SECOND MURRAY RIVER CROSSING, ECHUCA-MOAMA

SQUIRREL GLIDER HABITAT LINKAGE STRATEGY

Roads and Maritime Services, NSW

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July 2015

Report No. 8194 (18.1)

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1. EXECUTIVE SUMMARY

NSW Roads and Maritime Services (Roads and Maritime) engaged Brett Lane & Associates Pty. Ltd. (BL&A) to prepare a Squirrel Glider Habitat Linkage Strategy for the proposed second Murray River crossing at Echuca-Moama. This strategy is considered a key mitigation measure to reduce the likelihood of the project having a significant impact on the local Squirrel Glider population (van der Ree et al., 2015).

The Squirrel Glider (*Petaurus norfolcensis*) is a medium-sized, nocturnal, arboreal gliding marsupial found in dry Eucalypt woodlands and forests below 300m altitude between central Victoria and far-north Queensland. The Squirrel Glider is a species of conservation concern, and is listed as endangered in Victoria (FFG Act) and vulnerable in New South Wales (TSC Act).

The home range of Squirrel Gliders varies according to habitat quality, including food and den availability, but is also limited by habitat fragmentation and urbanisation. The Squirrel Gliders previously recorded in the study area were found to be in relatively low abundance and density, likely reflecting a lower carrying capacity of the woodland habitat within the study area.

Following a field survey, key Squirrel Glider habitat components within the study area were found to be:

- Large and hollow bearing trees that are considered suitable den trees for Squirrel Gliders;
- Species that provide a reliable winter food source, including Grey Box, Silver and Golden Wattle; and
- Areas where several canopy trees taller than 10 m occur within 20 m of each other (representing average Squirrel Glider glide distance).

The use of crossing structures such as rope bridges and wooden poles is known to be a proven measure to mitigation the impacts of linear transport infrastructure on Squirrel Glider (Soanes et al., 2013, van der Ree et al., 2015). However, wherever possible, canopy cover should be maintained across the road to provide habitat linkage for Squirrel Gliders. The feasibility of this will need to be determined at the detailed design phase of the project.

The provision of five crossing zones, each with several rope bridges is recommended to maintain habitat linkage between areas of high quality habitat across the proposed alignment. Post-implementation monitoring at a population-wide scale will be required to determine the efficacy of the installation of crossing zones.

Secondary habitat linkage recommendations include the installation of glide poles and revegetation to improve habitat connectivity in areas adjacent to the proposed alignment over the short- and medium-long term time frames respectively.

An assessment of significance under the EP&A Act has been undertaken. Potential impacts on the Squirrel Glider resulting from the proposal are considered in this assessment to have been mitigated through this plan and recommendations contained in van der Ree (2015) such that impacts would not be significant and a *species impact statement* would not be required.

2. INTRODUCTION

NSW Roads and Maritime Services (Roads and Maritime) engaged Brett Lane & Associates Pty. Ltd. (BL&A) to prepare a Squirrel Glider Habitat Linkage Strategy for the proposed second Murray River crossing at Echuca-Moama (referred to hereafter as the project). A habitat linkage strategy was considered necessary by van der Ree et al. (2015) as a key mitigation measure to reduce the likelihood of the project having a significant impact on the local Squirrel Glider population.

The rationale for the investigations that underpin involves three objectives:

- to identify where habitat is most suitable for Squirrel Gliders either side of the key barriers that affect habitat connectivity (i.e. the project and the Murray River);
- to develop a strategy using a combination of tools to maintain and enhance connectivity between areas of suitable habitat; and, therefore
- to facilitate the movement of individuals, and therefore gene flow, that will maintain the local Squirrel Glider population.

Specifically, the scope of the investigation included:

- Review of existing available information, focussing on the following:
    - Key habitat requirements of the Squirrel Glider;
    - The effectiveness of wildlife crossings for roads and other barriers;
    - Wildlife crossing examples from Australia and overseas, focusing on effective methods for maintaining movements of animals across roads; and
    - A specific evaluation of the effectiveness of wildlife crossing structures and glide poles for Squirrel Gliders and other tree-dwelling mammals in Australia.
- A site survey involving the activities below:
    - Characterisation of the key habitat attributes known to be required by Squirrel Glider and those present in the portion of the study area in which the local population of the species lives, adjacent to Moama, north-west of the proposed alignment route in NSW;
    - Mapping of potential habitat either side of the proposed alignment and proposed bridge across the Murray River, and field evaluation and mapping of its suitability for Squirrel Gliders to identify the most appropriate location for crossings, such that crossings connect areas of the most suitable habitat possible. The characteristics used in mapping habitat suitability include:
        - Visual, category-based estimate of tree density;
        - Dominant tree species;
        - Presence and category-based visual assessment of the density of hollow-bearing trees (including those with coppice-hollows);
        - Presence, species representation and cover of sub-canopy and understorey wattles (a critical, winter carbohydrate source for the Squirrel Gliders); and
        - Observation of evidence of signs of chewed bark (i.e. glider feeding activity) on wattles.

- Identification of areas where specific habitat enhancement works will promote the long term recovery of habitat quality where practical limitations exist to connecting existing areas of suitable habitat; and
- Identification of the most appropriate locations for the installation of wildlife crossings and habitat enhancement works.

This report is divided into the following sections:

Section 3 presents an overview of the proposed project.

Section 4 provides the legislative background including details of relevant Commonwealth and State legislation and policies.

Section 5 briefly describes the methods used for the literature review and field survey.

Section 6 presents the results of the literature review, including discussion of habitat requirements of the Squirrel Glider and evaluation of potential habitat linkage tools.

Section 7 outlines the field survey methodology, developed from the results of the literature review.

Section 8 presents the results of the field survey.

Section 9 discusses habitat linkage recommendations in light of both the literature review and field survey results.

Section 10 documents a significance assessment (seven part test) under Part 1, Section 5A (2) of the EP&A Act (NSW) in light of habitat connectivity mitigation measures contained in this strategy.

This investigation was undertaken by a team from BL&A, comprising Elinor Ebsworth (Botanist), Brett Macdonald (Senior Ecologist & Project Manager), Alan Brennan (Senior Ecologist & Project Manager) and Brett Lane (Principal Consultant).

2.1. Limitations

Squirrel Glider habitat suitability within the study area has been determined based on current literature and field observation of conditions in areas in which Squirrel Gliders have previously been trapped (van der Ree et al., 2015). Squirrel Glider trapping was undertaken in the study area during autumn (van der Ree et al., 2015). The utilisation of habitat components may vary seasonally, and preferred autumn habitat may differ from that used in other seasons. For example, food availability is likely to have been higher during the autumn trapping period than later in the year during winter, and thus the importance of den availability may have been more limiting during the trapping period than the availability of winter food sources. This has been addressed in this strategy by:

- Mapping various habitat components, including den and winter food source availability, and then combining these to locate overall habitat suitability; and
- Recommending linkage between areas that support a combination of favourable habitat components.

Habitat linkage recommendations have been provided based on the site conditions encountered and informed by current literature. While shown to be effective in linking habitat elsewhere, it is important that the success (or otherwise) of any measures implemented for Proposal are monitored (Goldingay et al., 2013; Rytwinski et al., 2015).

An adaptive approach to habitat linkage should be applied if it is determined that some elements are more successful than others.

3. PROJECT BACKGROUND

The existing bridge across the Murray River was built in 1878 and operated as a combined road/rail bridge until 1989. The nearest alternative road crossings are at Barham, 86 km to the west, Barmah 36 km to the east, or Tocumwal 120 km to the east.

The existing road bridge and its approaches have inherent safety and operational limitations including an inability to carry over-width loads and higher mass-limited vehicles used by an increasing proportion of the freight transport industry. Rehabilitation works to upgrade the operational capacity of the bridge would require lengthy road closures and would be further complicated by heritage considerations.

