distributional range of threatened glider populations, incorporating other known records of sightings and anecdotal evidence.
- The presence of known population hotspots based on NSW Wildlife Atlas data and field data from the EIS.
- The distribution of known habitats and in particular the location of the older growth forests with hollow bearing trees, vegetation patch size, suitable tree species and connectivity with the surrounding landscape.
- The known effectiveness of pole type, height and rope bridge length as components of the crossing structures.

Detailed design would include a focus on refining the location of proposed structures and would be informed by further targeted surveys and consultation with OEH. Target surveys would be undertaken in all sections of the project. These surveys would include a review of the distribution of the species, and habitat and tree surveys. Target surveys have already been undertaken for Sections 1 and 2 of the project. These surveys provided advice on the location and design of aerial crossings. The following methodology was used for this survey:

- Site inspections and assessment:
  - Inspection of potential aerial crossing sites as identified in the EIS including two other locations to enable the project team to become familiar with the sites.
  - Site inspections included a discussion regarding siting and design of structures. Information on habitat types, distribution and suitability for arboreal mammals was obtained throughout the survey.
  - During the site inspection cameras where installed to record the presence of otherwise of threatened gliders and other threatened mammals, spotlighting was undertaken to confirm the presence and activity of threatened gliders. Site habitat assessment was also recorded during the inspection.
- Following the site inspection and habitat assessment potential pole locations were plotted to infom the detailed design.
- An assessment of existing Glenugie rope bridges was also undertaken with recommendations regarding modifications to locations and reassessment of the suitability of each location provided.

A survey using similar methodologies to the survey undertaken for Section 1 and Section 2 of the project would be completed for the remaining sections of the project during the detailed design.

## 3.3 Mitigation and monitoring

A number of measures to mitigate and monitor the impact of the project on threatened gliders during construction and operation of the project were suggested in the EIS (Biodiversity Working Paper) (Roads and Maritime 2012). In general these measures related to:

- A targeted connectivity strategy.
- Provision of exclusion fencing, including physical and planted directional fencing.
- Arboreal crossing structures, widened medians with retained vegetation.
- Targeted surveys for Squirrel Glider and Yellow-bellied Glider to refine crossing structures.
- A staged habitat removal process consistent with the Roads and Maritime Biodiversity Guidelines (RTA 2011)
- The minimum design and locations of crossing structures for threatened gliders would be based on the principles outlined in the EIS and the process for managing connectivity requirements described in the Biodiversity Connectivity Strategy. This includes a comprehensive monitoring program.
- The proposed approach to management of potential impacts to the threatened glider populations throughout the pre-construction, construction and operational phases is illustrated below.

**Table 3-1 Proposed staging of management measures**

| | |
|---|---|
| **Preconstruction:** | • Completed targeted glider surveys to inform detailed design and monitoring program and nest box strategy. |
| | • Refine crossing locations (detailed design) and consult with OEH. |
| | • Complete targeted population surveys and finalise monitoring sites impact and control sites. |
| | • Identify habitat exclusion zones. |
| **Construction:** | • Pre-clearing and clearing surveys. |
| | • Fauna handling and relocation. |
| | • Construct crossing structures. |
| | • Implement nest box strategy. |
| **Operation:** | • Monitoring of glider crossing structures, zones and glider activity. |
| | • Maintenance of crossing structures. |
| | • Maintenance of habitat revegetation and next boxes. |

## 3.4 Effectiveness of mitigation measures

Providing connectivity between important habitat either side of the project is considered critical to successfully retaining threatened glider populations and preventing fauna fatalities on the future highway. Connectivity can be achieved via appropriately placed crossing structures (i.e. poles and rope bridges) in addition to exclusion fencing, which would also act as directional guide to the crossing structures. Current evidence suggests this approach can be effective and would be confirmed through the use of a survey program using the methods recommended in this document.

Road crossing structures have been shown to reduce fauna mortality rates and to reduce the habitat fragmentation impacts of linear infrastructure. However the extent to which population viability can be maintained subsequent to installing the structures remains unclear.

Studies have shown Squirrel Gliders use glider poles and rope bridges to cross minor and major roads (Veage and Jones 2007, Ball and Goldingay 2008, Goldingay, Taylor and Ball 2011, Soanes *et. al.* 2013, Goldingay, Rohweder and Taylor 2013). Less is known about Yellow-bellied Glider use of fauna connectivity structures.

Monitoring of wildlife road crossing structures by Soanes *et al.* (2013) found the rate of glider crossing increased over several years as animals habituated to the structure. They suggest monitoring periods of at least two years to allow gliders adequate time to habituate to the crossing structures.

A summary of the proposed threatened glider specific mitigation measures and evaluation of their effectiveness based on past experience with other highway upgrades is described in Table 3-2.

## 3.5 Adaptive management approach

The management plan has been presented using an adaptive management approach based on firstly identifying specific goals for management, implementation of management actions followed by monitoring of the performance of these measures against the goals and identified thresholds. As a final step the monitoring would evaluate the effectiveness of the management measures using identified thresholds for performance and implementing corrective actions to improve mitigation where required.

To ensure the success of this approach the management goals presented in the plan have been based on the following SMART principles:

- **S**pecific.
- **M**easurable.
- **A**chievable.
- **R**esults-based
- **T**ime-based.

Details of the proposed monitoring program are described in **Chapter 7** and includes monitoring:

- Change in threatened glider activity in proximity to the upgrade, the methodology includes a Before-After-Control-Impact (BACI) approach including the use of crossing zones and crossing structures.
- Mortality monitoring adjacent to all arboreal crossing structures and the widened medians in relevant project sections.
- The success of threatened glider habitat revegetation.

**Table 3-2 Mitigation measures and evaluation of their effectiveness**

| Issue | Mitigation measure | History of success | Effectiveness rating |
|---|---|---|---|
| Mortality due to vehicle strike during both the construction and operational phase. | Implementation and maintenance of fauna fencing and connectivity structures | Maintenance of fauna fencing is undertaken as a regular component of asset maintenance. A number of Roads and Maritime projects have had additional fauna fencing installed as a result of fauna road kills including Bonville Deviation, Tandys Lane Upgrade and Karuah to Bulahdelah. | Moderate, monitor success and implement corrective actions |
| Loss of habitat including loss of potential den sites and foraging opportunities. | Identify exclusion zones and limits of clearing. | A standard procedure has been developed by Roads and Maritime and documented in the Biodiversity Guidelines for Construction (RTA 2011). The guidelines were developed in consultation with the NSW Office of Environment and Heritage (OEH), NSW Department of Primary Industries (DPI) (Fisheries), biodiversity specialists and Roads and Maritime staff including project managers, construction personnel and designers. Consultation was facilitated through a number of workshops carried out in 2009. These procedures have been developed using knowledge gained from a long history of upgrades on the Pacific highway and other road projects in NSW. | High |
| | Installation of exclusion fencing. | When used in combination with targeted crossing structures, exclusion fencing can be effective and reducing the number of fauna deaths associated with roads. | High |
| | Implementation of pre-clearing and clearing procedures. | Pre-clearing and clearing procedures offer the potential to remove existing threatened gliders from the proposed highway areas and median. Targeted inspection of suitable tree hollows, providing time allowance for fauna to vacate the habitat to be cleared and providing alternative nest box sites that would be assessed all comprise effective methods to reduce the risk to threatened gliders. | High, monitor success and implement corrective actions |
| | Construction related infrastructure to be planned and sited within cleared or disturbed areas of the ancillary site (particularly avoiding proximity to natural water sources and fauna movement areas). | The Roads and Maritime *Stockpile Site Management Procedures* (RTA 2011) would be used to site ancillary facilities. As such, the siting of temporary construction related infrastructure would be where possible within existing cleared or disturbed areas. This approach can substantially reduce the overall area of impact to vegetation and fauna habitat, while also reducing the area required to be rehabilitated at the end of construction. | High |
| Fragmentation of habitat and | Confirmation and installation of targeted crossing structures. | Poles, rope bridges and exclusion fences have been demonstrated as effective at permitting safe crossing of roads by threatened gliders and reducing the interactions or collisions with vehicles.<br><br>Targeted glider surveys were undertaken during the phase for the Woolgoolga to Glenugie project in February 2013. This survey was to review and confirm the proposed location of connectivity structures. The findings of this survey report would be used to inform the detailed design for the Woolgoolga to Glenugie project.<br><br>Studies have shown Squirrel Gliders use glider poles and rope bridges to cross minor and major roads (Veage and Jones 2007, Ball and Goldingay 2008, Goldingay, Taylor and Ball 2011, Soanes et. al. 2013, Goldingay, Rohweder and Taylor 2013). Less is known about Yellow-bellied Glider use of fauna connectivity structures. | Moderate, monitor success and implement corrective actions |

| | | | |
|---|---|---|---|
| | Maintenance of poles, rope bridge crossings and exclusion fences. | This aspect is considered to be the principal method for providing connectivity to adjacent habitat either side of roadways for glider species and has been proven as effective elsewhere in New South Wales when implemented. | High, monitor success and implement corrective actions |
| | Maintenance of revegetation | Maintaining revegetation may generally assist threatened glider populations to utilise existing areas, while potentially providing future habitat trees. Roads and Maritime contract specifications require the successful establishment of landscaping. Where landscaping has failed revegetation would be required to replace failed plantings and/or undertake additional weed control  Examples of where landscaping has been undertaken successfully on Roads and Maritime projects include the Bonville Deviation, Brunswick Heads to Yelgun, Karuah Bypass, Halfway Creek,  Ewingsdale Interchange, Tandys Lane Upgrade to name a few. | Moderate |
| Edge effects such as altered light levels and noise from construction and general traffic | Light, dust and noise would be managed in accordance with procedures in the CEMP. | Minimising the effects of light, dust and noise are considered to be essential for maintaining the quality of remnant habitat during construction and minimising impact to threatened gliders. In particular, minimising daytime construction noise and avoiding night time noise would be important for reducing the risk of changes to the foraging behaviour of gliders where population hotspots are known to exist.<br><br>Glider monitoring studies (van der Ree 2006, McCall 2010 and ngh environmental 2011) on the Hume Highway and Goulburn Valley Freeway indicate a decline in annual survival rates over time for constructed highways compared to areas of lower traffic volumes and small road widths. Environmental variables along the roadside such as vegetation structure, width of the road and traffic volumes may encourage or discourage glider movement. Monitoring glider movements and habitat utilisation during construction and operation of highways (ngh environmental 2011) has been successful for measuring glider population health and identifying risks. | Moderate monitor success and implement corrective actions |

# 4. Pre-construction management measures

## 4.1 Potential impacts during pre-construction

- Location of infrastructure within ancillary facility sites including heavy vehicle access may impact on threatened glider habitat, movements, foraging and behaviour.

## 4.2 Main goals for management

- No damage to threatened glider habitat outside of an ancillary facility during the pre-construction planning.
- Targeted surveys completed during detailed design to inform the detailed design and monitoring program.
- Complete habitat tree survey to quantify hollows for input into the nest box strategy.
- Identify habitat exclusions zones prior to construction.

## 4.3 Management measures

### 4.3.1 Targeted surveys

Targeted surveys for threatened gliders would be conducted during detailed design (as outlined in **Section 3.2**). Surveys would be undertaken in known and likely habitat areas at proposed arboreal crossing and where widened medians have been located to confirm presence, inform the selection of monitoring locations, and refine the location of connectivity structures targeted for gliders (refer **Section 5.3.5**).

The information would build on the threatened species distributional data presented in the EIS. For crossing structures, the location of threatened glider populations from these targeted surveys would further inform the detailed design, particularly in relation to the types of revegetation and fauna connectivity structures to be used to suit the target species.

Tree surveys would also be undertaken during detailed design at each of the widened medians to gather information on tree heights and ensure the tree heights are suitable for threatened glider crossings. If there are no trees greater than 20 metres in height, the location of the widened median would be refined. The survey would also consider assessment of trees in the adjacent road reserve. Additional sites would be proposed and assessed if there location is not sufficient.

A habitat tree survey would be undertaken after the surveyors have marked the limits of clearing. This survey would identify the hollow number and size classes of habitat trees to inform the nest box strategy regarding the number of boxes required. This survey would also aim to identify areas that are naturally depleted in habitat trees and the installation of nest boxes would be targeted for these areas.

The targeted population surveys would be completed pre-construction at monitoring locations to determine population abundance. This data would inform the monitoring program post-construction (refer to **Chapter 7**). Survey methods are described in detail in **Chapter 7**. The additional surveys would have three objectives, as follows:

1) To identify known or potential habitat and gather adequate baseline information for ongoing population monitoring to ass construction and operational mitigation measures.
2) To inform the detailed design with respect to refining the locations of the arboreal crossing structures targeted for threatened gliders (rope crossings and vegetated medians) and assessment of the need for crossing zones or single structures.

3) To identify suitability of tree heights at the widened medians for threatened glider crossings to inform the detailed design with respect to refining the locations of widened medians.
4) To identify the hollow number and size classes to inform the next box strategy.

### 4.3.2 Identify habitat exclusion zones

An exclusion zone is a designated ‘no-go’ area that is clearly identified and appropriately fenced to prevent damage to native vegetation and fauna habitat. This procedure would be documented in the CEMP and implemented along the entire construction corridor for all threatened species and endangered ecological communities.

Habitat exclusion zones and limits of clearing would include consideration of threatened glider habitat. Habitat exclusion zones would be informed by the targeted surveys and established during the on-ground survey of the road corridor. Exclusions zones would be established prior to the commencement of construction to ensure that construction activities such as clearing does not unnecessarily remove protected vegetation within the project, proposed widened median areas, and roadside vegetation that would be retained in and /or near threatened glider habitat areas.

The identification of exclusion zones may be staged with a priority for early works sites and then remaining areas of the construction corridor. Survey personnel would be inducted to ensure they do not encroach outside the limits of clearing.

Ancillary facility sites (ie temporary sites for construction related activities) would be sited in cleared land or sites with low ecological value to avoid unnecessary clearing of habitat (Roads and Maritime 2013).

## 4.4 Performance thresholds and corrective actions

**Table 4-1** summarises the pre-construction environmental planning measures for threatened gliders that are to be completed prior to the commencement of construction.

**Table 4-1 Mitigation measures, performance measures and corrective actions - pre-construction**

| Main goals for mitigation | Proposed mitigation measure | Monitoring/timing frequency | Performance thresholds | Corrective actions if deviation from performance thresholds |
|---|---|---|---|---|
| No damage to threatened glider habitat outside of an ancillary facility during the pre-construction planning. | Pre-clearing and clearing surveys.<br><br>Identification of exclusion areas.<br><br>Construction related infrastructure to be planned and sited within cleared or disturbed areas of the ancillary site. Particularly away from water sources and movements areas. | Report results in the CEMP/EMS.<br><br>Detailed plans to be prepared showing the proposed location of construction related infrastructure and signed off prior to commencement of construction. | Location of ancillary facilities approved prior to commencement of clearing. | Delay clearing / construction activities until details of ancillary facilities and stockpile sites have been identified and approved. |
| Targeted surveys completed during detailed design to inform the detailed design and monitoring program. | Targeted surveys undertaken during detailed design and structure locations refined.<br><br>Identification of ongoing monitoring site from targeted survey findings. | During detailed design prior to construction. | Targeted survey undertaken and monitoring program developed prior to construction. Survey and program signed off prior to construction. | Undertaken targeted survey and develop monitoring program prior to construction commencing. Do not commence construction until actions have been completed and signed off. |
| Complete habitat tree survey to quantify hollows for input into the nest box strategy | Tree habitat survey to quantify number of hollows to be removed for input into the nest box strategy. | Prior to clearing hollows informed by the targeted surveys undertaken during detailed design. | Tree habitat survey not undertaken.<br><br>Next box strategy not developed and approved. | Ensure tree hollow survey completed and nest box strategy has been developed and approved prior to construction commencing. |
| Identify habitat exclusions zones prior to construction | Temporary and permanent exclusion zone identification. | Pre-construction informed by the targeted surveys. | Exclusions zones not identified and approved prior to construction. | Delay construction until exclusions zones have been identified and approved. |

# 5. Construction management measures

## 5.1 Potential impacts during construction

- Loss of connectivity and access to important habitats during construction.
- Loss of habitat including potential den sites.
- Dust and noise impacting on movements and habitat use.
- Loss of foraging resources for threatened gliders.
- Direct mortality of fauna from construction activities.