The existing bridge with one lane in each direction also does not provide a suitable level of service for the increased volume of light vehicle traffic experienced during peak summer tourist events. Extensive delays are commonly experienced at these times which are easily exacerbated by any minor traffic incidents. This results in sizeable delays and in particular restricts the movement of emergency services vehicles from one town to the other.

Early investigations to provide for a second Murray River crossing at Echuca-Moama commenced in 1965. Since then, extensive planning investigations have been undertaken. Over the past 15 years, five corridors have been considered for an additional Murray River crossing.

As a result of the investigations completed and stakeholder consultation conducted, significant knowledge has been gained of existing environmental, social and economic conditions and community values in the Echuca-Moama region.

3.1. The Proposal

The Echuca-Moama Bridge project (the project) involves the construction and operation of a second road bridge crossing of the Murray and Campaspe Rivers at Echuca-Moama. The Project includes an elevated roadway and extensive bridging across the Campaspe and Murray River floodplains, as well as changes to existing approach roads.

The Project comprises a Right-of-Way sufficient to build a four lane road and duplicated bridges across both Rivers. Construction of the Project would be staged to meet traffic demands and includes the initial alignment and an ultimate duplication.

The initial alignment comprises the construction of a two lane, single carriageway road including a bridge across each waterway. The ultimate duplication comprises the construction of a duplicated roadway and bridges, which would be constructed when future traffic demand warrants.

3.2. Project Objectives

The Proposal Objectives are to:

- Improve accessibility and connectivity for the community of Echuca-Moama and the wider region;
- Provide security of access between Echuca and Moama;
- To enable cross border access for high productivity vehicles and oversized vehicles;
- Provide road infrastructure that supports:

- The local and regional economy of Echuca-Moama; and
- The state and national economies through improved connectivity of goods and services.

3.3. Preferred Alignment

Three alignments were initially proposed and investigated, with the Mid-West alignment now the preferred option. The Mid-West alignment is approximately 4.1 kilometres in length and extends along Warren St from the intersection with the Murray Valley Hwy until near Payne St, where it turns in a north-west direction across Campaspe Esplanade and the Campaspe River. The alignment then extends north-east across the old Echuca High School site, towards the Echuca Sports and Recreation Reserve and continues north through Victoria Park to near the boat ramp, crossing the Murray River before joining Forbes St, Moama. It will terminate at the intersection of Perricoota Rd and the Cobb Hwy, NSW. The preferred alignment passes through areas of woodland to the west of Echuca and Moama and will be elevated on embankments and bridges across the Campaspe and Murray River channels and floodplains. Approximately 2.5 km of the alignment passes through potential Squirrel Glider habitat (the study area), as described below.

3.4. Study Area

The study area for this investigation occurs immediately adjacent and either side of the proposed footprint along a 2.5 km portion of the Mid-West alignment, extending to Boundary Road in the north, the Cobb Highway in the east, the Murray River in the south-east and west and the Campaspe River in the south-west (Figure 1).

Metres
0 125 250 500

Legend

- Study area
- Assessment sites
- Midwest Alignment
- Alignment 20 metre buffer

Figure 1: Study area

Project: Murray River Crossing Echuca

Client: VicRoads

Project No.: 8194	Date: 26/06/2015	Created By: M. Ghasemi / E. Ebsworth

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4. LEGISLATIVE CONTEXT

This strategy is considered a key mitigation measure to reduce substantially the likelihood of the proposed crossing having a significant impact on the local Squirrel Glider population (van der Ree et al., 2015).

It has been identified (BL&A, 2015) that without mitigation measures, the proposed project could potentially have impacts on Squirrel Gliders of relevance under the following NSW legislation:

- NSW Environmental Planning and Assessment Act 1979 (EP&A Act); and
- NSW Threatened Species Conservation Act 1995 (TSC Act).

These are discussed below.

4.1. NSW Environmental Planning and Assessment Act 1979

The project has been assessed under Part 5 of the EP&A Act (BL&A, 2015), which requires an assessment of threatened flora and fauna and their habitats that are likely to occur within the study area, or that may be indirectly affected by the construction and operational aspects of the project. The assessment informs whether or not an Environmental Impact Statement or Species Impact Statement is required. It has been determined that without mitigation measures, there may be a long-term impact on the local population of Squirrel Glider, arising from isolation of the population adjacent to Moama by the project (BL&A, 2015). A significance assessment under Part 5 of the EP&A Act, considering mitigation measures outlined in van der Ree et al. (2015) and herein, has been undertaken in Section 10 of this strategy.

4.2. NSW Threatened Species Conservation Act 1995

The TSC Act lists threatened species, populations and ecological communities that require a significance assessment under section 5A of the EP&A Act. Squirrel Gliders are listed as Vulnerable under the TSC Act.

Section 5A of the EP&A Act sets out seven criteria (the 'Seven Part Test') that determine whether a Species Impact Statement should be prepared under the TSC Act for a project. The aim of the Seven Part Test is to ascertain whether a proposed project is likely to lead to a significant impact on a threatened species or community that requires more detailed assessment under the TSC Act. It has been determined that without mitigation measures, there may be a long-term impact on the local population of Squirrel Glider (BL&A, 2015). Avoiding a significant impact on the local population of the Squirrel Glider is the primary purpose of this strategy. An updated significance assessment under Part 5 of the EP&A Act, undertaken considering mitigation measures, has therefore been undertaken in Section 10 of this report. Proposed measures that mitigate the impacts of a proposal can be considered in undertaking an assessment of significance if the measure has been used successfully for that species in a similar situation (Department of Environment and Climate Change 2007). The use of crossing structures such as rope bridges and wooden poles is known to be a proven measure to mitigation the impacts of linear transport infrastructure on Squirrel Glider (Soanes et al., 2013, van der Ree et al., 2015).

5. METHODS

5.1. Literature Review

A literature review was undertaken to elucidate the following:

- Key habitat requirements of Squirrel Gliders;
- The effectiveness of wildlife crossings for roads and other barriers;
- Wildlife crossing examples from Australia and overseas, focusing on effective methods for maintaining movements of animals across roads;
- A specific evaluation of the effectiveness of wildlife crossing structures and glide poles for Squirrel Gliders.

The key reports relating to the study area, below, were reviewed. A complete list of literature reviewed is provided in the reference list (Section 11).

- Murray River Crossing Echuca-Moama – Detailed Flora and Fauna Assessment. Report No. 8194 (1.3) (BL&A, 2009);
- Second Murray River crossing at Echuca – Moama: Preliminary Ecological Investigation. Report No. 8194 (15.2) (BL&A, 2015); and
- Final report of targeted Squirrel Glider surveys for second Murray River bridge crossing - Mid-West alignment, Autumn 2015 (van der Ree et al., 2015).

5.2. Field Survey Method Development

Following the literature review described in Section 5.1, a method for field survey of the study area was developed with the aim of mapping suitable Squirrel Glider habitat, and providing recommendations on the type and location of habitat linkage appropriate for the project. The complete field survey method is described in Section 7.

5.3. Field Survey

A field survey was undertaken from 29th June to 2nd July. During the field survey, the following vegetation elements were mapped and scored:

- Areas of potential habitat; and
- Potential habitat trees (including den trees, feed trees and habitat connectivity trees) within 20 m of the proposed road alignment.

Vegetation in the study area was divided into assessment patches prior to the field survey. Patches were allotted based on aerial imagery, along visible changes in land-use or vegetation (or both) (Figure 1). The methods utilised for the field survey are described in full in Section 7.

6. LITERATURE REVIEW RESULTS

6.1. Squirrel Glider Ecology

6.1.1. Description

The Squirrel Glider (*Petaurus norfolcensis*) is a medium-sized (190-300g), nocturnal, arboreal gliding marsupial (family Petauridae). The geographic range of Squirrel Gliders is broad, extending from central Victoria to far-north Queensland (Menkhorst & Knight, 2001). The Squirrel Glider is a species of conservation concern, and is listed as endangered in Victoria (FFG Act) and vulnerable in New South Wales (TSC Act). Squirrel Gliders are found in dry Eucalypt woodlands and forests below 300m altitude (Menkhorst et al., 1988; Rowston et al., 2002; Goldingay et al., 2010).

The home range of Squirrel Gliders varies according to habitat quality, including food and den availability, but is also limited by habitat fragmentation and urbanisation (Brearley et al., 2011b). Minimum reported Squirrel Glider home range is 0.7 hectares, with an average of four hectares in linear but high-quality habitat (van der Ree & Bennett, 2003), while home ranges up to 15 hectares have also been documented for this species (Traill, 1994; Goldingay et al., 2010). Interestingly, larger home ranges have been documented in continuous forest than near roads and residential areas (Brearley et al., 2011b). The Squirrel Gliders previously recorded in the study area were found to be in relatively low abundance and density, likely reflecting a lower carrying capacity of the woodland habitat within the study area (van der Ree et al., 2015), an assertion supported by the findings of Sharpe & Goldingay (2010).

6.1.2. Habitat Requirements

Den trees

Squirrel Gliders are obligate users of tree cavities as dens and commonly den socially in groups of two or more (Crane et al., 2010). Van der Ree (2000) examined den use by Squirrel Gliders in temperate Australian woodlands, and found that an average of 5 dens were utilised. Crane *et al*. (2010) found similar rates of den utilisation, with an average of seven den trees used by individual Squirrel Gliders over a five-month period. They also found that Squirrel Gliders utilise a small number of primary dens, with these den trees generally occurring on steeper slopes. Every 1° increase in slope increased the likelihood of a primary den tree occurring by 22% (Crane et al., 2010). The average rate of den-swapping in temperate Australian woodlands has been found to be between every three (Crane et al., 2010) and five days (van der Ree, 2000).

Van der Ree (2000) and Crane et al. (2008) determined tree characteristics that make them preferable as den sites for Squirrel Gliders. Dens in both tall trees and trees with a larger diameter at breast height (1.3m; DBH) are preferred, as are trees with multiple hollows, particularly branch hollows. Squirrel Gliders show a strong preference for dead trees, or trees in decline, although this is likely correlated with the number of hollows and larger internal cavity spaces of the trees. Where a large number (>4) of external hollows are visible, then a preference for trees in good health is shown (Crane et al., 2008). Tree context has also been found to be an important factor in den site choice, with sites with a greater basal area, a high number of trees with a diameter >30 cm within a 20-m radius and shorter distance to nearest trees being preferred (Crane et al., 2008).

The presence of a suitable hollow is difficult to ascertain by simple on-ground tree measurements (Crane et al., 2008). As such, it is recommended that tree characteristics that indicate a higher likelihood of containing a suitable hollow be used. The number of visible hollows, the presence of dieback, and the tree being dead are such characteristics. While tree size does not necessarily indicate the presence of hollows, trees generally must be large to contain an internal cavity of suitable size for use by the squirrel glider. When a suitable hollow is present squirrel gliders prefer trees that are large and healthy, with neighbouring trees close by (Crane et al., 2008).

Foraging habitat

The diet of Squirrel Gliders consists of nectar, pollen, arthropods, honeydew and sap (Holland et al., 2007; Sharpe & Goldingay, 1998; Smith & Murray, 2003). Nectar and pollen are thought to be the primary and preferred food sources of Squirrel Gliders (Sharpe & Goldingay, 1998; Smith & Murray, 2003), although exudates are also identified as an important dietary component, particularly in winter when nectar and pollen may be less available (Holland et al., 2007). Forests and woodland with a canopy of winter-flowering eucalypts are recognised as being one of the preferred habitat types for Squirrel Gliders (Menkhorst et al., 1988; Smith & Murray, 2003), and where a canopy of winter-flowering eucalypts is absent, an understorey of gum-producing wattles that will provide a winter food source can also be important (Menkhorst et al., 1988; Smith & Murray, 2003). Pinnate leaved wattles (Smith & Murray, 2003) as well as *Acacia pycnantha* (Golden Wattle) (Holland et al., 2007) are known to be reliable and preferred gum sources for Squirrel Gliders. Vegetation types with an understorey of banksia (*Banksia* spp.) are also recognised as preferred foraging habitat as they provide a reliable and abundant nectar source during winter (Sharpe & Goldingay, 2015). As no banksias have been recorded within the study area (BL&A, 2009, 2015), this vegetation type is not considered further in this strategy.

Brearley *et al.* (2011a) note the importance of large trees as a foraging resource as they provide an abundance of nectar and pollen when in flower, and are also thought to provide superior protection from predators. Other foraging tree characteristics that Squirrel Gliders have a documented preference for include good canopy health (Crane et al., 2012) and traits including winter flowering, 'gum' type bark and those species in the sub-genus *Symphomyrtus*. The latter two traits are believed to support a greater abundance and diversity of invertebrate food sources for Squirrel Gliders (Menkhorst et al., 1988). Crane *et al.* (2012) found that Squirrel Gliders showed a preference for *Eucalyptus melliodora* (Yellow Box) when eucalypts were not flowering. Mixed stands of eucalypt species are also recognised as providing a more reliable nectar source across the year (Brearley et al., 2011a).

Four *Eucalyptus* species have previously been recorded in the area (BL&A, 2009), all in the sub-genus *Symphomyrtus*. Two of these species have existing literature documenting their specific utility as a food source for Squirrel Gliders. *Eucalyptus camaldulensis* (River Red-gum) has been documented as a source of nectar and sap (Smith & Murray, 2003), while *Eucalyptus melliodora* (Yellow Box) is known as a preferred foraging tree species when no flowering eucalypts are available. Both these species, as well as *Eucalyptus largiflorens* (Black Box) are summer flowering eucalypts, while *Eucalyptus microcarpa* (Grey Box) flowers in autumn-winter (Costermans, 2006). It is therefore likely that stands containing Grey Box will provide a more consistent source of nectar and pollen throughout the year, although this association has not been documented for Squirrel

Gliders. No *Eucalyptus melliodora* (Yellow Box) was recorded in the specific study area for the current field assessment, while *Eucalyptus camaldulensis* (River Red-gum), *Eucalyptus largiflorens* (Black Box) and *Eucalyptus microcarpa* (Grey Box) were all recorded in high numbers during the field survey. Flowers were also recorded underneath some Grey Box trees, indicating recent flowering, in line with documented flowering times in the literature (Costermans, 2006).

Habitat connectivity

Squirrel Gliders are strongly arboreal, and while they are capable of movement on the ground, it is actively avoided (Goldingay & Taylor, 2009). As such, they are restricted to areas of forest/woodland with sufficient tree cover to allow them to glide between trees (Rowston et al., 2002). Goldingay & Taylor (2009) found that Squirrel Gliders tend to launch from a horizontal position (canopy or outer branches 1-10 cm in diameter) just below (~2 m) the top of the launch tree, and an average of 2.3m away from the trunk of the launch tree. Squirrel Gliders generally land on the trunk of the landing tree. The average launch height documented by Goldingay & Taylor (2009) was 17.4 m, while the average landing height was 5.7 m. Mean glide lengths for Squirrel Gliders were 21.5 m, with longer glides strongly correlated with greater launch height. It is generally recognised that Squirrel Gliders' maximum glide range is 30-40 m (van der Ree, 2006; Goldingay & Taylor, 2009), although this is highly dependent on the availability of launch trees of sufficient height. Mean DBH of landing trees observed by Goldingay & Taylor (2009) was 37 cm, while mean glide angle was 29°, with glides angles <25° associated with longer glides.