## 5.2 Main goals for management

- Construction of crossing structures targeted for threatened gliders completed.
- All threatened gliders recovered from hollows or habitat trees successfully relocated.
- Methods for rehabilitation of glider habitat adjacent to the road document included in landscape design.
- No damage to threatened glider habitat outside of an ancillary facility during construction.
- Injured gliders return to health for release back to the wild.
- Installation of 70 per cent of nest boxes prior to the removal of any vegetation.

## 5.3 Management measures

### 5.3.1 Construction work method statements

Construction work method statements would be prepared for specific activities to ensure sound environmental practices have been implemented and to minimise the risk of environmental incidents or system failures, in accordance with the CEMP. This management plan would be included as an annexure to the project CEMP.

Construction work method statements would be prepared to address all construction threatened glider management requirements in consultation with relevant agencies, Roads and Maritime and the relevant project environmental manager prior to the commencement of identified activities.

### 5.3.2 Construction induction and training

Induction training would be conducted with all contractors and other staff that would be working in the areas of known and potential for threatened gliders habitat and distribution within the project. This training would identify threatened glider habitat, and crossing zones and key threats as identified above. The importance of following the clearing, translocation and rehabilitation protocols would be made clear for any personnel that require access to the site.

### 5.3.3 Pre-clearing and clearing procedures

Pre-clearing and clearing procedures would be outlined in the project specific CEMPs and FFMP. The procedure would adopt a consistent approach across all project sections in accordance with the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011).

In summary, prior to the commencement of clearing operations (pre-clearance), a licensed ecologist would identify all areas within the project to identify exclusion zones where vegetation and habitat would be retained (refer to **Section 4.3.2**). The identification of exclusion zones includes undertaking targeted surveys for threatened gliders. Where possible, trees greater than 20 metres in height would not be cleared for exclusion fencing or drainage structures within the widened medians and in nearby habitat within the construction corridor.

Clearing of vegetation and habitat features would be undertaken in a two stage process following the completion of pre-clearance surveys. Under-scrubbing and the removal of non-habitat trees would be undertaken first. Habitat trees would be removed at least 24 hours after the removal of non-habitat trees, to enable resident hollow-dependent fauna to evacuate the tree prior to felling. A licensed ecologist would be present to supervise the felling of each habitat tree. The ecologist would inspect each felled tree and record habitat/hollow characteristics and evidence of habituation, as described in the Ecological monitoring program. The ecologist would manage any injured or displaced fauna with assistance from a wildlife carer or vet for rehabilitating injured wildlife. Organisations such as Wildlife Information Rescue Service (WIRES) and/or Northern Rivers and Clarence Valley Wildlife Carers would be involved in wildlife rehabilitation. The ecologist or wildlife carer would relocate and release displaced fauna upon confirmation of the animal's health.

Threatened glider species identified within the clearing footprint would be relocated to similar habitat adjacent to the project in accordance with the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011). Release sites for threatened glider would be identified prior to the commencement of clearing and informed by the additional targeted surveys described in **Section 4.3.1**.

### 5.3.4 Fauna rehabilitation protocol

A licensed ecologist would be present on site during all vegetation clearing and habitat removal activities to capture and relocate threatened gliders that may be encountered. Identified habitat would be left for at least 24 hours after removing non-habitat vegetation to allow fauna to escape. If necessary, fauna may need to be trapped or captured and relocated to pre-determined habitat identified for fauna release. The *NSW Code of Practice for Injured, Sick and Orphaned Protected Fauna* (OEH 2011) would be followed for trapping and relocating threatened gliders.

### 5.3.5 Arboreal crossing structures and widened medians

Road crossing structures have been shown to reduce fauna mortality rates and to reduce the habitat fragmentation impacts of linear infrastructure. However the extent to which population viability can be maintained subsequent to installing the structures remains unclear.

As noted in **Section 3.4**, studies have shown Squirrel Gliders use glider poles and rope bridges to cross minor and major roads (Veage and Jones 2007, Ball and Goldingay 2008, Goldingay, Taylor and Ball 2011, Soanes *et. al.* 2013, Goldingay, Rohweder and Taylor 2013). Less is known about Yellow-bellied Glider use of fauna connectivity structures.

Arboreal crossing structures and widened medians would be provided to maintain landscape connectivity between habitat areas on the eastern and western sides of the project. Structures targeting threatened gliders include:

- Canopy (rope) bridges.
- Glider poles.
- Vegetated overpasses (land bridges) with glider poles.
- Widened medians with retained trees.

Fauna connectivity structures and design principles, proposed locations and target species have been described in the Biodiversity Working Paper - Biodiversity Connectivity Strategy Appendix A (Tables A-3 and A-4) (Roads and Maritime 2012). Broad locations for structures targeting threatened gliders have been identified for the concept design and these are summarised in **Table 5-1**. As noted in **Section 4.3** the location of proposed connectivity structures would be reviewed following the targeted surveys. A further two widened medians with retained trees are proposed in **Chapter 7**.

**Table 5-1 Arboreal crossing structures***

| Project Section | Chainage | Connectivity structure | Functionality | Adjacent habitat/s |
|---|---|---|---|---|
| 1 | 1.500 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Dirty Creek Range to Newfoundland State Forest (SF) and Yuragir State Conversation Area (SCA) |
| 1 | 4.950 – 6.900 | Widened median | Dedicated fauna crossing for arboreal mammals | Dirty Creek Range to Newfoundland SF and Yuragir SCA |
| 1 | 12.750 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Dirty Creek Range to Newfoundland SF and Yuragir SCA |
| 2 | 17.020 | Glider poles | Dedicated fauna crossing for arboreal mammals | Dirty Creek Range to Newfoundland SF and Yuragir SCA |
| 2 | 22.550 – 23.800 | Widened median | Dedicated fauna crossing for arboreal mammals | Dry sclerophyll forest. |
| 3 | 48.100 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Dry open sclerophyll forest on sand |
| 3 | 50.500 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Dry open sclerophyll forest on sand |
| 3 | 53.850 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Dry open sclerophyll forest on sand |
| 4 | 75.880 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Local corridor |
| 4 | 75.92 | Glider poles | Dedicated fauna crossing for arboreal mammals | Local corridor |
| 7 | 111.550 | Glider poles | Dedicated fauna crossing for arboreal mammals | Tabbimoble SF to Bundjalung National Park (NP) |
| 7 | 114.100 – 121.100 | Widened median | Dedicated fauna crossing for arboreal mammals | Local corridor |
| 7 | 116.400 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Double Duke SF to Tabbimoble Swamp NR |
| 7 | 118.800 | Land Bridge | Dedicated fauna crossing for mammals (including glider poles) | Tabbimoble Nature Reserve (NR) |
| 9 | 138.796 | Land Bridge | Dedicated fauna crossing for mammals (including glider poles) | Broadwater NP |
| 9 | 139.916 | Land Bridge | Dedicated fauna crossing for mammals (including glider poles) | Broadwater NP |
| 9 | 140.620 | Rope crossing | Dedicated fauna crossing for arboreal mammals | Broadwater NP |
| 10 | 156.016 | Land bridge | Dedicated fauna crossing for mammals (includes glider poles) | Wardell Heath |

*Station locations follow the EIS concept design and would be subject to change during detailed design.

As detailed in **Section 4.3**, targeted surveys for the threatened gliders would be undertaken during detailed design. Tree surveys would also be undertaken at each of the widened medians to gather information on tree heights and ensure the tree heights are suitable for glider crossings. If there are no trees greater than 20 metres in height with connectivity to adjacent threatened glider habitat, the location of the widened median would need to be refined.

### 5.3.6 Habitat revegetation

A landscape design would be developed for construction of each stage section of the project which provides specific details for the re-establishment of native vegetation on batters, cut faces, surrounding sediment basins and other areas disturbed during construction including approaches to fauna connectivity structures and riparian corridors. Methods for topsoiling, seeding and planting would be in accordance with the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011).

The landscape management plan would provide due consideration to the landscape requirements around crossing structures by retaining existing large trees where possible and planting suitable trees around glider poles and canopy bridge support poles that can replace the function of the artificial structures over time. This plan would also detail where and how disturbed adjacent areas are to be revegetated during construction. Landscaping would use locally indigenous species and target threatened glider food sources to encourage usage on both sides of the structure and thus provide the habitat linkage to the structure. Species used would include summer and winter feed trees for threatened gliders. Known feed tree species for Squirrel Glider have been listed in **Appendix B**. Feed tree species for Yellow-bellied Glider from the Approved Recovery Plan for the Yellow-bellied Glider (NSW NPWS 2003) are listed in **Appendix C**.

Strategic revegetation would be undertaken to enhance connectivity through revegetation of lands within the road reserve prioritising the glider crossing zones, including surrounding targeted structures.

Specific locations identified for revegetation around arboreal crossing structures identified in the Biodiversity Connectivity Strategy (Roads and Maritime 2012) include Section 9 of the project (chainage 140.620) where a canopy bridge would be combined with revegetation of an area of crown land adjacent to Broadwater National Park.

### 5.3.7 Nest boxes

To mitigate impacts from removal and loss of hollow-bearing trees from the project, nest boxes would be installed to compensate for this loss. Guidance regarding the dimensions of nest boxes, installation and maintenance is provided in the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011). The procedure for next box management on the project has also been detailed in the Ecological Monitoring program.

Project specific nest box management plans (NBMPs) would be developed as part of the project specific FFMPs. Each NBMP would identify the number, type and dimensions of nest boxes required based on the number, quality and size of the hollows lost and would specify installation requirements. Installation of 70 per cent of nest boxes prior to the removal of any vegetation would be completed.

## 5.4 Performance thresholds and corrective actions

**Table 5-1** summarises the construction environmental planning measures for threatened glider and corrective actions if the measure deviates from the performance criteria.

**Table 5-2 Mitigation measures, performance measures and corrective actions - construction**

| Main goals for mitigation | Proposed mitigation measure | Monitoring/timing frequency | Performance thresholds | Corrective actions if deviation from performance thresholds |
|---|---|---|---|---|
| Construction of crossing structures targeted for threatened gliders completed. | Installation of connectivity structures based on target survey findings. | Completed prior to operation. | Connectivity structures not installed prior to operation. | Delay opening road to traffic until connectivity structures have been installed. |
| All threatened gliders recovered from hollows or habitat trees are successfully relocated. | • Staged clearing around habitat trees to provide time for fauna to vacate the area.<br>• Implementation of fauna handling protocols as per the Roads and Maritime biodiversity guidelines. | 24 hours to 48 hours prior to clearing of habitat trees that may potentially support gliders.<br>Daily monitor procedures to ensure effectiveness. | Threatened glider species fatalities occurring within clearance areas. | Review existing procedures and processes.<br>Re-evaluate risks and modify pre-clearance activities accordingly. |
| Methods for rehabilitation of glider habitat adjacent to the road document in the completed Landscape Management Plan | Development of a landscape management plan that considered threatened glider population habitat and revegetation habitat areas. | Development landscape management plan during construction. Implement progressively throughout construction as sections have been completed. | Landscape management plan not developed and implemented during construction. | Develop and implement landscape management plan. |
| No damage to threatened glider habitat outside of an ancillary facility during construction. | • Identify all areas within the project corridor that contain vegetation and habitat to be retained, identifying exclusion zones.<br>• Ancillary facility sites (i.e. temporary sites for construction related activities) sited in cleared land or sites with low ecological value. | Check ancillary facility areas and surrounds monthly for habitat damage. | Zero damage to habitat surround ancillary facilities sites. | Stabilise, revegetate damaged area and monitor as per revegetation monitoring program (operational measure) |
| Injured gliders return to health for release back to the wild. | • Injured gliders are transferred to wildlife carers or vet.<br>• Refer to FFMP for wildlife carer and vet details. | • Monitoring to occur daily as part of routine site inspections.<br>• Injured gliders to be transferred to wildlife carers within 8 hours of collection. | Low mortality among threatened gliders injured and transferred to care. | Review mitigation measures and corrective actions to identify points where improvements must be made then implement these. Monitor for success. |
| Installation of 70% of nest boxes prior to the removal of any vegetation | Installation of nest boxes prior to the removal of vegetation. | Review of the number of next boxes installed prior to vegetation removal. | Less than 70% of next boxes have been installed prior to vegetation removal. | Install nest boxes prior to any further vegetation removal. |

# 6. Operational management measures

## 6.1 Potential impacts during operational phase

- Loss of connectivity and access to important habitats.
- Threatened gliders unable or unwilling to use designated road crossing mitigation measures.
- Degradation of habitat values due to edge effects in habitats adjoining the road in identical important areas.
- Direct mortality of gliders from vehicle strike on the highway.

## 6.2 Main goals for management

- Targeted glider crossing structures effective post-construction.
- Successful glider habitat revegetation on Roads and Maritime owned land post-construction.
- Targeted next boxes found to be used by threatened and/or other gliders species at three years post-construction.

## 6.3 Management measures

### 6.3.1 Maintenance of habitat restoration

Inspection, monitoring and maintenance of revegetated areas would be specified in the FFMP. Maintenance of revegetated areas would continue as required, although this would be monitored to measure effectiveness. The recommended maintenance and monitoring schedule for the revegetated areas in the first year is outlined in **Table 6-1** and for year two to five in **Table 6-2**.

**Table 6-1 Recommended monitoring and maintenance schedule (Year 1)**

| Monitoring | Timing | Maintenance |
|---|---|---|
| Site preparation | Commencement | Weeds controlled within 2 metres of planting locations, blanket treatment of weed areas if appropriate or targeted treatment of weed outbreaks. |
| Sufficient soil moisture for plant growth | First month | Weekly watering or as required. |
| Weed and plant health | 3 months | Weeds not smothering plants, plants healthy with active growth, replanting required if plant survival not at required percentage. |
| Mulch/weed suppression<br>Plant nutrient deficiency | 3 Months | Addition of mulch where required.<br>Addition of fertiliser/nutrients where required. |
| Monitoring weeds and plant health | 6 months | Weeds not smothering plants, healthy with active plant growth, replanting required if the target percentage survival rate not achieved (e.g. 80%). |
| Mulch/weed suppression<br>Plant nutrient deficiency | 6 months | Addition of mulch where required.<br>Addition of fertiliser/nutrients where required. |
| Weed and plant health | 9 months | Weeds not smothering plants, healthy active plant growth, replanting required if the target percentage survival rate not achieved. |
| Mulch/weed suppression<br>Plant nutrient deficiency | 9 months | Addition of mulch where required.<br>Addition of fertiliser/nutrients where required. |
| Weed and plant health | 12 months | Weeds not smothering plants, healthy active plant growth, replanting required if the target percentage survival rate not achieved. |
| Mulch/weed suppression<br>Plant nutrient deficiency | 12 months | Addition of mulch where required.<br>Addition of fertiliser/nutrients where required. |

**Table 6-2 Recommended monitoring and maintenance schedule (Year 2 to Year 5)**

| Monitoring | Timing | Maintenance |
|---|---|---|
| Mulch/weed suppression<br>Plant nutrient deficiency | Every 6 months for 2 years, then annually | Addition of mulch where required.<br>Addition of fertiliser/nutrients where required.<br>Weeds controlled within 2 metres of planting locations, blanket treatment of weed areas if appropriate or targeted treatment of weed outbreaks. |
| Weed and plant health | Every 6 months for 2 years, then annually | Weeds not smothering plants, healthy active plant growth, replanting required if the target percentage survival rate not achieved. |

### 6.3.2 Maintenance of arboreal crossing structures

The Roads and Maritime would maintain fauna crossing structures as part of the standard maintenance requirements for stability and damage for perpetuity as required.

Poles suspending the ladder would be made from treated timber to minimise the risk of rope bridges falling onto the road. Rope would be inspected periodically for signs of decay or weakening, and replaced where necessary.

### 6.3.3 Maintenance of nest boxes

The Ecological Monitoring Program outlines a consistent approach to maintain and monitor nest boxes. Nest boxes would be installed to compensate for the loss of hollow-bearing trees from the project. Installation and maintenance would be in accordance with the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA Projects* (RTA 2011).

Monitoring would be required to determine the usage of nest boxes by the target species and other fauna and any maintenance requirements. Monitoring requirements for next boxes is outlined in **Section 7.5**.

Factors to be considered as part of the maintenance schedule include:

- The need to remove exotic pests species such as Common Mynas, Common Starling and European Bees.
- Replacement of fallen, damaged or degraded nest boxes.
- Repositioning, re-erection or relocation of dysfunctional nest boxes.
- Checking each box is not holding water or leaking.
- Removing excess nesting material as this may impede access over time.

Nest box inspections would be scheduled outside the breeding season for the threatened gliders. Squirrel glider young are produced from April through to November and remain in the nest for an additional three months (NSW Scientific Committee 2008). Yellow-bellied Gliders have peak births in the period July to September, young remaining with their parents for one to two years (Goldingay 2008). As such, nest box maintenance would ideally be scheduled to be undertaken annually in March.

## 6.4 Performance measures and corrective actions

**Table 6-3** summarises the operational environmental planning measures for threatened gliders and corrective actions if the measure deviates from the performance criteria.

## 6.5 Monitoring effectives of mitigation measures

Monitoring methods and parameters, performance thresholds have been discussed in **Chapter 7**.

**Table 6-3 Mitigation measures, performance measures and corrective actions - operation**

| Main goals for mitigation | Proposed mitigation measure | Monitoring/timing frequency | Performance thresholds | Corrective actions if deviation from performance thresholds |
|---|---|---|---|---|
| Targeted glider crossing structures effective post-construction. | • Maintenance of widened medians and crossing structures.<br>• Conduct threatened glider connectivity structure and road mortality survey at regular intervals and record road deaths as detailed in Chapter 7. | • Evaluate effectiveness of crossing structures and widened medians as per monitoring program as detailed in Chapter 7.<br>• Annual monitoring report. | • No evidence of use of arboreal crossings and widened medians by threatened gliders post-construction.<br>• High visitation/usage rates by exotic predators. | Review location and type of connectivity structures installed and implement additional controls or provisional measures where appropriate and in consultation with OEH. |
| Successful glider habitat revegetation on Roads and Maritime owned land post-construction. | Revegetation of areas outlined in the Landscape Management Plan for the threatened glider. | Annual monitoring of revegetated areas. Monitoring of revegetation areas would commence within six months of after initial establishment and would occur annually (in Spring/Summer) until success of the revegetation has been achieved against criteria | • Revegetated habitat used by target species.<br>• >30% mortality of planted vegetation. | Review maintenance schedule for revegetated areas and plant more feed and habitat trees as required. |
| Targeted next boxes found to be used by gliders at three years post-construction. | Inspection of next boxes and confirmation that next boxes have been used by the target species. | 12 months after installation followed by summer or winter census to account for seasonal variation. It is proposed that annual monitoring and maintenance would continue for five consecutive monitoring periods. Annual monitoring report. | • Seventy per cent (70%) of the nominated nest boxes would be installed prior to or during the clearing works.<br>• Threatened gliders not using next boxes. | • Re-evaluate nest box strategy if boxes continue to not be used by target species or are used by pest species.<br>• Replace nest boxes as required. |

# 7. Monitoring program

Monitoring would be undertaken to determine the effectiveness of construction and operational mitigation measures for threatened gliders. The monitoring program would use a BACI approach (Before versus After / Control versus Impact) comparing before and after data with impact versus control sites.

Monitoring would focus on areas of known and potential habitat for the target species. The majority of records for threatened gliders are from Sections 1 to 3 and 6 to 8 of the project. The Halfway Creek area in Section 2 is considered to be a hotspot for Yellow-bellied Glider, and there is also a high proportion of Squirrel Glider records that occur around Halfway Creek (Section 2), Pillar Valley to Tyndale (Section 3), and Mororo to Broadwater (Section 6 to 8). The EIS describes predictive habitat along the remaining project sections based on Biometric vegetation types and these are also considered likely habitat to be targeted.

## 7.1 Objectives

Monitoring would be conducted before, during and after construction until such time as the proposed mitigation measures have been proven to be effective. The monitoring data would aim to provide robust information to draw sound conclusions around the effectiveness of mitigation measures for the target species. The objectives of the monitoring program include:

- The monitoring of threatened gliders adjacent to the project footprint to provide data to identify changes to habitat usage and determine if this can be attributed to the project.
- To provide an adaptive monitoring program to assess the effectiveness of the mitigation measures proposed, and allow corrective measures to be implemented.
- Details of contingency measures that would be implemented in the event of changes to habitat usage patterns or evidence that mitigation measures are ineffective and directly attributable to the construction or operation of the road.
- Provision of annual reporting of monitoring results.

## 7.2 Glider population monitoring

### 7.2.1 Objectives

- Targeted survey to establish presence/absence at potential/likely habitat as identified by predictive habitat modelling and described in the EIS and identify ongoing monitoring sites including impact and control sites
- Monitor glider populations/abundance in an adjacent to the project corridor at mitigated sites and compare with control/reference sites
- Inform the detailed design with regard to refining the location of crossing structures or crossing zones including widened medians
- Where possible identify den sites for consideration during vegetation clearing

### 7.2.2 Selection of monitoring locations

Targeted surveys for the threatened gliders would be undertaken during detailed design to confirm the presence of populations and finalise the impact and reference sites. The surveys would target known and potential habitat identified in the EIS with the aim of establishing a set of monitoring sites that meet the following criteria:

- Impact sites (these would be mitigated sites such as widened medians and near crossing structures within 100 metres of the road edge or both sides of the road).

- Control sites (these would be unmitigated sites within 100 metres of the road edge on both sides of the road).
- Reference sites (>300 metres from the project).

It is envisaged that surveys would be conducted on all project sections however the efficacy of conducting ongoing monitoring for each project section would be informed by the results of the targeted surveys. The program has been designed on a target species approach rather than project by project. In this way the need for ongoing monitoring would be targeted at a set of known population locations rather than conducted for each of the project upgrade sections.

The initial surveys would include targeted surveys in the vicinity of the proposed crossing structures identified in **Table 5-1** to confirm presence / absence of gliders at these locations for direct input into the detailed design. Detailed design would consider the location of all identified populations, the provision of crossing zones or single structures and data from the widened median tree surveys.

Following completion of the targeted surveys, the final monitoring sites would be identified and include impact, control and reference sites. The locations and habitat details of monitoring sites would be reported in the first monitoring report for each project and ongoing monitoring would be replicated at these sites and reported annually.

The location of reference sites would depend on ongoing consultation between Roads and Maritime, landowners and stakeholders which may include state forest, conservation reserves, private forested land or offset sites. The program would aim to ensure that control and reference sites are in the same habitat type as impact sites, this would be stratified by vegetation association (biometric vegetation types) and consider soil types, elevation, slope and aspect.

### 7.2.3 Timing and methods

The program intends to compare the ‘before’ construction data with ‘during’ and ‘after’ construction data and the impact sites with control sites and reference sites. Surveys are to be conducted every three months to sample for seasonal variability with time as a factor in assessing the impacts on glider populations. The initial surveys before construction should aim for a minimum of two seasonal surveys and depending on timing of construction could be increased to once every three months. Repeat surveys would be conducted to maximise detection rates and index of abundance.

The monitoring program would aim to compare species abundance at each site to be estimated based on spotlight transect surveys. Goldingay and Sharpe (2004) found spotlighting under suitable condition by experience personnel was equally effective as trapping in detecting and providing population index of Squirrel Gliders. This technique has also proven effective for Yellow-bellied Glider (Davey 1990), and other glider species (refer Taylor and Goldingay 2009).

Spotlight surveys would be conducted along transects (200 m in length) and placed to sample the same habitat at each site as described above. As the aim would be to compare relative abundance, one transect would be sampled per site. Transects at impacts site would be located adjacent to the crossing infrastructure and parallel to and 100 metres from the proposed road upgrade. Transects at control sites would also be parallel to and 100 metres from the proposed road upgrade at unmitigated sites. This was designed to assist in understanding of the proximity of gliders to the crossing structures and therefore the likelihood that dispersing individuals would encounter the structures. The procedure for monitoring the structures themselves and glider mortality is detailed in **Section 7.3** and **Section 7.4**.

Spotlighting would be conducted over three nights by a single operator with a 50 watt spotlight aimed at sampling the same time period (e.g. 25 minutes per transect). Gliders would be recorded within 40 metres of the spotlight transect (as per Taylor and Goldingay 2009). For each glider observation, the species, behaviour, time and location would be recorded.

The mean number of gliders on each transect from the three surveys would be calculated for comparison between before and after impact and impact versus control and reference sites.

### 7.2.4 Performance thresholds and contingency measures

Reliability of these indicators would also rely on being able to take into account population fluctuations due to changing availability of food sources, hence the use of control and reference sites. Squirrel Glider populations are very susceptible to reduced food availability during poor flowering seasons (Sharpe 2004). The main performance thresholds and corrective actions are outlined in Table 7-1:

**Table 7-1 Performance measures and corrective actions during monitoring of threatened glider activity monitoring**

| Performance threshold | Corrective actions |
|---|---|
| Decline in the before construction relative abundance of Squirrel Glider or Yellow-bellied Glider at impact sites over 3 consecutive monitoring sessions. | Review monitoring methods, considering further monitoring and assessment should there be a decline in population abundance.<br>Consider potential for natural variation to be responsible for decline in population numbers/density.<br>Review location of the arboreal crossing structures and consider moving and/or adding structures.<br>Investigate habitat adjoining the highway and consider improving habitat condition and connectivity. |

## 7.3 Arboreal crossing structures and widened medians

### 7.3.1 Objectives

- Monitor the effectiveness of targeted arboreal crossing structures and widened medians for facilitating the dispersal of threatened gliders.

### 7.3.2 Selection of monitoring locations

Monitoring locations would include the connectivity structures targeted for threatened gliders listed in **Table 5-1**, including rope crossings, targeted land bridges and widened medians.

### 7.3.3 Timing and methods

Monitoring of the arboreal crossing structures and widened medians would be undertaken to assess their effectiveness to facilitate movement of threatened gliders across the project.

The monitoring locations would occur at each of the proposed structures and locations identified in **Table 5-1** and follow a similar design to other studies on the Pacific Highway (example Goldingay *et al* (2013) as described below. The program would be undertaken until the success of the mitigation measures have been proven.

- A digital camera activated by an infrared motion sensor and infrared flash installed at each end of the rope crossing (at the top of support poles) with the objective to record successful crossings of threatened gliders from one side of the highway to the other. Installing a camera at each end of the rope bridge would aid in the confirmation of complete crossing by an individual.
- Cameras are to be set to record between 1930 and 0600 hours for the monitoring period. Data would be downloaded and batteries changed very 14 day.
- Camera set up would be standardised to allow comparison with subsequent monitoring events.
- Hair funnels attached to glider poles and rope crossing support poles, or placed along three transects within and either side of the widened medians. Funnels would be baited with a mixture of peanut butter, honey, oats and pistachio nut oil for 14 consecutive nights per monitoring period. Hair samples would be sent to an appropriately qualified/experienced specialist for identification.

Monitoring of wildlife road crossing structures by Soanes *et al.* (2013) found the rate of glider crossing increased over several years as animals habituated to the structure. They suggest monitoring periods of at least two years to allow gliders adequate time to habituate to the crossing structures.

Monitoring of arboreal crossings would commence six months after installation of the structures (i.e. Veage and Jones 2007) and then continue every once every three months timed to coincide with the population monitoring described in **Section 7.2** until the effectiveness of each crossing site has been proven, after which the need for further monitoring would be reviewed in consultation with OEH.

Additional monitoring may be required in the event the monitoring data suggests any of the crossings have been ineffective and modification/treatments are required.

### 7.3.4 Performance thresholds and contingency measures

Populations of threatened gliders would be monitored to identify the effectiveness of mitigation measures and to inform the need for corrective actions. The main performance thresholds and corrective actions for arboreal crossing structures and widened medians are outlined in Table 7-2.

**Table 7-2 Performance measures and corrective actions during monitoring of arboreal crossing structures and widened medians**

| Performance threshold | Corrective actions |
|---|---|
| No evidence of use of arboreal crossings and widened medians by threatened gliders post-construction. | Review location and type of connectivity structures installed and implement provisional measures in consultation with OEH.<br>Consider more strategic planting of habitat or the installation of additional glider poles to informed by the long-term population monitoring data. |

## 7.4 Road mortality monitoring

### 7.4.1 Objectives

- Monitor the incidence of glider / vehicle collisions at mitigated and unmitigated sites.

### 7.4.2 Timing and methods

Monitoring of threatened glider mortalities would occur adjacent to all arboreal crossing structures and the widened medians in relevant project sections and also at control sites established as per **Section 7.2**. Threatened glider mortality monitoring would occur every three months and coincide with the glider population monitoring program (see **Section 7.2**). The survey would involve a walking a transect 500 metres either side of the crossing on both sides of the upgraded highway. For widened medians this would include an additional transect within the median.

The number of road mortalities would be collated per monitoring event and geographic coordinates recorded for each road kill specimen to be assessed in relation to the closest fauna crossing structure to evaluate their effectiveness.

Incidental observations of road mortalities would also be collected by the construction team during the construction phase.

### 7.4.3 Performance thresholds and contingency measures

Performance of the connectivity structures in preventing threatened glider road mortalities would be measured by achievement of a zero rate of vehicle strikes. Detection of threatened glider road kill is difficult, as most individual animals if struck are thrown far from the road by the collision, or damaged too extensively to be identified. Reliance on this method alone could result in an under-estimation of the number of individuals struck by vehicles. The main performance thresholds and corrective actions for road mortality monitoring are outlined in Table 7-3.

**Table 7-3 Performance measures and corrective actions during monitoring of threatened glider road mortality monitoring**

| Performance threshold | Corrective actions |
|---|---|
| Zero rate of target threatened glider vehicle strikes. | Review monitoring methods, considering further monitoring and assessment should there be a decline in population abundance.<br>Consider potential for natural variation to be responsible for decline in population numbers/density.<br>Review location of the arboreal crossing structures and consider moving and/or adding structures.<br>Investigate habitat adjoining the highway and consider improving habitat condition and connectivity. |

## 7.5 Nest boxes

The procedures for installation and monitoring of nest boxes relate to a range of fauna species and would be consistently applied across all project sections and are therefore documented in the Ecological Monitoring Program.

## 7.6 Habitat revegetation

### 7.6.1 Objectives

- Evaluate the success of habitat revegetation for glider species adjacent to crossing zones.

### 7.6.2 Timing and methods

After the first year of maintenance of habitat revegetation (**Section 6.3.1**), annual monitoring of revegetated areas adjacent to crossing structures and widened medians would be undertaken using a condition assessment approach, modified from the BioBanking assessment methodology (DECC 2008) to evaluate the progress of revegetation against benchmark data for the target vegetation community. These tasks would be integrated into the landscape design for the project, as habitat restoration would benefit a diversity of species.

BioBanking is a site-based, quantitative and therefore repeatable assessment procedure that provides a numeric score of the condition of native vegetation. A series of permanent monitoring plots (100 metres x 50 metres) would be established in revegetation areas. Nested plots would be placed on both sites of the structure and assessed for site-based vegetation attributes as follows (note the attribute ‘number of large trees with hollows’ and logs has been removed as revegetation would not develop large trees with hollows within the monitoring period):

1. Native plant species richness.
2. Native over storey cover.
3. Native mid-storey cover.
4. Native ground cover (grasses).
5. Native ground cover (shrubs).
6. Native ground cover (other).
7. Exotic plant cover.
8. Proportion of over-storey species occurring as regeneration.

Revegetation criteria for the site-based attributes would be developed, derived from benchmark data for the target vegetation community.

Monitoring of revegetation areas would commence within six months of after initial establishment and would occur annually (in Spring/Summer) until success of the revegetation has been achieved against criteria. The following information would be collected:

- Record of treatments used, including topsoil source, soil treatment, seeding and planting rates and mixes.
- Photographs of the revegetation areas from permanent photographic points.

- BioBanking site-based vegetation attributes from permanent monitoring plots.
- Slope and erosion.
- Any failure of revegetation works.

### 7.6.3 Performance thresholds and corrective actions

Table 7-4 outlines the monitoring program, performance indicators and corrective actions if monitoring finds poor outcomes as measured by performance indicators.

**Table 7-4 Performance measures and corrective actions during monitoring for habitat regeneration**

| Performance threshold | Corrective actions |
|---|---|
| • The mean mortality of planted trees and shrubs per plot is greater than 30%.<br>• Mean cover abundance in any one strata has reduced by 30%.<br>• Mean cover of weeds is greater than 30%. | Review maintenance schedule for revegetated areas and/or replant as required. |

## 7.7 Evaluation, project review and reporting

Detailed threatened glider reports would be prepared outlining the results of any monitoring undertaken pertaining to the project.

### 7.7.1 Responsibility

The contractor employed to undertake the threatened glider monitoring for each relevant project would be responsible for the evaluation of the monitoring information collected. Monitoring of threatened glider crossing structures, widened medians and habitat restoration has been anticipated to be undertaken separately for each relevant project section.

### 7.7.2 Timing

A brief annual report would be prepared by the contractor for distribution to the Roads and Maritime and relevant government agencies regarding the annual population counts.