Roads present a potential barrier to movement where the road forms a gap between trees that exceeds the maximum glide distance of Squirrel Gliders (Goldingay & Taylor, 2009; McCall et al., 2010; van der Ree et al., 2010; Soanes et al., 2013). Brearley *et al.* (2010) demonstrated the detrimental edge effects of urban landscapes on Squirrel Glider abundance, but attributed these effects to a reduction in flowering overstorey plants and hollow nest sites rather than edges *per se*. Brearley *et al.* (2011a) found a significant reduction in the number of visible nest hollows, floristic species diversity and abundance of large trees along road edges when compared with both forest fragment interiors and residential edge habitats. The extent to which Squirrel Gliders possess behavioural inhibitions to crossing roads due to factors such as traffic noise and light is not fully known (Goldingay & Taylor, 2009), however evidence suggests that on roads of modest width and volume this inhibition may not occur (van der Ree, 2006), and that on larger roads this inhibition will reduce but not prevent road crossings (Soanes et al., 2013). Inhibition surrounding the use of road crossings may arise from disturbance from headlight glare (Bax, 2006) and/or increased exposure to predators (Gleeson & Gleeson, 2012). Major, un-mitigated roads have been shown to impact survival rates of Squirrel Gliders by 60% when compared to populations near smaller roads, although this may reflect a combination of mortality and emigration from areas adjacent to major roads (McCall et al., 2010).

6.2. Habitat Linkage Tools

Three habitat linkage tools have been shown to be effective in maintaining habitat connectivity for Squirrel Gliders where major roads pass through habitat patches (Goldingay et al., 2013). Evidence suggests that maintenance of canopy cover with canopy gaps less than Squirrel Glider's average glide distance (~20 m) is effective in maintaining habitat connectivity (van der Ree et al., 2010). Where sufficient canopy cover cannot be maintained, wooden poles have been utilised on the Hume Freeway in Victoria (Soanes et al., 2013) and several major roads in Queensland (Taylor & Goldingay, 2012, 2013), while rope bridges have used on the Hume Freeway in Victoria (Soanes et al., 2013) and the Pacific Highway (Goldingay et al., 2013) and Karuah Bypass (Bax, 2006) in NSW. The implementation and success of these habitat linkage tools are discussed further below. Other habitat linkage tools, such as underpasses (including modified drains, culverts and dedicated wildlife underpasses) and land bridges are recognised as being ineffective in linking habitat for Squirrel Gliders due to the species' strongly arboreal habits (Taylor & Goldingay, 2012; Goldingay et al., 2013).

6.2.1. Maintenance of canopy cover

Evidence suggests that squirrel gliders are able to regularly cross road gaps if launch trees are maintained and gaps in tree cover do not exceed maximum gliding distance (van der Ree, 2006; Ball & Goldingay, 2008; Goldingay & Taylor, 2009; Brearley et al., 2011a). Furthermore, Soanes et al. (2013) demonstrated that Squirrel Gliders cross small road gaps (<10 m) more often than those with large gaps mitigated with wooden poles or rope bridges. Canopy cover can be maintained by retention of sufficiently large trees either side of the road, and also within the median strip where feasible. Whether canopy cover can be maintained needs to be determined at the detailed design phase of the project.

6.2.2. Glide Poles

Glide poles provide habitat linkage in areas where there is insufficient tree cover for gliders to move across a landscape. Those trialled for gliding mammals in Australia have been 30-50 cm in diameter, 5-15 m in height, and spaced approximately 10-25 m apart with cross-bars just below the top (Ball & Goldingay, 2008; Taylor & Goldingay, 2012, 2013; Soanes et al., 2013) to best mimic gliders' preferred launch and landing trees. Glide poles are generally constructed from treated wooden logs to withstand weathering, and on occasion have PVC pipe 'hides' attached to provide cover from predators.

Taylor and Goldingay (2012) recorded Squirrel Glider use of wooden poles located on land bridges across major roads in Queensland on an average of every four nights, and in 2013 recorded Squirrel Gliders crossing Scrub Road in Brisbane using glide poles an average of once every eight nights over a 125 night period (Taylor & Goldingay, 2013).

6.2.3. Rope Bridges

Rope bridges are a structure comprised of two wooden poles at either end (sometimes with cross-bars near the top to provide a launch platform for gliding mammals) with either a single rope strand, a rope ladder or a rope tunnel suspended between them. The rope tunnel design is intended to provide cover from predators during crossing. Rope bridges utilising both ladder and tunnel designs have been shown to be successful in providing habitat links for Squirrel Gliders in Australia (Bax, 2006; Goldingay et al., 2013; Soanes et al., 2013), although most crossings were undertaken along the top of rope tunnels where these were installed. Single rope strand crossings are considered unsuitable owing to stability, turbulence and loss of tautness (DTMR, 2010). Rope bridges with demonstrated success in linking Squirrel Glider habitat have all been 6 m or greater in height, 50-70 m in length and manufactured from marine grade rope (to maximise weather durability).

Bax (2006) recorded four confirmed Squirrel Glider crossings over a period of 244 days, while Goldingay et al. (2013) found that Squirrel Gliders utilised rope bridges to cross the Pacific Highway in New South Wales at least once every month (including the rope bridges previously investigated by Bax (Bax, 2006)). The use of both rope bridges and wooden poles for crossing the Hume Freeway in Victoria were examined by Soanes et al. (2013), and both these habitat linkage tools were found to quickly re-establish habitat connectivity of patches separated by the Freeway for 30 years, although the rate of crossing was lower than for the control sites at single-lane, low-volume country roads. Squirrel Gliders were recorded crossing roads using the rope bridges slightly more often than wooden poles, although the context of the habitat surrounding the crossing structure may have influenced the results. Furthermore, previously isolated populations from either side of the Hume Freeway have subsequently been shown to have genetic exchange, indicating the success of these crossing structures (Smith, 2015).

7. HABITAT ASSESSMENT METHODOLOGY

7.1. Assessment of habitat quality

Potential Squirrel Glider habitat was assessed across the study area during the field survey between 29th June and 2nd July. Vegetation in the study area was divided into assessment patches prior to the field survey (Figure 1). Patches were allotted based on aerial imagery, along visible changes in land-use or vegetation (or both). The size of each patch was based on the area of visibly uniform vegetation. It is, however, recognised that assessment patches do not necessarily represent habitat boundaries to Squirrel Gliders, and that, in actuality, Squirrel Gliders may preferentially use a variety of vegetation types for foraging, as den sites and movement through the forest. Where strong differences in habitat quality were perceived within an assessment patch during the field survey, it was divided into smaller sub-patches. Additional patches were also assessed beyond the study area where this was deemed necessary due to potentially important links with the vegetation in the study area. A total of 42 sub-patches were finally assessed, based on ground-truthing and these are shown in Figure 2.

Patch 1a (see Figure 2), to the north-west of the proposed bridge alignment is considered to represent known and preferred Squirrel Glider habitat within the study area as van der Ree (2015) trapped four of a total seven gliders within this patch during autumn surveys. Patch 1a, as known Squirrel Glider habitat (van der Ree et al., 2015), was assessed first, and the scoring method for the remaining vegetation adjusted on the basis of this.

Squirrel Glider habitat quality was assessed for each sub-patch by scoring the following components:

- Den habitat quality;
- Foraging habitat quality; and
- Habitat connectivity.

Scores (Good, Moderate or Poor) were attributed according to the qualitative descriptions in the table below (Table 1). This method reflects the findings of the literature review, presented in Section 6, relating to Squirrel Glider habitat preference. Numerical categories for den habitat quality were calculated based on observation of more than twenty hollow-bearing trees in assessment sub-patch 1a, an area of approximately 6.25 hectares. Category scores for Wattle covers were based on the range of covers observed in sub-patches adjacent to 1a on the first day of survey.