A final report would be prepared at the conclusion of the monitoring period. This report would incorporate all the results of the monitoring and recommend any additional measures (if deemed necessary) to facilitate the long-term survival of Squirrel Glider and Yellow-bellied Glider populations in the locality.

# 8. Summary table and implementation schedule

**Table 8-1** provides an overall example summary of the actions proposed in the above plan. It also identifies the person responsible for the actions and the estimated timing of the project.

*The program schedule would be updated following a review of the approval and project timelines.*

**Table 8-1 Summary table and implementation schedule of management plan**

| No. | Task | Responsibility | Pre-construction | Construction | Post-construction (Year and Season) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | | | | 2 | | | | 3 | | | | 4 | | | | 5 | | | |
| | | | | | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring |
| 1. Pre-construction management | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.1 | Targeted surveys including baseline monitoring, tree surveys and habitat tree surveys | Contractor's ecologist | X | | | | | | | | | | | | | | | | | | | | | |
| 1.2 | Identification of exclusion zones | Contractor's ecologist | X | | | | | | | | | | | | | | | | | | | | | |
| 1.3 | Location of temporary construction sites | Contractor's ecologist, Roads and Maritime | | X | | | | | | | | | | | | | | | | | | | | |
| 2. Construction management | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.1 | Construction work method statement | Contractor | | X | | | | | | | | | | | | | | | | | | | | |
| 2.2 | Construction induction and training | Contractor | | X | | | | | | | | | | | | | | | | | | | | |
| 2.3 | Pre-clearing and clearing procedures | Contractor | | X | | | | | | | | | | | | | | | | | | | | |
| 2.4 | Fauna rehabilitation protocol | Contractor's ecologist | | X | | | | | | | | | | | | | | | | | | | | |
| 2.5 | Arboreal crossing structures and widened medians | Roads and Maritime | | X | | | | | | | | | | | | | | | | | | | | |
| 2.6 | Nest boxes | Roads and Maritime | | X | | | | | | | | | | | | | | | | | | | | |
| 2.7 | Habitat restoration – Landscape Management Plan | Roads and Maritime | | X | | | | | | | | | | | | | | | | | | | | |
| 3. Operational management | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.1 | Maintenance of widened medians | Roads and Maritime | | | X | | | | | | | | X | | | | | | | | X | | | |
| 3.2 | Maintenance of habitat restoration | Roads and Maritime | | | X | X | X | X | X | | | | X | | | | X | | | | X | | | |
| 3.3 | Maintenance of arboreal crossing structures | Roads and Maritime | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 3.4 | Maintenance of nest boxes | Roads and Maritime | | | | | | | X | | | | X | | | | X | | | | X | | | |
| 3.5 | Predator control | Roads and Maritime | | | | | | | | | | | | | | | | | | | | | | |
| 4. Operational monitoring | | | | | | | | | | | | | | | | | | | | | | | | |
| 4.1 | Threatened glider population monitoring | Ecologist | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 4.2 | Road mortality monitoring | Ecologist | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 4.3 | Arboreal crossing structure and widened median monitoring | Ecologist | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 4.4 | Habitat restoration | Ecologist | | | X | | | | X | | | | X | | | | X | | | | X | | | |

| No. | Task | Responsibility | Pre-construction | Construction | Post-construction (Year and Season) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | | | | 2 | | | | 3 | | | | 4 | | | | 5 | | | |
| | | | | | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring |
| | monitoring | | | | | | | | | | | | | | | | | | | | | | | |
| 4.5 | Evaluation and reporting | Ecologist | | | | X | | | | X | | | | X | | | | X | | | | X | | |

# 9. References

Ball, T. and Goldingay, R.L. (2008). Can wooden poles be used to reconnect habitat for a gliding mammal? Landscape and Urban Planning 87 (2008) 140–146

Claridge, A. W., and van der Ree, R. (2004). Recovering endangered populations in fragmented landscapes: the squirrel glider Petaurus norfolcensis on the south-west slopes of New South Wales. Pages 678-687 in D. Lunney, editor. Conservation of Australia's forest fauna. Second Edition. Royal Zoological Society of New South Wales, Mosman, New South Wales, Australia.

Department of Environment and Climate Change NSW (DECC) (2008) BioBanking Assessment Methodology.

Department of Environment and Conservation (2004). Threatened Species Survey and Assessment: Guidelines for developments and activities (working draft), New South Wales Department of Environment and Conservation, Hurstville, NSW.

Department of Sustainability, Environment, Water, Population and Communities (1996). Action Plan for Australian Marsupials and Monotremes. Wildlife Australia. Accessed online 4 April 2013 at http://www.environment.gov.au/biodiversity/threatened/publications/action/marsupials/29.html

Department of Sustainability, Environment, Water, Population and Communities (2011). Survey guidelines for Australia's threatened mammals. Commonwealth of Australia. Accessed online 18 July 2013 at http://www.environment.gov.au/epbc/publications/threatened-mammals.html

Forman R. T. T., Sperling D., Bissonette J. A., Clevenger A. P., Cutshall C. D., Dale V. H., Fahrig L., France R., Goldman C. R., Heanue K., Jones J. A., Swanson F. J., Turrentine T. and Winter T.C. (2002). 'Road Ecology. Science and Solutions, Island Press: Washington.

Gibbons, P. and Lindenmayer, D. (2002). Tree hollows and wildlife conservation in Australia. CSIRO Publishing.

Goldingay, R.L. and Kavanagh, R.P. (1991). The Yellow-bellied Glider: a review of its ecology, and management considerations, in Lunney D. (Ed.) Conservation of Australia's Forest Fauna. pp. 365-375. Mosman, NSW.

Goldingay, R.L. (2008). Yellow-bellied Glider Petaurus australis Shaw 1791. In S. Van Dyck and R. Strahan (Ed.) The Mammals of Australia (Third Edition). New Holland Publishers.

Goldingay, R.l., Taylor, B.D., and Ball, T. (2011). Wooden poles can provide habitat connectivity for a gliding mammal. Australian Mammalogy, 33, 36–43

Goldingay, R.I., Rohweder, D. and Taylor, B.D. (2013). Would arboreal mammals use rope-bridges across a highway in eastern Australia? Australian Mammalogy, 2013, 35, 30–38

Kavanagh, R. P. (1984). Seasonal changes in habitat use by gliders and possums in southeastern

McCall, S. C., M. A. McCarthy, R. van der Ree, M. J. Harper, S. Cesarini, and K. Soanes. 2010. Evidence that a highway reduces apparent survival rates of squirrel gliders. *Ecology and Society* **15**(3): 27.New South Wales. In 'Possums and Gliders'. (Eds A. P. Smith and I. D. Hume.).Australian Mammal Society: Sydney. pp. 527-543.

New South Wales National Parks and Wildlife Service (NPWS) (2003). Recovery Plan for the Yellow-bellied Glider Petaurus australis). NSW National Parks and Wildlife Service, Hurstville.

New South Wales Scientific Committee (2008) Squirrel Glider Petaurus norfolcensis. Review of current information in NSW. August 2008. Unpublished report arising from the Review of the Schedules of the Threatened Species Conservation Act 1995. NSW Scientific Committee, Hurstville.

Ngh environmental (2011) Terrestrial Monitoring Program, Albury-Wodonga National Highway Project. Conneq Infrastructure Services.

Office of Environment and Heritage (OEH) (2011). Code of Practice for Injured, Sick and Orphaned Protected Fauna. State of NSW and the Office of Environment and Heritage.

Office of Environment and Heritage (OEH) (2013). NSW BioNet. [online]. Available from: http://www.bionet.nsw.gov.au/ [Accessed April 12, 2013].

van der Ree, R. (2006). Road upgrade in Victoria a filter to the movement of the endangered Squirrel Glider Petaurus norfolcensis: Results of a pilot study. Ecological Management and Restoration 7, 226-228.

Roads and Traffic Authority (RTA) (2011) Biodiversity Guidelines – Protecting and managing biodiversity on RTA projects, Roads and Traffic Authority of New South Wales.

Roads and Maritime (2012) Upgrading the Pacific Highway Woolgoolga to Ballina Upgrade Working paper: Biodiversity Assessment. November 2012

Roads and Maritime (2013). Woolgoolga to Ballina Pacific Highway Upgrade: DRAFT Ecological Monitoring Program Version R.0.3. NSW Roads and Maritime Services.

Sandpiper Ecological Surveys (2013) Pacific Highway Upgrade – Woolgoolga to Glenugie. Aerial Crossings and Exclusion Fencing. Report for ARUP/PB Joint Venture.

Sharpe, DJ (2004) Effect of flower failure on a population of squirrel gliders (Petaurus norfolcensis) in northeast New South Wales. In ‘The Biology of Australian Possums and Gliders’. (Eds RL Goldingay and SM Jackson) pp. 339-349. (Surrey Beatty: Sydney)

Soanes, K., Carmody L.M., Vesk, P. A., McCarthy, M. A., Moore, J. L., van der Ree, R. (2013) Movement re-established but not restored: Inferring the effectiveness of road-crossing mitigation for a gliding mammal by monitoring use. Biological Conservation 159 434–441

Trudgeon, M. (2006) Husbandry Manual For Squirrel Glider. Petaurus norfolcensis.

Veage, L. and Jones, D.N. (2007) Breaking the Barrier: Assessing the Value of Fauna-friendly Crossing Structures at Compton Road. Report for Brisbane City Council. Centre of Innovative Conservation Strategies, Griffith University, Brisbane, Qld, Australia.

# 10. Acronyms and abbreviations

| Acronym / Abbreviation | Description |
|---|---|
| BACI | Before-After- Control-Impact |
| CFFMP | Construction Flora and Fauna Management Plan |
| CEMP | Construction Environmental Management Plan |
| CMS | Construction Method Statements |
| DoPI | Department of Planning and infrastructure |
| DECC | Department of Environment and Climate Change NSW |
| DPI | Department of Primary Industries |
| DSEWPaC | The Department of Sustainability, Environment, Water, Population and Community |
| EIS | Environmental Impact Statement |
| EMR | Environmental Management Representative |
| EMS | Environmental Management System |
| EPA | Environmental Protection Authority |
| EP&A Act | Environmental Planning and Assessment Act 1979 |
| EPBC Act | Environment Protection and Biodiversity Conservation Act 1999 |
| FFMP | Flora and Fauna Management Plan |
| NBMP | Nest Box management plan |
| NSW | New South Wales |
| OEH | The NSW Office of Environment and Heritage |
| Roads and Maritime | Roads and Maritime Service |
| RTA | Roads and Traffic Authority |
| S/PIR | Submissions / Preferred infrastructure Report |
| SEPP 14 wetlands | State Environmental Planning Policy No 14 Wetlands |
| TSC Act | *Threatened Species Conservation Act 1995* |
| WIRES | NSW Wildlife Information Rescue and Education Service Inc |

# Appendix A – Dr Rodney van der Ree CV

## Curriculum Vitae

**PERSONAL DETAILS**

Dr Rodney van der Ree
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**EDUCATION**

1995 – 2000 Ph.D. School of Ecology and Environment, Deakin University "Ecology of arboreal marsupials in a network of remnant linear habitats".

1994 Bachelor of Science (1st Class Honours), Deakin University. "The distribution and abundance of mammals in 1939 and 1983 regrowth *Eucalyptus regnans* (Mountain Ash) forests in the Central Highlands of Victoria".

1991 – 1993 Bachelor of Applied Science, Deakin University, with majors in Biology, Terrestrial Ecology, Earth Sciences and Environmental Science.

**EMPLOYMENT HISTORY**

**2009-present: Deputy Director and Manager, Ecological Sciences: Australian Research Centre for Urban Ecology (ARCUE)**

**Employment history at ARCUE:**
2001 – 2004 Post-Doctoral Research Fellow
2004 – 2006 Ecologist
2006 – 2008 Senior Ecologist

ARCUE is a research division of the Royal Botanic Gardens Melbourne and is also part of the School of Botany at The University of Melbourne. I am responsible for conducting high quality scientific research on the impacts of human activities on wildlife as well as managing the commercial and collaborative research partnerships and consultancies between ARCUE and our clients. My research projects are diverse, and broadly cover the effects of habitat loss and fragmentation due to the construction of cities and towns as well as other infrastructures, such as roads, and agricultural activities. For example, I am leading a team of scientists and postgraduate students researching the effects of roads and traffic on flora, fauna and ecological processes. This is a 8-year project with initial support from the ARC via the Linkage Projects scheme, with VicRoads and the NSW Roads and Maritime Service as major industry partners. I am also leading a team of scientists, postdocs and postgraduate students on another ARC Linkage Project to understand the impacts of urbanisation on insectivorous bats. In addition, I am responsible for the day to day management of all aspects of numerous small research and consulting projects.

In my role as Deputy Director I am responsible for the recruitment and supervision of staff and students on my projects (i.e. setting tasks, reviewing progress, managing expectations), as well as the management of multiple projects (up to 20) - including setting and monitoring budgets, liaison with clients, report writing - and co-ordinate the often competing demands on equipment, staff time and other resources. I supervise multiple students and postdoctoral fellows, write scientific papers, grant applications and review student theses, papers and reports. An important part of my role is engaging with project partners to financially and logistically support projects.

Throughout the year I frequently undertake higher duties when the ARCUE Director is on leave or travelling. In this capacity, I am fully responsible for all the functions and operations of ARCUE, including approval of expenditure, signing contracts, project management and staff supervision.

2001 – 2004 **Consultant Ecologist**
I have successfully undertaken consultancy projects for a range of clients in Victoria and New South Wales, including the New South Wales National Parks and Wildlife Service, VicRoads, and the Albury-Wodonga Development Corporation. The research included studies of the distribution and abundance of Squirrel Gliders in New South Wales and Victoria and the development of mitigation measures to facilitate the crossing of major roads by fauna. I have contributed to the design of a strategy to conserve biodiversity in the Thurgoona district of Albury, an agricultural area being rapidly developed for housing. As an environmental consultant, I was required to establish my own business, undertake field research and literature reviews, be responsible for budgeting and accounting, report writing and working to deadlines.

1994 – present **Lecturer, Tutor and Demonstrator - Deakin University, The University of Melbourne**
I regularly lecture and in undergraduate ecology classes at Melbourne Uni and have taught classes in Biology, Environmental Management and Conservation Biology at Deakin University.

1999 **Ecologist - Department of Natural Resources and Environment**
Consultancy to investigate the spatial organisation of the endangered Brush-tailed Phascogale within a highly fragmented and cleared agricultural landscape in northern Victoria. The consultancy involved project planning and budgeting, fieldwork (trapping, radiotracking), data analysis and report writing.

### Supervision of postdoctoral fellows and students

Current

Dr Fiona Caryl (Post Doc). Australian Research Centre for Urban Ecology and University of Melbourne. Habitat models of insectivorous bats in urban Melbourne.

Dr Pia Lentini (Post Doc). Australian Research Centre for Urban Ecology and University of Melbourne. Population viability of insectivorous bats under different urbanisation scenarios.

Dr Cheryl Krull (Post Doc). University of Auckland, New Zealand. Is the grass greener on the other side? Applying road ecology to invasive species management in New Zealand.

Kylie Soanes (PhD). Australian Research Centre for Urban Ecology and University of Melbourne. Assessing the use and effectiveness of wildlife crossing structures for the endangered Squirrl Glider.

Caroline Wilson (PhD). Australian Research Centre for Urban Ecology and University of Melbourne. The foraging and roosting requirements of insectivorous bats in an urban environment.

Tanja Straka (PhD). Australian Research Centre for Urban Ecology and University of Melbourne. The role of waterbodies and perceptions of the public to urban bats.

Chris Stewart (PhD). Australian Research Centre for Urban Ecology and University of Melbourne. Investigating the effects of roads on wildlife populations using simulation modelling.

Jody Taylor (PhD) Monash University. Landscape connectivity in fragmented habitat: Lizard-eyed views of remnant vegetation in Victoria.

2007 Silvana Cesarini (PhD). Monash University. Quantifying and mitigating the barrier effect of roads on the Squirrel Glider, *Petaurus norfolcensis.*

2007 Natasha Kreitals (1st Class Hons). Australian Research Centre for Urban Ecology and University of Melbourne. Using stable isotopes to identify food sources for Spectacled Flying-foxes.

2006 Micaela Main (1st Class Hons). Australian Research Centre for Urban Ecology and University of Melbourne. Living life on the edge: abundance and diversity of lizards on roadsides.

2006 Nadine Gulle (1st Class Hons). Australian Research Centre for Urban Ecology and University of Melbourne. The effects of roads on the movement patterns of the Common Brushtail Possum.

2006 Shannon Troy (1st Class Hons) Australian Research Centre for Urban Ecology and University of Melbourne. Quantifying source-sink dynamics in Yellow-footed Antechinus.

2006 Sarah McCall (1st Class Hons). Australian Research Centre for Urban Ecology and University of Melbourne. Modelling the survival of Squirrel Gliders adjacent to major roads.

2005 Ashley Herrod (1st Class Hons) Monash University. Quantifying a barrier effect of a major freeway to Yellow-footed Antechinus occurring in roadside habitat in northern Victoria, using genotypic analyses.

2005 Katrina Thompson (1st Class Hons). Australian Research Centre for Urban Ecology and University of Melbourne. Spatial organisation of the Sugar Glider in urban bushland remnants.

2005 Hayley Broecker (1st Class Hons). Australian Research Centre for Urban Ecology and University of Melbourne. Modelling detectability of small mammals during surveys.

2005 Michael Harper (PhD). Australian Research Centre for Urban Ecology and University of Melbourne. 'The distribution and development of tree hollows and the ecology of hollow-dependent fauna along an urbanisation gradient in Melbourne.'

2003 Carolina Cordeiro (H2A Hons). Australian Research Centre for Urban Ecology and University of Melbourne. ‘Relationship between activity levels of predators and prey in patches of remnant Red Gum woodland along an urban-rural gradient.’

2001. Michael Harper (1st Class Hons). Australian Research Centre for Urban Ecology and University of Queensland. 'Assessing trees for tree hollows: a comparison of techniques.'

1999. Mark Venosta (3rd Year Research Project) Deakin University. 'Time budget and related aspects of the foraging and habitat use of the Brush-tailed Phascogale *Phascogale tapoatafa* within fragmented habitat near Euroa, Victoria.'

1998. Daniel Gilmore (3rd Year Research Project) Deakin University. 'The influence of isolation of the occurrence of arboreal marsupials in small patches of woodland in an agricultural landscape.'

1998. Greg Holland. (1st Class Hons) Deakin University. 'Time budget and related aspects of the foraging behaviour and habitat use of the Squirrel Glider *Petaurus norfolcensis.'*

1997. Luke Murphy (1st Class Hons) Deakin University). 'Ecology of the Common Brushtail Possum (*Trichosurus vulpecula* KERR, 1792) in roadside corridors in north east Victoria.'

**ACADEMIC and PROFESSIONAL ACTIVITIES**

I am an active member of the following professional organisations: Australasian Wildlife Management Society, Ecological Society of Australia, International Association for Landscape Ecology, Infra-Eco Network of Europe, International Conference of Ecology and Transportation and the Australian Mammal Society.

I have been invited to sit on a number of expert scientific committees across Australia. In 2004 I was a member of the Grey-headed Flying-fox Reference Group to provide advice to the Victorian Minister for the Environment on issues relating to the management of this nationally threatened species. In 2009-12 I advised the Royal Botanic Gardens Trust (Sydney) on management of the Grey-headed Flying-fox. In 2013 I was invited to be a scientific expert for the web-based company "MyRoadkill.com" who donate proceeds from their sales to wildlife conservation organisations. I have been appointed to expert committees for the International Conference on Ecology and Transportation (USA) and the Infra-Eco Network of Europe conferences in 2010, 2011 and 2012. In 2012 I was appointed to the Leadbeater's Possum Recovery Team. From 2005 – 2007 I was a member of the Environmental Advisory Committee for the City of Knox, advising them on a wide range of environmental issues. In 2001, I was invited to sit on the panel to judge applications for the National Banksia Environmental Awards. I have acted as a judge of student presentations at > 10 national and international conferences within Australia and overseas, including the 2004 meeting of the Society for Conservation Biology in the U.S.A. and the 2002 meeting of the Australian Mammal Society.

I have refereed manuscripts for numerous international scientific journals, including Journal of Applied Ecology, Acta Oecologia, Acta Theriologica, Austral Ecology, Animal Conservation, Ecological Management and Restoration, Journal of Environmental Management, Journal of Zoology, Wildlife Research, Landscape and Urban Planning, Landscape Ecology, Forest Ecology and Management, Biological Conservation, Urban Ecosystems, Australian Mammalogy, as well as manuscripts for various books. I have reviewed grant applications for the National Science Foundation (USA), Natural Sciences and Engineering Council (Canada), Killam Research Fellowship (Canada), and the Foundation for Research, Science and Technology (New Zealand). I have assessed four PhD, two Masters and >10 Honours theses from various universities across Australia and overseas.

I have made it a priority to give lectures and seminars about my research to a variety of audiences, including universities, research institutes, and special interest and community groups (see below for a selection of seminars). I have given Plenary lectures at the Infra-Eco Network of Europe Conference in Potsdam, Germany (October 2012), Society for Conservation Biology meeting in India (August 2012), International Conference on Ecology and Transportation, USA (May 2007). In 1999, I received a professional enhancement award from National Aeronautics and Space Administration (NASA) and Michigan State University to attend the Congress of the International Association of Landscape Ecology in Colorado, USA. In 2000, I received the Bolliger Award for the best spoken paper by a student at the annual conference of the Australian Mammal Society in Alice Springs.

I have organised numerous specialist symposia as part of national and international ecological conferences, as well chaired the organising committees for national conferences. The specialist symposia include:

- "Wildlife Management in Urban Areas", 3rd International Wildlife Management Congress, Christchurch, New Zealand, December 2003.
- "Ecological Effects of Roads, Traffic and Infrastructure Corridors", Ecological Society of Australia Adelaide, December 2004.
- "Effects of roads and traffic on wildlife populations and landscape function", International Association for Landscape Ecology Conference, The Netherlands, July 2007.

**PUBLICATIONS (refereed)**

Ascensao, F., S. LaPoint, van der Ree R. (in press). Roads and traffic: big problems for small mammals. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

D'Angelo, G. J. and R. van der Ree (in press). Use of wildlife reflectors and whistles to prevent wildlife-vehicle collisions. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

Jones, D., H. Bekker, van der Ree R (in press). Road ecology in an urbanising world. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

Milton, S. J., R. Dean, van der Ree R et al. (in press). The function and management of roadside vegetation. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

Reck, H. and R. van der Ree (in press). Insects, snails and spiders: the role of invertebrates in road ecology. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

Soanes, K. and R. van der Ree (in press). Arboreal animals and roads Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

Van der Grift, E. A., J. A. G. Jaeger, van der Ree R (in press). Study designs to measure effectiveness of road mitigation measures. Ecology of roads: and international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

van der Ree, R., D. J. Smith, et al., Eds. (in press). Ecology of roads: An international practitioners guide. London, Wiley.

van der Ree, R. and S. Tonjes (in press). How to maintain safe and effective mitigation measures. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

van der Ree, R., S. Tonjes, et al. (in press). Ensuring the completed road project is designed, built and operates as intended. Ecology of roads: an international practitioners guide. R. van der Ree, D. J. Smith and C. Grilo. London, Wiley.

Soanes K, Carmody Lobo M, Vesk PA, McCarthy MA, Moore JL, van der Ree R. (2013). Movement re-established but not restored: inferring the effectiveness of crossing mitigation by monitoring use. Biological Conservation **159**, 434 - 441.

Caryl F, Thompson K, van der Ree R. (2013). Permeability of the urban matrix to arboreal gliding mammals: Sugar gliders in Melbourne, Australia. Austral Ecology **38**, 609 - 616.

Van der Grift EA, van der Ree R, Fahrig L, Findlay S, Houlahan J, Jaeger JAG, et al. (2012). Evaluating the effectiveness of road mitigation measures. Biodiversity and Conservation **22**, 425 - 428.

Taylor, A. C., F. M. Walker, van der Ree, R, et al. (2011). "Degree of landscape fragmentation influences genetic isolation among populations of a gliding mammal." PLoS One **6**(10): e26651.

van der Ree, R., J. A. G. Jaeger, et al. (2011). "Effects of Roads and Traffic on Wildlife Populations and Landscape Function: Road Ecology is Moving toward Larger Scales." Ecology & Society **16**(1): 1 - 9.

van der Ree, R., S. Cesarini, et al. (2010). "Large gaps in canopy reduce road crossing by a gliding mammal " Ecology and Society **15**(4): 35. [online] URL: http://www.ecologyandsociety.org/vol15/iss34/art35/.

McCall, S., R. van der Ree, et al. (2010). "Highway living reduces survival of Squirrel Gliders." Ecology and Society 15(3). [online] URL: http://www.ecologyandsociety.org/vol15/iss3/art27/

Pavlova, A., F. Walker, van der Ree, R, et al. (2010). "Threatened populations of the squirrel glider *Petaurus norfolcensis* show evidence of evolutionary distinctiveness on a Late Pleistocene timescale." Conservation Genetics **11**: 2393 - 2407.

Simmons, J., P. Sunnucks, van der Ree, R, et al. (2010). "Beyond road-kill, radiotracking, recapture and FST – a review of some recent genetic methods to improve understanding of the influence of roads on wildlife." Ecology And Society **15**(1): 9 [online] URL: http://www.ecologyandsociety.org/vol15/iss1/art9/

van der Ree, R. (2010). The role of linear strips and small patches of woodland in conserving endangered mammal fauna. Temperate Woodland Conservation and Management, D. Lindenmayer, A. F. Bennett and R. Hobbs, CSIRO**:** 151 - 158.

van der Ree, R., M. A. McCarthy, et al. (2009). "Wildlife tunnel enhances population viability." Ecology and Society **14**(2): 7 [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art7/

van der Ree, R. (2009). The ecology of roads in urban and urbanising landscapes. Ecology of Cities and towns: A Comparative approach M. J. McDonnell and A. Hahs, pp 187 - 194.

van der Ree R. & Suckling G. C. (2008). The Squirrel Glider. In: *Mammals of Australia* (Eds. S. van Dyck and R. Strahan) pp. 235-6. New Holland Publishers, Sydney.

Harper M. J., Mccarthy M. A. & van der Ree R. (2008). Landscape resources influence possum abundance. *Austral Ecology* **33**, 243.

Holland, G., A. F. Bennett, et al. (2007). "Time-budget and foraging behaviour of the Squirrel Glider, *Petaurus norfolcensis*, in remnant linear habitat " Wildlife Research **34**(4): 288 – 295.

van der Ree, R., A. F. Bennett, et al. (2006). "Nest tree selection by the threatened brush-tailed phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae) in a highly fragmented agricultural landscape." Wildlife Research **33**: 113-119.

Harper M. J., McCarthy M. A. & van der Ree R. (2005). The use of nest boxes in urban natural vegetation remnants by vertebrate fauna. *Wildlife Research* **32**, 509-16.

van der Ree R., van der Grift E. A., Mata C. and Suarez F. (2007). Overcoming the barrier effect of roads – how effective are mitigation strategies? An international review of the effectiveness of underpasses and overpasses designed to increase the permeability of roads for wildlife. In 'International Conference on Ecology and Transportation ', Little Rock, Arkansas, USA. (Eds. CL Irwin, D Nelson and KP McDermott) pp. 423-431, (Center for Transportation and The Environment, North Carolina State University, Raleigh, NC).

van der Ree R (2006). Road upgrade in Victoria a filter to the movement of the endangered Squirrel Glider *Petaurus norfolcensis*: Results of a pilot study. Ecological Management and Restoration **7**, 226-228.

van der Ree, R., Bennett, A. F., and Soderquist, T. R. (2006). Nest tree selection by the threatened brush-tailed phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae) in a highly fragmented agricultural landscape. Wildlife Research **33**, 113-119.

Williams N. S. G., McDonnell M. J., Phelan G. K., Keim L. and van der Ree R. (2006). Range expansion due to urbanisation: increased food resources attract Grey-headed Flying-foxes (*Pteropus poliocephalus*) to Melbourne. Austral Ecology **31**, 190 - 198.

van der Ree, R., and McCarthy, M. A. (2005). Quantifying the effects of urbanisation on the persistence of indigenous mammals in Melbourne, Australia. Animal Conservation **8**, 309-319.

van der Ree R., McDonnell M. J., Temby I. D., Nelson J. and Whittingham E. (2006). The establishment and dynamics of a recently established urban camp of flying foxes outside their geographic range. Journal of Zoology (London) **268**, 177-185.

van der Ree R., Ward S. J. and Handasyde K. (2004). Distribution and conservation status of possums and gliders in Victoria. In 'The Biology of Australian Possums and Gliders'. (Eds. RL Goldingay and S Jackson) pp. 91-110, (Surrey Beatty and Sons PTY LTD: Chipping Norton).

Harper, M.J., McCarthy, M.A., & van der Ree, R. (2005). The abundance of hollow-bearing trees in urban dry sclerophyl forest and the effect of wind on hollow development. Biological Conservation **122**, 181 - 192.

van der Ree, R. (2004). The impact of urbanisation on the mammals of Melbourne - do atlas records tell the whole story or just some of the chapters? In 'Urban Wildlife: more than meets the eye'. (Eds. D. Lunney and S. Burgin.) pp. 195-204, (Royal Zoological Society of New South Wales: Mosman, NSW).

Claridge A. W. and van der Ree R. (2004). Recovering endangered populations in fragmented landscapes: the squirrel glider *Petaurus norfolcensis* on the south-west slopes of New South Wales. In 'Conservation of Australia's Forest Fauna' (second edition), (Ed. D Lunney) pp. 678-687, (Royal Zoological Society of New South Wales: Mosman, New South Wales).

Harper, M. J., McCarthy, M. A., van der Ree, R., and Fox, J. C. (2004). Overcoming bias in ground-based surveys of hollow-bearing trees using double sampling. Forest Ecology & Management **190**, 291-300.

McCarthy, M. A., Parris, K. M., van der Ree, R., McDonnell, M. J., Burgman, M. A., Williams, N. S. G., McLean, N., Harper, M. J., Meyer, R., Hahs, A., and Coates, T. (2004). The habitat hectares approach to vegetation assessment: An evaluation and suggestions for improvement. Ecological Management and Restoration **5**, 24-27.

van der Ree, R., Bennett, A. F. and Gilmore, D. C. (2003). Gap-crossing by gliding marsupials: thresholds for use of isolated woodland patches in an agricultural landscape. Biological Conservation **115**, 241-249.

van der Ree, R., and Bennett, A. F. (2003). Home range of the Squirrel Glider *Petaurus norfolcensis* in a network of linear habitats. Journal of Zoology (London) **259**, 327-336.

van der Ree, R. (2003). The occurrence of the yellow-footed antechinus *Antechinus flavipes* in remnant linear habitats in north-eastern Victoria. Australian Mammalogy **25**, 97-100.

van der Ree, R. (2002). The population ecology of the Squirrel Glider *Petaurus norfolcensis*, within a network of remnant linear habitats. Wildlife Research **29**, 329-340.

van der Ree, R. and Loyn, R. H. (2002). The influence of time since fire and distance from the fire boundary on the distribution and abundance of arboreal marsupials in *Eucalyptus regnans*-dominated forest in the Central Highlands of Victoria. *Wildlife Research,* **29**, 151-158.

van der Ree, R. and Bennett, A. F. (2001). Woodland remnants along roadsides - a reflection of pre-European structure in temperate woodlands? Ecological Management and Restoration, **2**, 226-228.

van der Ree, R., Soderquist, T. R. and Bennett, A. F. (2001). Home range use by the Brush-tailed Phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae) in high-quality, spatially limited habitat. Wildlife Research, **28**, 517-525.

Bennett, A. F., and van der Ree, R. (2001). Roadside vegetation in Australia: conservation and function of a linear habitat network in rural environments. In 'Hedgerows of the world: their ecological functions in different landscapes', (Eds. C. Barr and S. Petit.) pp. 231-240, (IALE (UK)).

van der Ree, R. (1999). Barbed wire fencing as a hazard for wildlife. The Victorian Naturalist **116**, 210-217.

**In addition, I have published more than 60 reports and popular articles, given in excess of 70 presentations at conferences, workshops, community groups and > 20 media appearances, including TV, radio, and newspaper.**

# Appendix B – Expert review

Review of Draft Threatened Glider Management Plan Version 0.3, Woolgoolga to Ballina Pacific Highway Upgrade. Prepared by NSW Roads and Maritime, Aurecon and SKM.

Review by: Dr Rodney van der Ree 19 August 2013, updated 10 September 2013.