Numerical scores were then attributed to each category as follows, and indicated in Table 1:

- Good = 3
- Moderate = 2
- Poor = 1

Table 1: Squirrel Glider habitat quality scoring method

Habitat Quality Component	Good (3)	Moderate (2)	Poor (1)
Den habitat quality	High number (> 3/ha) of large and hollow-bearing trees.	Moderate number (1-3/ha) of large and hollow-bearing trees; OR High number of medium-sized hollow-bearing trees.	Few (<1/ha) hollow-bearing trees.
Foraging habitat quality	Winter-flowering eucalypt species dominant; OR High (>10%) cover of Golden Wattle or pinnate-leaved wattles.	Scattered winter-flowering eucalypts; OR Moderate (5-10%) cover of Golden Wattle or pinnate-leaved wattles; OR High number of large, old trees.	No winter-flowering eucalypts; OR Low (<5%) cover of Golden Wattle or pinnate-leaved wattles.
Habitat connectivity	Many trees <20 m from neighbouring trees; OR Continuous canopy >10 m tall.	Few trees within 20 m of neighbouring trees; OR Continuous canopy ≤10 m tall.	Most trees isolated with canopy gaps between trees exceeding 20 m; OR No canopy trees present.

The scores for all habitat components within each sub-patch were then summed to provide an overall Habitat Quality Score between 3 and 9. These were then categorised as Low Quality Habitat, Medium Quality Habitat and High Quality Habitat as shown in Table 2.

Table 2: Habitat Quality Categories

Habitat Quality Score	3	4	5	6	7	8	9
Habitat Quality Category	Low	Low	Medium	Medium	Medium	High	High

7.2. Identification of important habitat trees adjacent to the alignment

Where high quality habitat was identified adjacent to the proposed alignment, individual trees within 20 m of the proposed footprint that were considered to be important habitat for Squirrel Gliders were identified and mapped with a handheld GPS (accurate to approximately 10 m). The following data were collected for each tree:

- Species;

- Height (m);
- Diameter at Breast Height (1.3m; DBH) size class (cm);
- The den habitat quality of the tree based on its size and number of visible hollows, with trees with more than four visible hollows being considered to provide good den habitat, trees with 1-4 visible hollows being classed as providing moderate den habitat and trees with no visible hollows classed as providing poor den habitat;
- The foraging habitat quality of the tree based on the tree species, its size, evidence of insect attack and presence of Golden Wattle or pinnate-leaved wattles underneath the tree;
- The habitat connectivity based on the abundance of trees within 20 m; and
- A photograph of the tree.

Metres
0 125 250 500

Legend

- Study area
- Midwest Alignment
- Assessment sub-patches

Figure 2: Assessment sub-patches

Project: Murray River Crossing Echuca

Client: Roads and Maritime Services

Project No.: 8194	Date: 8/07/2015	Created By: M. Ghasemi / E. Ebsworth

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8. HABITAT ASSESSMENT RESULTS

Descriptions of the habitat mapped within each sub-patch are provided in Appendix 1. Broad patterns in habitat quality across the study area are described below.

8.1. Vegetation types within the study area

Vegetation within the study area included the following broad vegetation types:

- Riparian/floodplain River Red-gum forest/woodland, often with Silver Wattle in the understorey;
- Black Box forest/woodland with either a sparse understorey and groundlayer, or an understorey dominated by Pale-fruit Ballart with few or no wattles;
- Grey Box forest/woodland, often with Golden Wattle in the understorey; and
- Mixed forest/woodland comprised of two or all of the above canopy species.

8.2. Den Habitat

Many large and hollow-bearing trees, considered potential den trees, were identified and scored in the study area. Potential den trees were most common in areas of River Red-gum forest/woodland, with Black Box forest/woodland supporting the lowest number of potential den trees. As the study area falls within the floodplain of the Murray and Campaspe Rivers, very little variation in slope was recorded. As such, while it is recognised that den tree suitability increases with an increase in slope (Crane et al., 2010), slope did not form a component of the habitat quality assessment for this strategy. Hollows were observed both in stags and trees in poor health, as well as trees in good health. As such, the suitability of a tree as a potential den tree was assessed based on tree size and the abundance of visible hollows, rather than tree health.

Den habitat quality scores are presented for each sub-patch in Table 3 and mapped in Appendix 3.

8.3. Foraging Habitat

A variety of winter food sources were identified within the study area during the assessment, including:

- Winter-flowering Grey Box, which had just finished flowering at the time of the survey;
- Golden Wattle (*Acacia pycnantha*);
- The pinnate-leafed Silver Wattle (*Acacia dealbata*); and
- Planted winter-flowering trees, including Red Ironbark (*Eucalyptus sideroxylon*) and Spotted Gum (*Corymbia maculata*).

Evidence of glider feeding on Silver Wattle exudates was observed within sub-patch 10d, and is shown in Plate 1.

Plate 1: Evidence of glider feeding on a Silver Wattle branch in sub-patch 10d

Other food sources identified in the study area included:

- River Red-gum, which is an important source of nectar and sap (Smith & Murray, 2003); and
- Large trees, which provide large amounts of nectar and pollen when in flower, as well as superior protection from predators.

Foraging habitat quality scores are presented for each sub-patch in Table 3 and mapped in Appendix 4.

8.4. Habitat Connectivity

The study area had generally good habitat connectivity, with large (18-25 m tall) canopy trees along both the Murray and Campaspe Rivers, and in most sub-patches. Canopy gaps in most patches were considered to be small enough that Squirrel Gliders could cross them (~ 20 m). Areas of poorest connectivity included:

- Sub-patches 2b and 11a on the NSW side of the Murray River, that had been previously cleared and as a result had a sparse (gaps >20 m) or short (<10 m) canopy;
- The car park between sub-patches 4a and 4b on the Victorian side of the Murray River that supported no vegetation; and
- Sub-patches 7b and 8c (former school site) that supported no canopy trees.

Habitat connectivity scores are presented for each sub-patch in Table 3 and mapped in Appendix 5.

8.5. Habitat Quality

The scores for each habitat quality component have been summed to provide an overall habitat quality score. These are presented for each sub-patch in Table 3 and in Figure 3. Areas of high habitat quality are found in the riparian zones along the Murray and Campaspe Rivers, and in three large blocks of vegetation to the north-west of the proposed alignment in Victoria, around the north of the alignment, and in the south-east of the study area in New South Wales. Some 22 of a total 42 sub-patches assessed were considered to be high quality Squirrel Glider habitat, and ten of these were considered to provide good den, foraging and habitat connectivity (giving them a maximum habitat quality score of 9). Areas of high quality squirrel glider habitat represent large, contiguous areas of native vegetation with an abundance of large and hollow-bearing trees, a variety of winter food sources and good habitat connectivity within and between sub-patches.

8.6. Important Habitat trees within 20 m of the proposed alignment

Thirty-three important habitat trees within areas of high quality habitat and within 20 m of the proposed alignment have been mapped, although these by no means provide an exhaustive list of trees in this category. Details of each tree are provided in Appendix 2. The majority (67%) were River Red-gums, while 18% were Grey Box while Black Box and stags each comprised 6% and 9% respectively of the recorded trees.