The W2B Pacific Highway upgrade is 155 km in length and extends from Woolgoolga to Ballina in northern NSW. The project has been divided into 10 sections of varying length and character, depending on the landscape and conditions for each section. The planning process has been extensive, and the EIA documents are lengthy. The draft threatened glider management plan is 40 pages in length, and addresses the potential impacts of the project and proposed mitigation measures on Squirrel Gliders and Yellow-bellied Gliders to ensure the long-term survival of these species in the area of the project.

The plan is relatively comprehensive and represents a good step towards ensuring the impact of the Pacific Highway upgrade does not threaten the viability of populations of squirrel gliders or yellow bellied gliders. There are however, some significant limitations and deficiencies of the plan which need to be addressed before the construction of the Highway upgrade can commence.

I have given my comments in three sections. The first is a response to the specific question detailed by SKM to be considered in my review, the second is general comments and specific recommendations that relate to the plan overall and the third part contains detailed comments that relate to certain sections of the plan.

### PART 1: RESPONSE TO SPECIFIC QUESTIONS DETAILED BY SKM TO BE CONSIDERED DURING REVIEW

#### a) is the design of the monitoring project appropriate for the species?

Potentially. The monitoring program for threatened gliders needs to be revised after (i) the targeted pre-construction surveys are completed; (ii) the goals of mitigation have been revised and clearly articulated; (iii) the goals of monitoring have been clearly articulated; and (iv) the monitoring program has been designed and the feasibility evaluated. It is not possible to design an adequate monitoring program until these other steps have been completed.

#### b) is the frequency and timing of mitigation adequate?

If the “frequency” of mitigation relates to the number of crossing structures – then no, mitigation frequency is not adequate. 20 crossings for gliders over a distance of 155 km is inadequate.

The timing of mitigation, which I take to mean when crossing structures are installed, is not discussed in the plan. However, the immediate installation of crossing structures for gliders is probably not required in areas with large areas of habitat for gliders because there are probably sufficient resources on both sides of the highway such that a temporary severing of connectivity is unlikely to be a major issue. Smaller populations, or locations where necessary resources are on opposite sides of the road will be at greater risk due to medium-term (i.e. 1 – 2 years) fragmentation.

#### c) is the management plan clear on what basis the monitoring locations would be selected?

No – the management plan states that monitoring locations will be based on the results of the pre-clearing targeted surveys, discussion with landowners etc. This is reasonable, given the current stage of the project. However, a distance of 300 m from the road is given as the distance for reference sites, which is insufficient. Gliders easily move this distance and more in a night, and thus sites 300 m from the road are effectively an “impact” site.

#### d) are appropriate goals being set?

No – the goals for mitigation and the goals for monitoring are not clearly distinguished. The goals for mitigation and the goals for monitoring may or may not be the same – but they need to be differentiated and separated out. Importantly, the goal for mitigation should not be dependent on whether or not it is possible to measure effectiveness. For example, the goal for mitigation may be the dispersal of a rare species – which may only happen once per year, and trying to measure this is virtually impossible. However, this does not mean we should alter the goal of mitigation.

**e) Are the mitigation and management actions sufficiently targeted for the species?**

Generally yes. The crossing structures (rope bridges, glider poles, medians with trees) are currently the best and most appropriate techniques to mitigate fragmentation for YBG and SqG. However, the mitigation of potential road mortality for gliders is not adequately addressed. Road mortality is likely to be reduced in areas with crossing structures, but with only 20 crossings over 155 km, mortality is likely to be occurring away from each structure over long sections of road. Clearly not all 155 km is going to be suitable habitat for gliders, but more crossing structures are likely to be required, principally because there is no proven or reliable technique to stop gliders from attempting to cross the road wherever there are trees.

**f) Are the objectives, performance measures, corrective actions and thresholds for corrective actions in accordance with SMART principles?**

Generally yes, but they need to be smarter, in that the goals need to be clearly defined so that success, or progress towards success, can be measured. Further details on this elsewhere in this review.

**g) do the management measure objectives, performance indicators, thresholds and corrective actions link sufficiently to allow effective implementation?**

Generally yes, but thresholds need to be better defined. For example, Table 5-2 has a threshold of "low mortality" (without defining what constitutes low). Other examples of this are highlighted elsewhere in this review

**h) has the Management Plan provided sufficient evidence where the proposed mitigation has previously been effective?**

Generally yes, however results of rope bridge and glider pole monitoring on the Hume Freeway in Victoria and NSW is notably absent. There are numerous reports that I have written which Roads and Maritime has.

**i) Does the Management Plan describe and discuss contingencies, should the proposed measures be ineffective?**

Yes.

**j) If we can't demonstrate mitigation proposed will be effective, can we demonstrate that corrective actions will be effective?**

It is difficult to assess effectiveness of mitigation measures or the effectiveness of corrective actions (it mitigation not successful) because the specific goals for mitigation have not been clearly articulated nor expressed in a SMART way.

**k) Where there is no known research / evidence of the effectiveness of the specific measure proposed – have relevant alternative contingencies been committed to?**

No. the primary unknown in this management plan is the likelihood that YBG will use rope bridges and/or glider poles and/or widened medians to cross the Pacific Highway. For example, the corrective action if crossing structures not effective for YBG (Table 6-3) is to "review the location and type of connectivity structures installed and implement additional controls or provisional measures where appropriate and in consultation with OEH". This alternative contingency has been committed to, but it doesn't specify exactly what course of action will be taken. This is not unreasonable though, because mitigation is in reality an experiment, and it is impossible to specify concrete alternatives when the outcomes of the monitoring are still unknown.

**l) Have indirect impacts been addressed in the Management Plan, as relevant?**

There is little known about the indirect impacts of roads and traffic on gliders. However, one paper by (McCall et al., 2010) highlighting the reduction in apparent survival of squirrel gliders adjacent to the Hume Freeway in Victoria has not been mentioned.

**m) Are qualifications and experience of authors in subject field relevant?**

Generally yes. The authors appear to be highly experienced in the preparation of EIA and road planning and the level of detail in this plan and all the others is to be commended. However, the design of scientifically robust monitoring programs to evaluate the effects of a road project and effectiveness of mitigation measures is a specialised field and the plan is deficient in this area. This is not unusual nor unexpected, and most monitoring programs of this nature around the world are not as scientifically robust as they need to be (van der Ree et al., 2008, van der Ree et al., 2011, van der Ree et al., 2007). Please see (Lindenmayer and Likens, 2009, Lindenmayer and Likens, 2010b, Lindenmayer and Likens, 2010a) for general information on the design of effective ecological monitoring programs and (Van der Grift et al., 2013) for specific, detailed advice on evaluating the effectiveness or road mitigation measures.

**PART 2 GENERAL COMMENTS:**

1. Goal of mitigation is not clearly identified or articulated: It is heartening to read that the TGMP promotes the use of the SMART acronym for identifying goals – specific, measurable, achievable, realistic and time framed. However, the goal(s) of mitigation for gliders are not presented using this approach. The goals in 6.2 state that glider crossing structures are to be "effective" and the details of what constitutes effective varies throughout the plan, including:
    a. changes in glider activity
    b. changes to habitat usage
    c. permitting safe crossing of roads by gliders
    d. detecting a glider on cameras (where ineffective described as no gliders being detected on cameras)
    e. reducing the interactions or collisions with vehicles
    f. monitor glider populations/abundances in and adjacent to the corridor.

    The goal of mitigation and the goals for monitoring are used synonymously when in fact they are potentially two different things. For example, the hypothetical goal for mitigation may be to allow the dispersal of a rare species. However, if the species is so rare that trying to evaluate its use of a structure would be so difficult and expensive that it would not be feasible. In the context of gliders on W2B, the plan needs to clearly state the goals of mitigation, and clearly state the goals of the monitoring. These may be the same – but they need to be expressed so that the people involved in both tasks know exactly what is expected of them.

    Without explicit goals for mitigation, it is difficult to assess the adequacy of mitigation for threatened gliders. Is mitigation to allow the daily movement of gliders across the highway? Is it for occasional gene flow? Is it to allow all individuals the opportunity to be within 1 km of a crossing?

    RECC 1: The goals for mitigation need to be clearly articulated. They should include general goals (e.g. maintain connectivity for daily movements or maintain natural rates of gene flow across the road) and specific goals that are measurable (i.e. using the SMART approach).

2. Daily movements should be a goal of mitigation: Throughout the EIS and TGMP we read that gliders need winter flowering resources which are patchily distributed across the landscape. We also read that potential impacts include fragmentation and barrier effects leading to isolation of family groups. This strongly suggests that gliders will need to access resources on opposite sides of the highway on a relatively frequent basis, potentially every night when food resources may be limited, in order to survive.
   RECC 2: Therefore, one major goal of mitigation must be to allow regular movement of gliders.
3. Why is monitoring required? If monitoring is mandated as a condition of approval, then someone somewhere concluded that there is still some uncertainty about the effectiveness of glider poles and rope bridges and wider medians. What exactly was this uncertainty? Understanding what this uncertainty was and then using the monitoring to resolve this uncertainty so monitoring is not required on the next project should be upfront and central to this monitoring program. If the uncertainty was "what mitigation is most effective at maintaining populations", then the monitoring needs to address that qn. If the uncertainty was around "how do crossing structures improve gene flow", then monitoring should target that question. If monitoring was to see what type of use the structures are being used for (i.e. daily foraging, dispersal, seasonal migrations), then the monitoring should focus on that. At the moment, I am completely unclear as to what question the monitoring is trying to address. If it is simply: "will YBG use rope bridges", then different monitoring approaches might be required. The current monitoring program appears to be the minimum required to tick a box to satisfy a condition of approval. We already know that squirrel and sugar gliders can and do use rope bridges and poles – we don't need more cameras to confirm that!
   RECC 3: I recommend that the objectives and methods of the monitoring program for threatened gliders be further developed through a workshop with glider experts and monitoring design experts in order to develop a monitoring program that answers the most important and necessary questions. The current monitoring program will conclude: yes, squirrel gliders use crossing structures and yes/no – YBG use crossing structures.
4. Goals for monitoring: First up – it is almost impossible to evaluate the monitoring program if the goals for mitigation have not been identified (see point 1 above). The monitoring program can only be developed after the goals for mitigation have been developed and agreed to. The goals of monitoring should focus on the outstanding gaps in understanding for the target species. In this case, much of the lack of information is around the impacts of roads and mitigation on yellow-bellied Gliders. As such, I would expect some detailed study of the ecology of YBG around roads, with radiotracking or satellite/gps tracking (depending on transmitter sizes currently available) to look at movements of animals in areas where the proposed road corridor will dissect habitat, consequences of clearing and construction on resident YBG, population density and abundance in different zones from the highway to look at edge effects, surveys of population parameters (birth rates, death rates, reproductive output etc), collecting DNA samples to measure rates of gene flow, as well as use of rope bridges and glider poles and widened medians. If one of the overall goals of the project is to ensure the viability of populations of YBG and Squirrel Gliders, then simple spotlight surveys will not be sufficient.

I wouldn't expect much more work to focus on the use of crossing structures by Squirrel Gliders – we know they can and do use rope bridges, glider poles and widened medians to cross roads. If monitoring just for squirrel gliders, then need to think about the outstanding questions, not confirm something we already know. For example, the distance that gliders in contiguous forest will travel in order to access and use a crossing structure, rather than attempt to glide across the road.

RECC 4: developing and finalising a comprehensive, scientifically robust and useful monitoring program can not be completed before the goals for mitigation are revised and the targeted surveys are finalised. I recommend that the monitoring program be developed with relevant experts, as per RECC 3.

5. Monitoring will continue until mitigation is proven effective: this is an excellent approach, but I am concerned about the endpoint because effectiveness has not been adequately defined.

   RECC 5: revise this based on the RECC 1 and RECC 3.

6. Impacts associated with mortality and connectivity are not always differentiated in the TGMP but the mitigation of both is the same: Mortality due to collisions with vehicles and the reduction in ability to move around the landscape are two different impacts. This is acknowledged in some sections of the plan. In other sections, they are both seemingly rolled into one. However, the mitigation detailed for both impacts is the same – arboreal crossing structures. Yes – where there is a crossing structure, it will help restore connectivity and probably reduce mortality in the immediate vicinity, but in places without crossing structures, mortality will still continue unabated. In other words, there is no mitigation specifically for roadkill of gliders. If we don't have strategies to reduce mortality in places without crossing structures, we should explicitly acknowledge and articulate this. The plan needs to acknowledge that the effectiveness of crossing structures to reduce roadkill is limited to a short distance around each crossing structure – possibly the radius of 1 home range. Gliders are unlikely to travel through another gliders territory to access the crossing structure and will probably cross wherever they see an opportunity. If the monitoring program for the W2B project wants to learn something new – this would be an excellent question to address – over what distance will gliders travel to find and use a structure? And over what distance does the reconnection and reduction in mortality begin to reduce? Poorly framed questions – but hopefully it makes sense. Hence point 6 – there are insufficient crossing structures proposed.

   RECC 6: Ensure that the effects of mortality and reduced connectivity are clearly differentiated in the TGMP and ensure that the mitigation measures are appropriate for the impact.

7. The number of crossing structures is insufficient: There are 20 crossing structures spread over 155 km of proposed highway. I have reviewed the detailed maps within the EIA and the maps and text in Appendix A of the Biodiversity Working Paper and note that numerous "corridors" were marked on the maps, but there were no glider crossings. The project intersects with at least 30 key fauna movement corridors, but there is no mention in the plan about how many of these corridors contain mitigation for gliders. Appendix A of the Biodiversity Working Paper details the approach used to identify the location, type and number of glider crossings along the project, which is generally adequate. However, without

clear goals for mitigation, it is difficult to assess adequacy of mitigation measures. Even if the crossing structures are just about gene flow only – it is still probably not enough.

RECC 7: A greater number of crossing structures for gliders will be required.

8. Confusion around pre-clearing surveys: The plan talks about pre-clearing surveys to (i) refine location and design of road/mitigation; (ii) determine distribution of gliders; and (iii) determine pre-clearing population size/distribution for long-term monitoring. It is unclear if the surveys will be one and the same – please clarify. I am also concerned that there will be insufficient time to be able to do adequate pre-clearing surveys of population size and distribution to be able to do reliable assessments of the impacts of the highway upgrade on threatened gliders (this will of course depend on the goals for mitigation and the goals and methods of monitoring) (See RECC 12). It is also unclear what will happen if gliders are not detected in locations with optimal / top quality glider habitat. Will it be assumed they are truly absent and therefore no mitigation? I recommend taking the precautionary approach and assume that if there is a reasonable chance that gliders could be present in a patch of good quality habitat or they may use it as a corridor that mitigation should be considered.

   RECC 8: Clarify the role / purpose of the different surveys.
9. To what extent is this plan a stand-alone document?: I would suspect that during construction this plan will be the first point of contact when someone has an issue or question about threatened gliders. Therefore, I would've expected more detail generally, and specifically on the ecology and biology of both glider species, review of road impacts and mitigation etc. P

   RECC 9: Clarify how this plan is to be used in the introduction section.
10. Funnelling gliders to crossing structures: the plan mentions the use of fencing to funnel gliders towards crossing structures. Gliders live in tree canopies, and fencing will have no effect on their movements. There is also no mention of how to encourage gliders to crossings when road dissects continuous forest – there will be many km of forest frontage – and gliders will attempt to cross anywhere or everywhere.

    RECC 10: acknowledge in the TGMP that the only way to funnel gliders is with strategic tree planting and that gliders are likely to attempt to cross the highway wherever there are trees on both sides of the road, including in places where trees are too distant to successfully make the glide
11. Glide angles: An arbitrary height of 20 m is given as the minimum height of trees to be able to glide across the road. Minimum tree heights, and minimum pole heights, will depend on whether the road is in cut or on fill, and the more important information relates to using computations of glide angles at EVERY proposed crossing to ensure that gliders can safely glide across the road, in both directions, with a minimum clearance above truck height.

    RECC 11: Ensure glide angle calculations are completed for every set of glider poles and for treed medians and that minimum clearances can be achieved.
12. No detail of amount of time available before construction commences in which to do the pre-construction population surveys – so unable to assess if sufficient time available to estimate proper baseline / pre-construction population estimates

RECC 12: the amount of time required for pre-clearing baseline surveys will depend on the goals of monitoring and the monitoring questions being asked. 12 months would likely be the minimum time required, but this should be reviewed when the monitoring program is properly finalised.

13. Insufficient acknowledgment of gliders in fragmented areas: ensuring the integrity/quality of glider populations in areas with large blocks of forest is appropriate. However, I am concerned that the mitigation proposed for areas which are highly cleared or fragmented is inadequate. I have not had sufficient time nor resources (i.e. detailed GIS maps) to ensure that populations of gliders residing in small patches of forest or along roadsides or waterways have been identified and/or had sufficient mitigation installed. If these small populations are quite small or isolated, then the additional impacts of the upgraded highway may be sufficient to push the glider population over the edge and into local extinction. I would argue that without adequate mitigation of these smaller populations, some of them will become locally extinct. While these local extinctions of small populations is unlikely to send the regional population extinct, there is the risk of death by a thousand cuts.
    RECC 13: the mitigation proposed for highly cleared and fragmented areas be reviewed for adequacy.
14. Adopt the concept of crossing zones: There is considerable variability in the rate of use of crossing structures, often for unknown reasons. By installing multiple crossing structures in close proximity to each other (e.g. a rope bridge and two sets of gliders poles within 500 m of each other) will ensure that the crossing at that location is more likely to be effective. This approach is especially important if crossing structures are not spaced at regular and short distances from each other. If crossings are spaced at 1 km intervals or scaled for one crossing per average home range length, for example, then crossing zones are not as important.
    RECC 14: Use crossing zones with multiple crossing structures when crossings are few and far between. If crossings are spaced at shorter distances (e.g. one per average home range length), then crossing zones are not required.

**PART 3 SPECIFIC COMMENTS**

Section 1.2, 4th dot point: If the monitoring is designed to “assess the effectiveness of mitigation measures”, then how can it be used to change the management approach in localities affected *but unmitigated* by the project? The monitoring and evaluation needs to be broader than just assess effectiveness of mitigation measures. It must also set out to assess the impact of the highway on some measure of the population, to be able to detect an effect of the highway.

Figure 1.1: I do not understand why the expert review of planning stage does not feed back into the preparation of the plan during the pre-approval phase. According to figure 1.1, the expert review does not feed back into the design of the baseline monitoring.

2.2.1: I would like to see the regional distribution of the squirrel glider records and yellow bellied glider records from the Atlas to be able to picture how the upgraded highway might affect regional meta-populations.

The description of the size of the home range and mobility of yellow bellied gliders is too vague. It is stated to have large home ranger, but to be useful, we need actual sizes. Also – what is the mobility and home range of squirrel gliders?

2.3: what is the nature of the competition from honeybees and how might the highway modify or influence the level of this competition?

Figures 2.1 - 2.11: I understand the difficulty in showing a detailed map for a project that is 155 km in length, but I find it difficult to believe that important habitat does not occur in areas that are not currently shown as being vegetated. In other words, the unshaded areas on the maps may have narrow (20 or 30 or 50 m wide) strips of forest along roads and waterways that do not show up at the scale of this mapping. However, these are important and gliders, particularly squirrel gliders, will use narrow strips of bush along roads and creeks as habitat and for movement. Therefore, the focus of mitigation for this project on large tracts of forest potentially means that many important but small corridors will be severed and impacted by the highway.

It is also not clear from these maps if only predicted habitat is shown. Ie, fig 2-1 has 9 veg types shown – does this mean that these are all the predicted habitat types that gliders will use within the study areas?

Figs 2.1 – 2.11 also need to show the regional fauna corridors. Some of these corridors are also likely to be important for threatened gliders – and I need to know if the connectivity structures align with the location of these corridors.

In short, these maps need to be more detailed and at a finer scale to be able to pick up and identify important corridors that are not shown at the broad scale of the current mapping. I am not convinced that there are sufficient crossing structures nor am I convinced that all the necessary crossing locations have been identified.

3.1: this section is just a general description of potential impacts – I want to know more specifically about the nature and extent of these impacts and likely relative differences in severity for yellow bellied gliders and for squirrel gliders. Should our priority be to avoid mortality, or to ensure connectivity? And will the relative effects and importance of these two impacts vary depending on the regional size of the population adjacent to the highway? For example – if the hwy dissects a national park with a very high density and large population of YBG, should the priority be to maintain connectivity or prevent movement? And what if the road dissects a small population of gliders? is the priority in this situation to prevent mortality or reconnect? Need more discussion on this to ensure we are mitigating the greatest threat/impact. And this would be an appropriate location to list the aspects of the ecology of either species with respect to roads and traffic that require further investigation.

Mortality section: what do we know about current rates of mortality of gliders along the Pac Hwy or other major roads, and what level of mortality is sustainable? To answer this, we need some information about population sizes.

What does being nocturnal have to do with having less mobility? Here you are implying that gliders are less mobile because they are nocturnal? And besides, SQ HR may be 1 km long, and YBG HR may be 40 – 60 ha. Neither of these are what I would describe as being "reduced mobility"

Loss of habitat section: need to give some info here on the types and characteristics of hollows used by each species of glider, as well as the number of different hollows used and the rate of swapping among den trees.

Fragmentation of habitat section: it is not just "remnant" vegetation patches that we need to protect and keep connected. It can be planted and regrowth veg patches.

What does "potentially discrete arboreal mammal populations on both a patch and landscape scale" actually mean?

What is the existing barrier effect of the existing hwy? is there a barrier effect? If you look at my 2006 prelim radiotracking results, plus my 2010 paper in ecology and society, it would imply that the current hwy is probably only a partial or selective filter to movement, not a barrier.

You have mis-quoted my 2006 paper – I found that females didn't cross a 4-lane hwy where the strip of veg was crossed by a raised bridge. Subsequent work confirms the lack of crossing a 4-lane hwy as you describe. But I don't know if it is an aversion to the hwy, or the gap was just too great. There is a subtle difference. If gap is too great, it doesn't matter if cars are present or not. If there is an aversion to the highway/traffic, then even small gaps wont be crossed.

How does a complex social structure affect feeding? YBG have equally as complicated a social structure as SQ. And why are species with complex social structures more sensitive to fragmentation?

Why are hollow dependent fauna more vulnerable to fragmentation?

Loss of ecological connectivity section: How is an important population defined? I could argue that smaller populations are more important from a conservation perspective and from a mitigation perspective.

I also don't understand what "as fragmentation proceeds, stochastic forces add to potential declines caused by a dwindling supply of habitat" – declines of what?

Edge effects: I read in the EIA (ch 10.15 of main volume) that edge effects extend for 50 m, and because Rufous bettong use edges, that edge effects were discounted. Does this mean that edge effects are assumed to penetrate just 20m? Depending on the edge effect measured, and topography etc, it can extend and be measured for hundreds of metres. The size of the edge effect also depends on the traffic volume and type of traffic.

I also want to know how squirrel gliders are affected by edge effects, which edge effect (noise, pollution, lights??) and to what extent, and where this data comes from? And why are YBG not affected in the same way?

3.2: again, I understand the focus on population hotspots, but the key regional fauna corridors (plus other smaller corridors or patches of forest) may not have high densities of gliders, but may be absolutely critical to population persistence. Don't discount these. Therefore, how are connectivity and mortality reducing measures located with respect to these locations that are not population hotspots?

Table 3.1: In the preconstruction stage you refer to targeted glider surveys to inform the detailed design etc, and also you refer to completed targeted population surveys, which I assume is for the monitoring program. Are these 2 surveys actually the same thing? Or are you proposing surveys to determine presence of gliders and then another survey to start estimating population density? The reason I ask is that the methods to achieve these 2 aims could be quite different. Population surveys need to be repeated a number of times to take detectability into account, whereas surveys to determine presence could finish as soon as presence is determined.

In the operation stage, you mention monitoring crossing structures, zones and glider activity. What exactly, with respect to activity, are you proposing to measure? After reading the rest of the plan I realise it is simply density along transects – not activity. Activity has other meanings in ecology – e.g. the distance travelled in a night, or where they spend most of their time – what you propose to measure is not actually activity.

3.4 Effectiveness of mitigation measures: You suggest that fauna crossing structures are effective at reducing mortality – actually, we don't know this – we assume this and it makes sense – but we don't have actual mortality data before and after mitigation to prove this. Crossing structures help animals get across the road safely – but we don't know if they were getting across successfully or unsuccessfully prior to mitigation. I suspect that based on glide angles, that if they did try to get across, it would often end in collision with cars – but we don't know if crossing structures actually prevent mortality. We know gliders will attempt to glide across roads, and assume that at least some of the time, it was successful, and some of the time, not successful.

My point here is that crossing structures are about restoring connectivity safely – but it doesn't do anything about preventing mortality in locations away from crossing structures. We also don't know how far gliders will travel to reach a crossing structure. Therefore – don't say that we have addressed all mortality issues if we put up crossing structures. For ground dwelling animals we can put up fences to funnel them towards culverts, for example. The fencing stops mortality, and culvert restores connectivity. For gliders – rope ladder/glider pole/widened medians can restore connectivity, and it reduces the risk of mortality in the vicinity of the structure, but it doesn't prevent mortality away from the structure.

In this section you imply/state that fauna exclusion fencing will direct gliders to rope bridges and poles – I don't know of any fence design that works for gliders and you don't provide any fence design details for me to assess this.

And what exactly will you deem to be a success? How do you define an effective mitigation measure? I was expecting Table 3.2 to give me a metric to say what will constitute a success with respect to mortality, connectivity etc. For example – how much mortality is acceptable? 1% of population per year per km? How many individuals crossing do we need per year? 5 individuals dispersing per rope bridge per year? 20 crossings for home range use per structure per year?

Table 3.2: says that fencing is highly successful at reducing fauna mortality. Not for gliders though! Completely 100% ineffective.

Table3.2 – does not address the impacts of loss of habitat. Habitat will be cleared, but there is nothing in this plan about where offset habitats are to be located, what type of habitats they should be (i.e. like for like or better). Of course it is too early in the process to have these offsets all organised and determined, but it would be good to put forth some principles – e.g. offsets for glider habitat shall not be immediately adjacent to the highway, or, offsets for lost glider habitat will focus on restoring connectivity in other parts of the landscape or bolstering existing but small populations.

4.2 – question about the targeted surveys to inform detailed design and monitoring program. The surveys to inform detailed design and to inform the design of the proper monitoring program could be the same – but these surveys will likely be insufficient to count as surveys for the population monitoring proper. These two surveys need to be more clearly defined throughout the plan. In 4.3.1 you imply that pre-construction surveys will be used to determine population abundance. Elsewhere it is said to determine distribution / presence. Please clarify this very clearly. I suggest that pre-construction surveys should be done to estimate population size, as if they will be sites for the long-term population monitoring. This will maximise the potential number of sites that can be included in the long-term monitoring, and it also ensures that the pre-construction density estimates are obtained as early as possible before construction starts. The greatest limitation to the pre-construction population density surveys is that they are usually “squeezed” in just before construction starts such that there is insufficient effort and data to confidently determine population size. This consequently results in doubt about the direction of any long-term trends when comparing during or post construction data with that collected prior to construction.

The plan states in a number of locations that surveys will be spotlighting transects, according to methods of Goldingay and Taylor. This method may or may not be appropriate, depending on the specific question that the monitoring needs to answer. In many respects, the approach of setting the survey method prior to clearly articulating the question is akin to putting the cart before the horse.

4.3.1: the issue around doing surveys only in known and likely habitat areas: There may well be populations in areas that are possible but unlikely habitat. I am not suggesting surveying within grasslands for gliders, but there may be woodland or forest that are not the “preferred” habitat for gliders, but may be supporting populations or may be suitable habitat for connectivity (i.e. they will use sub-optimal habitat for connectivity for short distances if they have no other options).

4.3.1: why is 20 m the critical minimum height of trees? The important criteria is tree height, relative to the size of the clearing. 20 m trees may still be too short if the size of the gap is too great or if the road is built on fill (in which case effective tree height will be less than 20m). So, please re-phrase this to relate to glide angles and capacity to make it across the gaps, not simply a blanket statement about tree height.

The first objective of the surveys is to “identify known or potential habitat….” – but surely we know this already? From vegetation mapping and collation of existing records – you should know the known habitat and know most of the potential habitat?

4.3.2: what exactly will constitute habitat exclusion zones for gliders? what ecological communities will be protected? Any other criteria for selecting no-go zones? Tree height? Density of hollow-bearing trees? As far as I can tell, and based on experience, this just means anywhere where trucks and machinery don’t need to go!

Table4.1: It is not enough to say that the monitoring program will be developed prior to construction commencing. The goal for mitigation should be that the monitoring program is developed AND sufficient "before" data has been collected to ensure that the monitoring program is meaningful and provides sufficient and reliable data. This may be implicit in what is being proposed, but it needs to be explicit. Depending on the question being asked of the monitoring program, the before data may need to be presence/absence of gliders, population estimates collected during 4 consecutive seasons, or something else again.

5.2: first dot point: - ensure the goal includes completing the construction of mitigation according to the designs/specifications.

I would also add a goal that there will be zero mortality of gliders during construction as a result of construction practises.

5.3.3: what is a glider release site? 4.3.1. doesn't actually define the selection criteria for release sites.

5.3.4: How will the "if necessary, fauna may need to be trapped…." be determined? Who decides if fauna need to be trapped, and on what basis?

5.3.5: road crossing structures for gliders have been shown to increase connectivity, and *probably* reduce mortality.

Studies have also shown that widened medians have also been shown to facilitate connectivity by gliders – these need to be discussed/mentioned, alongside rope bridges and poles. Indeed, widened medians are probably the most efficient at restoring connectivity, compared to rope bridges and poles.

I would like to see a discussion somewhere about the different levels of efficiency and effectiveness of the 4 different approaches to restoring connectivity that you have provided here. The approach that is most effective is probably a land bridge with mature trees (but don't have data on this yet), followed by vegetated medians, followed by rope bridges and poles.

Table 5-1: On first principles, and based on further viewing of this plan and the EIA docs – the 20 crossings over 155 km seems insufficient. If one of the goals is to maintain connectivity for home range movements – then this number of crossings is very insufficient. You would need crossings spaced a few home ranges apart if all home range movements are to be catered for. For genetic connectivity – they could be further apart- but 20 over 155 km is still likely to be insufficient.

5.3.6: here is where a potential conflict between restoring connectivity and increasing mortality may be a problem. By planting feed trees at crossing structures, you encourage gliders to the roadside, potentially increasing the risk of mortality. If the goal is to provide trees that replace structures over time, then choose the tallest tree species that live for the longest period of time. However, timber poles will always be required to hold up rope bridges, so trees will never replace those structures.

Third para: Please clarify what is meant by crossing zones. I use the word zone to describe a short length of road where a number of crossing structures are installed, depending on the length of forest adjoining the road and the road height/design. For example, a crossing zone may consist of a rope bridge, a set of poles, followed by another set of poles (or some other combination of poles, bridges, widened median and/or land bridge) over a distance of 500 m to 1 km. The rate of use of crossing structures is still variable, for unknown reasons, but probably relate to adjacent habitat conditions, road design, occurrence of animals to use the structure, structure design etc. Because we cant accurately predict that every structure will be used, we need to build in some redundancy to ensure that we put in "extra" structures to ensure some get used. This is particularly important for gliders which can't be effectively funnelled with fencing towards our "single" crossing structure.

5.3.7: I have not seen any discussion about longevity of nest boxes in the humid, moist sub-tropical nth coast of NSW. At the very least, this plan needs to discuss that nest boxes don't last forever and will be managed until the natural hollows form in the revegetation sites, which may be 80 – 120 years.

Table 5.2, 2$^{nd}$ goal: Surely the primary goal is to ensure zero mortality during construction, with gliders leaving the area to be cleared of their own accord (ie as part of the 2-stage clearing process), and then any remaining gliders that appear during tree felling or are removed from hollows are successfully relocated. And the performance threshold is not specific enough – are we aiming for zero mortality, 10 animals per year? Need to specify a threshold that will trigger a response.

Table 5.2, 4th row. How to deal with habitat damaged during construction, because this additional habitat wont have been accounted for when offsets and the number of replacement nest boxes was calculated. Need to add in that a final review of habitat losses will pick up any additional and unforseen losses.

Table 5.2, 5th row. Please define what “low” mortality means for this performance threshold.

6.1: What is meant by identical important areas?

6.2, 1st goal: Need to define what is meant by an “effective” crossing structure. How is that defined?

6.2, 3rd goal: Need to say how many nest boxes will be occupied. Also this goal does not mean much ecologically. If the glider population moves from natural hollows into nest boxes, does this equate to a successful nest box program? And surely the location of nest boxes matters here. If nest boxes in young revegetation with zero hollows, then occupation of nest boxes located within the young revegetation is a good thing. This goal needs some thinking about.

Table6.2, last row: how long will the revegetation be monitored and maintained as revegetation?

6.3.2: Need to state the frequency at which the “ropes” will be checked for wear and tear.