Table 3: Habitat Quality Results

Sub-patch	Den habitat quality	Foraging habitat quality	Habitat connectivity	Score	Habitat Quality
1a	Good (3)	Moderate (2)	Good (3)	8	High
1b	Moderate (2)	Moderate (2)	Good (3)	7	Medium
2a	Poor (1)	Poor (1)	Poor (1)	3	Low
2b	Poor (1)	Poor (1)	Poor (1)	3	Low
3	Good (3)	Good (3)	Good (3)	9	High
4a	Moderate (2)	Moderate (2)	Moderate (2)	6	Medium
4b	Good (3)	Good (3)	Good (3)	9	High
4c	Moderate (2)	Moderate (2)	Moderate (2)	6	Medium
4d	Good (3)	Good (3)	Good (3)	9	High
4e	Good (3)	Moderate (2)	Good (3)	8	High
4f	Good (3)	Good (3)	Good (3)	9	High
4g	Poor (1)	Poor (1)	Moderate (2)	4	Low
5a	Good (3)	Moderate (2)	Good (3)	8	High
5b	Good (3)	Moderate (2)	Good (3)	8	High
5c	Good (3)	Good (3)	Good (3)	9	High
7a	Good (3)	Good (3)	Good (3)	9	High
7b	Poor (1)	Poor (1)	Poor (1)	3	Low
7c	Moderate (2)	Moderate (2)	Good (3)	7	Medium
8a	Moderate (2)	Poor (1)	Good (3)	6	Medium
8b	Poor (1)	Good (3)	Moderate (2)	6	Medium
8c	Poor (1)	Moderate (2)	Poor (1)	4	Low
9a	Good (3)	Good (3)	Good (3)	9	High
9b	Moderate (2)	Poor (1)	Moderate (2)	5	Medium
9c	Good (3)	Good (3)	Moderate (2)	8	High
9d	Poor (1)	Good (3)	Poor (1)	5	Medium
9e	Moderate (2)	Good (3)	Good (3)	8	High
10a	Moderate (2)	Good (3)	Good (3)	8	High
10b	Poor (1)	Poor (1)	Good (3)	5	Medium
10c	Good (3)	Good (3)	Good (3)	9	High
10d	Good (3)	Good (3)	Good (3)	9	High
10e	Moderate (2)	Moderate (2)	Good (3)	7	Medium
11a	Poor (1)	Moderate (2)	Poor (1)	4	Low
11b	Good (3)	Moderate (2)	Good (3)	8	High
12a	Good (3)	Moderate (2)	Good (3)	8	High
12b	Moderate (2)	Moderate (2)	Moderate (2)	6	Medium
12c	Moderate (2)	Poor (1)	Good (3)	6	Medium
13a	Good (3)	Moderate (2)	Good (3)	8	High
13b	Good (3)	Good (3)	Moderate (2)	8	High
14a	Good (3)	Moderate (2)	Good (3)	8	High
14b	Moderate (2)	Poor (1)	Moderate (2)	5	Medium
14c	Good (3)	Good (3)	Good (3)	9	High
15	Moderate (2)	Moderate (2)	Good (3)	7	Medium

Legend

Study area
Midwest Alignment

Habitat Quality

High
Medium
Low

Squirrel Glider records

van der Ree (2015)
BL&A

Metres
0 200 400 800

Figure 3: Habitat quality		
Project: Murray River Crossing Echuca		
Client: Roads and Maritime Services		
Project No.: 8194	Date: 22/07/2015	Created By: M. Ghasemi / A. Brennan

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9. HABITAT LINKAGE RECOMMENDATIONS

Evidence suggests that the most effective habitat linkage tool for Squirrel Gliders is the maintenance of canopy with gaps <15-20 m (van der Ree et al., 2010; Soanes et al., 2013). As such, the preferred method of maintenance of habitat connectivity is retention of large trees and canopy cover adjacent to the road, particularly in areas that provide links to high-quality habitat. Where this is not possible, rope bridges may be utilised as crossing structures by Squirrel Gliders slightly more often than wooden poles (Soanes et al., 2013), and also eliminate the possibility of glider collision with vehicles if poles are too short or spaced too widely (van der Ree et al., 2015). As such, the use of rope bridges as habitat linkage tools is recommended over wooden poles in cases where sufficient canopy cover cannot be maintained, a view supported by van der Ree et al. (2015). The design and exact placement of rope bridges is discussed below, but should be developed and approved by an expert in Squirrel Glider ecology for maximum effectiveness, as per van der Ree et al. (2015).

It is recognised that in a management context, habitat links need to be appropriate to the average glide distance (representative of the population) as opposed to the maximum glide distance of some individuals (Goldingay & Taylor, 2009). As such, it is recommended that habitat links are formed with consideration of the average glide distance of ~20 m for Squirrel Gliders, although this may be less than their glide capability.

9.1. Maintenance of canopy cover

Whether canopy cover can be maintained will need to be determined at the detailed design phase, and take into consideration lopping and/or impacts to the root zone of trees adjacent to the road. Canopy connectivity may be maintained over the initial, single carriage-way alignment, however it is likely that ultimate duplication of the alignment will present a barrier to movement of Squirrel Gliders across the road (van der Ree et al., 2015). It is therefore recommended that rope bridges be instated at the initial alignment construction phase with consideration for the ultimate duplication design, as past assessment of the success of road-crossing mitigation measures has indicated a period of habitation to use of structures by Squirrel Gliders is required (Soanes et al., 2013).

Where possible, maintenance or planting of eucalypts should be considered adjacent to the single-carriageway road where ultimately the median strip will be located in the final duplicated road design. This will maximise gliding opportunities across the ultimately duplicated road. The timeframe for road duplication may permit planted trees to grow to a height suitable for use by gliding Squirrel Gliders before duplication is required, minimising the risk that road duplication will reduce habitat connectivity through a lack of canopy cover.

9.2. Crossing zones

Van der Ree et al. (2015) have recommended the provision of 'crossing zones' along the alignment with several rope bridges along an area at least 100 m long, with a crossing zone provided every 500m. For the 2.5 km section of the alignment that passes through Squirrel Glider habitat, this would equate to the provision of five crossing zones. An additional crossing zone has been provided across the Murray River to link high quality habitat in Victoria and NSW. The recommended placement of crossing zones is shown in Figure 4. Crossing zones have been placed based with consideration to the following:

- Connection of areas of high quality habitat;
- Connection of areas that address different habitat requirements (eg. connection of good den habitat with good foraging habitat);
- Connection of areas that provide different winter food sources (eg. connection of habitat that supports a high cover of Silver Wattles with that dominated by Grey Box); and
- Connection of large patches of habitat with good connectivity to adjacent patches.

Figure 4 also shows important habitat trees within/adjacent to proposed crossing zones. These are numbered and details of each tree provided in Appendix 2. It is recommended that rope bridges be placed within gliding distance of these trees and/or with feeder ropes connecting the pole of the rope bridge to these trees. Trees adjacent to the middle crossing zone shown in Figure 4 were not mapped during the field assessment, and will need to be identified during rope bridge design in consultation with an expert on Squirrel Gliders.

A rationale for each of the crossings is provided briefly below.

- **Crossing A** links known Squirrel Glider habitat in sub-patch 1a (to the west of the alignment) with high quality habitat in sub-patch 14c that provides good den, winter foraging and connectivity habitat. This is considered of especial importance as no winter forage sources were recorded in sub-patch 1a, and thus Squirrel Gliders are likely leaving this area (either on a nightly basis, or seasonally) to access foraging habitat during winter.
- **Crossing B** links high-quality Squirrel Glider habitat in sub-patches 3 and 10a that provide good den, winter foraging and connectivity habitat. Further links are provided to patches 4a and 9b on the Victorian side of the Murray River through the provision of an under-road rope bridge. This is considered of important as contiguous vegetation (much of it high habitat quality) is found in the riparian zone along the Murray River both in New South Wales and Victoria, which has previously been identified as an important wildlife corridor (BL&A, 20015).
- **Crossing C** links high-quality Squirrel Glider habitat in sub-patches 4f and 9c that provide good den and winter foraging habitat. Sub-patch 4f also has good habitat connectivity, and is contiguous with a large, high habitat quality patch in Victoria Park. Crossing C also links a variety of winter foraging habitat that provides winter carbohydrates at different times during winter.
- **Crossing D** links sub-patches 5a and 5b (on the western side of the alignment) with 9e. 5a and 5b provide good den habitat and have good connectivity, while 9e provides good foraging habitat and habitat connectivity. As such, this crossing links areas that address different Squirrel Glider habitat requirements.
- **Crossing E** links sub-patches 8a and 15. While these sub-patches only provide moderate quality habitat, this crossing is considered important to maintain connectivity with the riparian vegetation along the Campaspe River, which is known to support populations of Squirrel Gliders (Kent & Hodgens, 2010).
- **Crossing F** across the Murray River links high quality habitat in Victoria to high quality habitat in NSW. This will greatly increase the area of habitat available to Squirrel Glider within the study area.