6.3.3: Maintenance of nest boxes. It is likely that over the 155 km of this project, that many hundreds or possibly 1000s of nest boxes of different shape and size will need to be installed. This represents an incredible opportunity to unequivocally determine the optimal dimensions, location, aspect etc of nest boxes, for different species. I strongly encourage Roads and Maritime to establish a partnership with a good research group to undertake this study as part of the mitigation process. Don’t just install nest boxes anywhere, but install them strategically to actually answer some important questions that we have all been asking for many years about nest boxes.

Nest box inspections: the frequency of inspection and mode of inspection will influence when inspections should take place. If inspection is simply inserting a camera on a pole into the entrance hole, then it can happen at anytime of year. If the monitoring involves removing and processing gliders occupying the nest boxes, then need to consider the timing to avoid sensitive periods. Need more detail on the inspection and monitoring program for glider boxes.

Table 6.3, 1st row: how much evidence of use do you need to be satisfied crossing structures are effective? Is one glider using one rope bridge enough? Or 1 glider per year on each and every structure? Or 10 crossings or 100 crossings per year after 5 years….. This threshold needs to be clearly defined.

What is the problem with exotic predators visiting or using crossing structures – this has not been discussed in the main body of the plan yet. And what is defined as a “high” visitation rate? And how do you expect an exotic predator (ie fox or cat) to use a rope bridge or glider pole?

Table 6.3 3rd row: please clarify if you only intend to monitor and maintain the nest boxes for 5 years post construction? If the goal of nest boxes is to replace hollows destroyed by the project then surely maintenance needs to continue until natural hollows replace those that were destroyed? I suggest inspecting nest boxes less frequently, but for a longer period of time, potentially 50 – 100 years.

Table 6.3 – 3rd row: the first performance threshold relates to the pre-construction threshold – that 70% of boxes will be installed prior to construction commencing. Why is it included as an operational performance threshold?

7. Monitoring Program: It is great to see that Roads and Maritime has recognised the importance of the BACI design in its monitoring program! Because the objectives for the mitigation are not clearly defined, it is difficult to comprehensively review the monitoring program. I strongly advise that the mitigation goals be revised, and then the monitoring program be developed to determine if the goals of the mitigation have been addressed.

7.1, 1st obj: I don’t understand what is meant by changes to habitat usage. Please define more clearly. I also don’t know how, explicitly, any changes might be attributed to the project.

7.1, 2nd obj: The adaptive monitoring framework is not clearly articulated in this plan. Adaptive management and/or adaptive monitoring are very important, and there is a whole methodology that has been developed to guide these, however the TGMP has not covered this in enough detail.

7.1, 3rd obj: This is not an objective – just a statement. What goal or objective are you trying to achieve?

7.2.1, 1st obj: need to clearly state if the targeted surveys to inform road design/mitigation design are the same as targeted population surveys that will form the basis of the pre-construction population / abundance data.

7.2.1.: 2nd obj: Is monitoring populations / abundance the same as determining patterns in habitat usage (with habitat usage being the first obj in 7.1).

7.2.1, 4th obj: I don't understand what is meant by "identify den sites for consideration during veg clearing. Consideration for /of what?

7.2.2: what criteria will be used to identify impact and control sites? Are you suggesting that sites with glider populations will remain unmitigated? This would be fantastic from a study design perspective (e.g. – find 20 sites with glider populations, and then randomly select 10 to mitigate and 10 to remain unmitigated), but I don't know if OEH will accept this. And I certainly wouldn't be recommending such an approach based on the quality of the proposed monitoring program as detailed in this plan. But, the potential to develop a strong monitoring program that can answer outstanding questions about the effectiveness of mitigation by not mitigating some areas is really strong, and one which should be considered for W2B.

I note that control and reference sites will be matched to highway sites with respect to aspect, habitat type, slope, region. Also need to ensure that reference sites should also be matched to similar site type – e.g. large blocks of forest at highway and large blocks of forest away from highway, if highway site includes narrow corridors, then narrow corridors should be found as reference sites.

And on what basis is the >300 m recommended as the minimum distance from the road for reference sites? I would say reference sites need to be at least a few km away from the road, probably around 5km. Reference sites need to be far enough away from the road for the organism of interest to not be impacted by the road. 300 m definitely not far enough from the road! The home range of both species could easily be greater than 300 m in diameter, and thus encompass both impacts and reference sites.

I support the notion that the monitoring program should ignore the boundaries of the divisions of the 155 km project and be based on the best locations to answer the specific questions of the monitoring program.

Do you propose to include potential "reference" sites, which are more than 300 m from the road, in the initial surveys? All site types should be included in the pre, during and post-construction surveys.

7.2.3.: It is unclear how much time will actually be available to conduct the necessary pre-construction baseline population surveys. Please provide a timeline to demonstrate that sufficient time, based on the current expected/planned program of approvals and other works, is available to actually complete the pre-construction surveys to get a reliable baseline population estimate.

The second sentence of 7.2.3 says "surveys will be conducted every 3 months….". The next sentence says "initial surveys before construction should aim for a minimum of two seasonal surveys, and depending on timing could be increased to once every 3 months". This is contradictory and doesn't make sense.

7.2.3, 3rd para: it says that the spotlight surveys were "designed to assist in understanding the proximity of gliders to the crossing structures and therefore the likelihood that dispersing individuals would encounter the structures". Is this the only reason to do population surveys? I though t you said earlier it was about changes to habitat usage patterns. Why isn't estimating the density of the population or abundance one of the key measures of effectiveness? Gliders can still use the structures, and still occur in close proximity to structures, but the overall population density can still decline due to impacts of the road/traffic. If this is a consequence of the widened pacific hwy, then surely we want to know this? The monitoring program won't be able to detect a population decline like this if all surveys are within 100 m of the road.

Similarly, YBG have quite large home ranges and it is quite possible that detectability is so low that it is going to be very difficult to detect changes in population density if sample sizes are small. There needs to be some discussion around the issue of detectability and necessary sample sizes to be able to confidently detect changes in population as well as ascribe those changes to the hwy. This demonstrates the potential difference between the goals of mitigation and the goals of monitoring.

7.3.1: Why is some measure of "facilitating dispersal of threatened gliders" the key objective? How can you determine the extent to which something facilitates dispersal? Can't really ask a glider "do you feel more comfortable dispersing using poles, rope bridge or widened median?" In other words, the things we can measure are actual rates of use, and then use other techniques to try and figure out if it was for daily movement or an occasional dispersal movement. And depending on local population sizes, we may be able to figure out what parameters (habitat conditions, landscape conditions, local population sizes, road design, type of structure etc) influence rates of use.

7.3.2.: no glider poles?

7.3.3: the timing and methods proposed for the monitoring needs to be reviewed after the goals and objectives of the monitoring program have been carefully reviewed and revised.

7.3.4: why monitor populations of gliders if the performance threshold is use of crossing structures?

7.4.1: an objective of trying to monitor the rate of glider – vehicle *collisions* is nonsensical. It will be impossible to measure this. It might (and I stress *might*) be possible to measure an index of road kill, but it will be impossible to measure how many times gliders hit a vehicle. If gliders, particularly squirrels which are smaller than YBG, get hit by a truck, they will likely be thrown from the road, stuck to the front of the truck or very quickly disintegrate. Therefore, using measures of mortality is very difficult and unlikely to be successful.

7.4.2: are you wanting someone to walk on the emergency lane, in the road reserve/verge, on both sides of each carriageway – so four transects per site?

7.4.3.: you acknowledge that "relying on this method (ie walking transects to detect roadkill) alone" could result in an underestimate of actual mortality – so what do you propose to do to correct this bias / underestimate? If you did survival analyses of a marked population you could have a second approach to estimating mortality. Similarly, I understand genetic techniques can also be used to estimate mortality rates. In short, I am concerned that assessing roadkill may be a waste of time, and that to use only this approach to assess survival/mortality will not give the information we need.

The first sentence also doesn't make sense: "performance…. will be measured by achievement of a zero rate of vehicle strikes". Performance will be measured by doing a survey, not by achieving zero mortality. Success might be defined as achieving zero mortality.

Table 7-3. I don't understand why you would review monitoring methods if you don't achieve a zero rate of mortality from collision with vehicles.

What will you do if mortality occurs away from the crossing structures? What sort of corrective action will be applied then? Also – what will you do if mortality occurs near to the structures, but you have evidence that gliders use the structures?

How will you "consider" that natural variation might be responsible for population declines? And how will you confirm that population declines are due to mortality and not some other cause?

7.6.2: I understand why large trees with hollows has been removed but surely, if conservation of threatened gliders is the key goal here, then wouldn't we be installing nest boxes where we can within revegetation sites – in which case why wouldn't we measure hollows from boxes in some way?

Please explain what the criteria against which the success of the revegetation will be assessed.

Photo points are usually / often a waste of time. The main issue is that the storage of photos is rarely done very well, stuff gets lost, photo point locations get lost etc. Most importantly though, is the comparison of data from photo points over time. How will changes from photos be assessed? What will the comparison be? Is it just to make people feel good by "eye-balling" the before and after shots?

7.6.3: hard to follow "planted" plants over time, especially when natural regeneration may occur, and planted plants may die and rot away and not be visible after 12 months – so how will "planted plants" be identified/plots marked?

References

LINDENMAYER, D. B. & LIKENS, G. E. 2009. Adaptive monitoring: a new paradigm for long-term research and monitoring. *Trends In Ecology & Evolution,* 24, 482-486.

LINDENMAYER, D. B. & LIKENS, G. E. 2010a. *Effective ecological monitoring,* Collingwood, Victoria, Australia, CSIRO PUBLISHING.

LINDENMAYER, D. B. & LIKENS, G. E. 2010b. The science and application of ecological monitoring. *Biological Conservation,* 143, 1317-1328.

MCCALL, S., VAN DER REE, R., MCCARTHY, M. A., CESARINI, S., SOANES, K. & HARPER, M. J. 2010. Highway living reduces survival of Squirrel Gliders. *Ecology and Society,* 15, 27.

VAN DER GRIFT, E. A., VAN DER REE, R., FAHRIG, L., FINDLAY, S., HOULAHAN, J., JAEGER, J. A. G., KLAR, N., MADRIÑAN, L. F. & OLSON, L. 2013. Evaluating the effectiveness of road mitigation measures. *Biodiversity and Conservation,* 22.

VAN DER REE, R., CLARKSON, D. T., HOLLAND, K., GULLE, N. & BUDDEN, M. 2008. Review of Mitigation Measures used to deal with the Issue of Habitat Fragmentation by Major Linear Infrastructure, Report for Department of Environment, Water, Heritage and the Arts (DEWHA), Contract No. 025/2006, Published by DEWHA.

VAN DER REE, R., JAEGER, J. A. G., VAN DER GRIFT, E. A. & CLEVENGER, A. P. 2011. Effects of Roads and Traffic on Wildlife Populations and Landscape Function: Road Ecology is Moving toward Larger Scales. *Ecology & Society,* 16, 1-9.

VAN DER REE, R., VAN DER GRIFT, E. A., MATA, C. & SUAREZ, F. Year. Overcoming the barrier effect of roads – how effective are mitigation strategies? An international review of the effectiveness of underpasses and overpasses designed to increase the permeability of roads for wildlife. *In:* IRWIN, C. L., NELSON, D. & MCDERMOTT, K. P., eds. International Conference on Ecology and Transportation 2007 Little Rock, Arkansas, USA. Center for Transportation and The Environment, North Carolina State University, Raleigh, NC, 423-431.

# Appendix C Squirrel Glider feed trees in NSW to be targeted in revegetation

Source: Husbandry Manual For Squirrel Glider. *Petaurus norfolcensis* (Trudgeon 2006)

| Scientific name | Common name | Food utilized | Time of year used | Distribution in Australia |
|---|---|---|---|---|
| *Acacia concurens* | Curracabah | Nectar/pollen<br>Seed arils | Autumn/winter<br>Spring | NSW/QLD |
| *Acacia irrorata* | Green wattle | Gum | Autumn/winter | NSW/QLD |
| *Acacia pycnantha* | Golden wattle | Nectar/pollen<br>Gun | Winter/spring<br>Autumn/winter | NSW/VIC |
| *Angophora* | Smooth barked apple | Nectar/pollen<br>Sap | Summer<br>Autumn/winter | NSW/QLD |
| *Banksia integrifolia* | Coast banksia | Nectar | Summer/autumn | NSW/QLD |
| *Banksia serrata* | Saw banksia | Nectar | Spring/summer | NSW/VIC |
| *Banksia spinulosa* | Hairpin banksia | Nectar | Autumn/winter<br>Spring | NSW/QLD/VIC |
| *Corymbia glommifera* | Red bloodwood | Nectar/pollen<br>Sap | Summer<br>Winter | NSW/QLD/VIC |
| *Corymbia maculata* | Spotted gum | Nectar/pollen<br>Sap | Winter/spring<br>Autumn/winter | NSW/QLD/VIC |
| *Eucalyptus amplifolia* | Cabbage gum | Nectar/pollen<br>Sap | Summer<br>Autumn/winter | NSW/QLD |
| *Eucalyptus camaldulensis* | River red gum | Nectar/pollen<br>Sap | Variable<br>Autumn/winter | NSW/QLD/VIC |
| *Eucalyptus melliodora* | Yellow box | Nectar/pollen | Summer | NSW |
| *Eucalyptus paniculata* | Grey ironbark | Nectar/pollen | Autumn/spring | NSW |
| *Eucalyptus pilarus* | Blackbutt | Nectar/pollen<br>Sap | Winter | NSW/QLD |
| *Eucalyptus punctata* | Grey gum | Nectar/pollen | Summer/Autumn | NSW |
| *Eucalyptus seeana* | Narrow-leaved red gum | Nectar/pollen<br>Sap | Spring/Summer<br>Autumn/winter | NSW/QLD |
| *Eucalyptus siderophloia* | Grey ironbark | Nectar/pollen | Spring/Autumn | NSW/QLD |
| *Lophostemon confertus* | Brushbox | Nectar/pollen | Spring/Summer | NSW/QLD |
| *Lophostemon suaveolens* | Swamp terpentine | Nectar/pollen | Spring/Summer | NSW/QLD |
| *Melaleuca nodosa* | Tea tree | Nectar/pollen | Winter/spring<br>Summer | NSW/QLD |
| *Melaleuca* | Tea tree | Nectar/pollen | Spring/summer | NSW/QLD |

| | | | | |
|---|---|---|---|---|
| *alternifolia* | | | | |
| *Melaleuca stypholoides* | Prickly leaved paperback | Nectar/pollen | Summer | NSW/QLD |
| *Nototthixos species* | Mistletoe | Fruit | Summer | NSW/QLD/VIC |
| *Xanthorhea species* | Grass tree | Nectar/pollen | Winter/spring | NSW/QLD/VIC |

# Appendix D - Yellow-bellied Glider Sap Feed Trees in north-east NSW to be targeted in revegetation

| Scientific name | Common name | Region |
|---|---|---|
| *Angophora subvelutina* | Broad-leaved Apple | North-east |
| *Corymbia henryi* | Large-leaved Spotted Gum | North-east |
| *Corymbia intermedia* | Pink Bloodwood | North-east |
| *Eucalyptus amplifolia* | Cabbage Gum | North-east |
| *Eucalyptus bancroftii* | Orange Gum, Bancroft's Red Gum | North-east |
| *Eucalyptus deanei* | Mountain Blue Gum, Round-leaved Gum | North Coast and adjacent ranges |
| *Eucalyptus dunnii* | White Gum | North-east |
| *Eucalyptus eugenioides (includes Eucalyptus nigra)* | Thin-leaved Stringybark | North-east |
| *Eucalyptus grandis* | Flooded Gum, Rose Gum | North-east |
| *Eucalyptus moluccana* | Grey Box | North-east |
| *Eucalyptus pilularis* | Blackbutt | North-east |
| *Eucalyptus propinqua* | Grey Gum | North-east |
| *Eucalyptus punctata* | Grey Gum | Central Coast, South Coast, North Coast and adjacent ranges |
| *Eucalyptus racemosa* | Narrow-leaved Scribbly Gum | North Coast |
| *Eucalyptus seeana*<br>*Eucalyptus signata* | Narrow-leaved Red Gum<br>Scribbly Gum | North-east<br>North-east |
| *Eucalyptus tereticornis* | Forest Red Gum | North Coast and adjacent ranges |
| *Lophostemon confertus* | Brush Box | North Coast |

Source: Recovery Plan for the Yellow-bellied Glider (*Petaurus australis*) (NSW NPWS 2003)