9.2.1. *Design*

Goldingay et al. (2013) recognise that the installation of rope bridges as habitat linkage tools for arboreal mammals across roads has outpaced the evaluation of the most suitable design, however the following should be taken into consideration:

- Ladder-style rope bridges appear to be preferred by Squirrel Gliders over tunnel-style bridges, with animals in New South Wales climbing along the top of tunnel-style bridges where they were installed (Bax, 2006; Goldingay et al., 2013). As such, the use of ladder-style rope bridges is recommended for this project. The intention of tunnel-style crossings in previous road crossings was to provide arboreal mammals with protection from predators (Bax, 2006; Goldingay et al., 2013). Alternative measures (such as a cover suspended some distance above the rope bridge along the length of the crossing or periodic refuge tunnels in the form of 10cm diameter PVC pipe spaced frequently along the rope ladder) should be considered to provide protection from predators;
- A cross-bar just below (~ 2 m) the top of the pole to which rope bridges are attached will allow gliders to glide to nearby trees after crossing the bridge;
- Several ropes should also be installed between the poles at either end of the rope bridge and nearby trees, particularly those identified as important habitat trees in Figure 4;
- Maintenance of crossing structures is essential for their effectiveness in linking habitat (DTMR, 2010; Gleeson & Gleeson, 2012). Use of durable materials, such as marine grade silver (high UV rating) rope attached to steel cables (to maintain tension) and treated wooden poles will minimised the maintenance required;
- Headlight glare and road noise may deter Squirrel Gliders from utilising crossings. One previous rope bridge crossing, at the Karuah Bypass in New South Wales, utilised a cloth wrap on a tunnel-style crossing to reduce the glare and noise experienced by animals using the crossing, however the effectiveness of this measure was not documented (Bax, 2006; DTMR, 2010). Increased height of crossings would distance animals from road lighting and traffic noise. Additional measures, such as the installation of a headlight glare barrier strung below the rope bridge should be considered;
- Rope bridges are more effective when installed above rather than below the carriageway (van der Ree et al., 2015), and the current road design is unlikely to provide sufficient clearance to install rope bridges underneath, as rope bridges need to be 4 to6 m above the ground or > 2 m below the carriageway (van der Ree et al., 2015). A previous study of rope bridges recorded no crossings by Squirrel Gliders of rope bridges suspended below the carriageway (Goldingay et al., 2013). As such, it is not recommended that a rope bridge be installed underneath the road to link high-quality habitat on either side of the Murray River. Rather, a rope bridge is recommended to be located downstream of the proposed second crossing of the Murray River at Echuca-Moama. The height of the rope bridge above the river will need to allow for boat passage.

9.2.2. *Monitoring*

While shown to be effective in linking habitat elsewhere, it is important that the success (or otherwise) of any measures implemented for Proposal are monitored (Goldingay et al., 2013; Rytwinski et al., 2015). Rytwinski et al. (2015) discuss pertinent considerations for the evaluation of habitat linkage tools in relation to the mitigation of the impacts of roads on wildlife. This strategy, in concert with the surveys undertaken by van der Ree et al. (2015), address the initial questions in this process by determining the appropriate type, placement and number of habitat linkage tools based on previous literature and the Squirrel Glider habitat documented on-site. Post-implementation monitoring at a population-wide scale will subsequently be required to determine the efficacy of the installation of habitat linkage tools (Rytwinski et al., 2015; van der Ree et al., 2015).

9.3. Additional habitat linkage works

To minimise the risk of impacts to the local Squirrel Glider population, the following habitat linkage works (in addition to the provision of crossing zones, described above) should be undertaken:

- Detailed design of the alignment should aim to avoid high-quality Squirrel Glider habitat, particularly large and hollow-bearing trees. Lay-down areas for construction should be located outside areas of native vegetation;
- Nest boxes should be provided to compensate for removal of large and hollow-bearing trees. These should be placed in areas where few current suitable den trees exist (van der Ree et al., 2015), but where other habitat components (connectivity and foraging) are of good quality. These can be identified through Table 3 and the mapping provided in Appendices 3 to 5;
- Revegetation, weed control and closure of tracks (where feasible) should be undertaken in the vicinity of the alignment as per van der Ree et al. (2015), including planting preferred forage species for Squirrel Gliders. Revegetation should aim to connect areas of high quality habitat, and provide connectivity to the known Squirrel Glider habitat along the Murray and Campaspe Rivers in the broader region;
- As a short-term measure consideration should be given to linking areas of high quality habitat in the vicinity of the alignment by the provision of glide poles in the car park between sub-patches 4a and 4c, and in sub-patch 8c between areas of high quality vegetation in sub-patch 8a (see Figure 2). It is recommended that at least 3 glide poles are installed in each of these locations to compensate for canopy gaps of 50 and 75 m respectively.

Legend

- Study area
- Midwest Alignment
- Important habitat trees
- Recommended crossing zone

Habitat Quality

- High
- Medium
- Low

Metres: 0, 200, 400, 800

Figure 4: Habitat connectivity recommendations

Project: Murray River Crossing Echuca

Client: Roads and Maritime Services

Project No.: 8194	Date: 28/07/2015	Created By: M. Ghasemi / A. Brennan

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10. SIGNIFICANCE ASSESSMENT UNDER THE EP&A ACT

A significance assessment for potential impacts on Squirrel Gliders has been undertaken in light of the recommended mitigation measures contained herein, in accordance with Part 1, Section 5A (2) of the EP&A Act. This assessment is documented below. The assessment has found that, with the implementation of the habitat linkage recommendations contained within this strategy and van der Ree et al. (2015), there is unlikely to be a significant impact on Squirrel Gliders. As such, a Species Impact Statement is not required.

Status in the study area

Squirrel Gliders have previously been observed within the study area both during spotlighting (BL&A, 2015) and trapping (van der Ree et al., 2015). It is considered that the study area supports a small, low-density but healthy population of the species (van der Ree et al., 2015).

Potential impacts

The proposal may result in the following potential impacts on Squirrel Glider:

- Clearance of habitat, including hollow-bearing trees;
- Degradation of habitat due to edge effects, particularly weed invasion;
- Increased predation;
- Noise, vibration and light; and
- Mortality and injury due to collision with vehicles.

Impact significance

Significance Assessment Questions, as set out in the *Threatened Species Conservation Act 1995/ Environmental Planning and Assessment Act 1979,* are included below, along with responses for Squirrel Gliders in relation to the proposal.

a) *in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction,*

   It is considered that the study area supports a small, low-density but healthy Squirrel Glider population. The proposed alignment passes through areas of high quality Squirrel Glider habitat both in Victoria and NSW, as well as areas of sub-optimal habitat (Figure 3). Areas of high quality habitat extend for several hundred meters either side of the proposed alignment in the northern section of the study area, and several hundred meters to the west in Victoria (Figure 3), and are contiguous with riparian vegetation and known Squirrel Glider habitat along the Campaspe (Kent & Hodgens, 2010) and Murray (Korodaj et al., 2014) Rivers. It has been assumed that Squirrel Glider are likely to occupy all suitable habitat within several kilometers of the project along the wildlife corridor linking the Barmah and Gunbower forest blocks (of which the study area is a part), and that those forest blocks would provide core habitat for the species in the region.

   Critical to the reproductive success of Squirrel Glider populations are the presence of large trees with abundant hollows for denning and nesting, and a reliable year-round food supply of nectar, pollen and plant exudates (sap).

Predation and mortality also has a considerable influence on reproductive success.

The construction phase of the proposal may have an adverse effect on the reproductive success of the local Squirrel Glider population through the removal of hollow-bearing trees and food resources, as well as noise and vibration. The loss of hollow-bearing trees will be compensated with the provision of nest boxes. The operational phase is considered unlikely to compromise reproductive success as the provision of crossing zones will avoid road mortality and injury, and maintain connectivity between sub-populations.

It is recognised that the already small Squirrel Glider population is at particular risk of extinction (van der Ree et al., 2015), but that Squirrel Gliders are known to use multiple dens (van der Ree, 2000; Crane et al., 2010). The study area provides large areas of good quality den and foraging habitat (see Appendix 3) and habitat links to known Squirrel Glider populations along the Campaspe and Murray Rivers. Squirrel Gliders are thought to have a maximum lifespan of at least five years (van der Ree, 2002) and construction represents a small proportion of the species' life span. It is therefore considered that while the proposal may have some short-term impacts on Squirrel Glider reproductive success, this is unlikely to place the local population at risk of extinction.

b) *in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction,*

Not applicable

c) *in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:*

(i) *is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or*

Not applicable

(ii) *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,*

Not applicable

d) *in relation to the habitat of a threatened species, population or ecological community:*

(i) *the extent to which habitat is likely to be removed or modified as a result of the action proposed, and*

Approximately 5.080 hectares of Squirrel Glider habitat is proposed to be directly removed under the proposal ((BL&A, 2015). When considering the modifying effects on habitat resulting from edge effects, a greater area of habitat would likely be degraded. Based on the current investigation, the nearby study area supports a total of 114.285 hectares of high quality and 48.374 hectares of medium quality habitat for the species. The habitat removed by the road represents three percent of this habitat, a proportion that is unlikely to endanger the status of the species in the area.

(ii) *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and*

The proposal has the potential to fragment Squirrel Glider habitat, as the carriageway would dissect it and result in an area of habitat being structurally isolated from adjacent habitat. This habitat linkage strategy seeks to address this fragmentation by providing several crossing zones along the alignment, based on proven mitigation measures for Squirrel Gliders. Such measures have been shown to re-establish but not fully restore movement across roads (Soanes et al., 2013). As such, habitat is likely to be somewhat separated but not completely isolated.

(iii) *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality,*

The proposed carriageway will be situated in one of the wider sections of a wildlife corridor that extends between the Barmah and Gunbower forest blocks, and will impact high, medium and low quality Squirrel Glider habitat within the study area. Of particular concern is the large number of hollow-bearing trees that will be affected by the proposed alignment (BL&A, 2015). The high quality habitat proposed for removal within the footprint is almost certainly currently be used by Squirrel Gliders, particularly as dens in hollow-bearing trees, however given the availability of other areas of high quality habitat, the proposed measures to maintain a degree of connectivity between these, and the links provided to other known Squirrel Glider populations along the Murray and Campaspe Rivers, it is considered unlikely that habitat removal will affect the long-term survival of the species in the locality.

e) *whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly),*

Not applicable

f) *whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan,*

A Squirrel Glider recovery or threat abatement plan has not been prepared.

g) *whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.*

The proposed action would, or potentially would, initiate or contribute to a number of key threatening processes (KTPs) which may have an adverse effect on Squirrel Gliders. However, it is unlikely that such KTP's would have a significant impact on the species in the locality as a consequence of the proportion of habitat affected and the provision of habitat connectivity measures to mitigate potential habitat isolation caused by the project.

Conclusion

The proposal meets, to some degree, three relevant significant impact criteria in relation to Squirrel Glider. While there would be a negative impact under each of these three criteria, overall impacts on the Squirrel Glider resulting from the proposal are considered to have been adequately mitigated through implementation of the measures described in this plan and in van der Ree (2015). As such, the impacts of the proposal would not be significant and a *species impact statement* would not be required for Squirrel Glider.

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Appendix 1: Sub-patch descriptions and photographs

Sub-patch	Description	Photograph
1a	Known Squirrel Glider habitat. Dominated by River Red-gum to 20 m. Canopy gaps approximately 10 m. In excess of 20 potential den trees, and in excess of 15 large old trees. No flowering eucalypts observed. No wattles recorded.	
1b	Dominated by River Red-gum to 18 m. Continuous canopy. Scattered large old trees with a moderate number of hollows. Scattered Silver Wattle to 3.5 m tall (5% cover).	
2a	Dominated by dense regenerating River Red-gum to 6 m. No large or hollow-bearing trees No wattles recorded.	

Sub-patch	Description	Photograph
2b	Very sparse small River Red-gums and Black Boxes to 10 m with canopy gaps exceeding 40 m. No hollows observed.	
3	Dense riparian River Red-gum forest to 20 m. Canopy continuous or with gaps to 5 m. Silver Wattle to 10 m (15% cover). Many large trees. Many hollow-bearing trees.	
4a	River Red-gum and scattered Grey Box canopy to 20 m with canopy gaps exceeding 20 m in some areas. Introduced grassy ground-layer. No wattles in understorey. Moderate number of hollow-bearing trees.	

Sub-patch	Description	Photograph
4b	Grey Box with scattered River Red-gum canopy to 15 m with canopy gaps 5-10 m . Golden Wattle to 4 m (20% cover) in understorey. Good number of large and hollow-bearing trees.	
4c	Narrow strip of River Red-gum to 20 m bounded by the Murray River and an access track. Moderate connectivity. Golden Wattle to 2 m (5% cover) in understorey. Moderate number of large and hollow-bearing trees.	
4d	Continuous River Red-gum canopy to 20 m. Silver Wattle to 8 m (15% cover) in understorey. Good number of large and hollow-bearing trees.	

Sub-patch	Description	Photograph
4e	Continuous Black Box canopy to 15 m. No wattles in understorey. Good number of large and hollow-bearing trees.	
4f	Mixed River Red-gum / Grey Box canopy to 18 m. Canopy gaps approximately 10-20 m. Many large and hollow-bearing trees present. Silver Wattle to 6 m (10% cover).	
5a	Black Box and scattered Grey Box canopy to 18 m with canopy gaps of approximately 5-10 m. No wattles in understorey. Many hollow-bearing trees.	

Sub-patch	Description	Photograph
5b	River Red-gum and scattered Black Box canopy to 18 m with canopy gaps of approximately 15-20 m. Silver Wattle in understorey to 3 m (5% cover). Many large and hollow-bearing trees.	
5c	Grey Box with scattered Black Box and River red-gum canopy to 18 m with canopy gaps of approximately 10-15 m. Silver Wattle and Golden Wattle in understorey to 5 m (20% cover). Many large and hollow-bearing trees.	
7a	Mixed River Red-gum / Black Box canopy to 20 m. Canopy gaps approximately 10 m. Many large and hollow-bearing trees present. Silver Wattle to 4 m (15% cover).	

Sub-patch	Description	Photograph
7b	Open grass area. No potential den, foraging or connectivity habitat.	
7c	Black Box canopy to 16 m with canopy gaps of approximately 5 m. No wattles in understorey. Moderate number of hollow-bearing trees.	
8a	Continuous River Red-gum canopy to 20 m with scattered Black Box. Moderate number of large and hollow-bearing trees. No wattles in understorey.	

Sub-patch	Description	Photograph
8b	Canopy of Murray Pines over Golden Wattle (15%) with Cacti and Peppercorn trees. No hollow-bearing trees. Canopy gaps 20-30 m.	
9a	Mixed River Red-gum / Black Box canopy to 20 m. Canopy gaps approximately 10 m. Many large and hollow-bearing trees present. Silver Wattle to 6 m (5% cover).	
9b	Large trees over paved / introduced grass ground layer. River Red-gum / Black Box canopy to 20 m. Canopy gaps in excess of 20 m in some places. Moderate number of tree hollows.	

Sub-patch	Description	Photograph
9c	Grey Box woodland to 15 m with canopy gaps exceeding 20 m in some areas. Ground layer of gravel / introduced grass with scattered Gold-dust Wattle and Golden Wattle to 2 m (<1% cover). Many large and hollow-bearing trees.	
9d	Caravan Park with a mix of scattered planted eucalypts (native and introduced) to 20 m. Species include Black Box, River Red-gum and Grey Box, as well as Spotted Gum, Red Stringybark, Lemon-scented Gum and Red Ironbark. Spotted Gum and Red Ironbark in flower at time of survey. Canopy gaps in excess of 30 m.	
9e	Continuous Grey Box canopy to 20 m with Golden Wattle to 3 m (10% cover). Moderate number of large and hollow-bearing trees.	

Sub-patch	Description	Photograph
10a	River Red-gum canopy to 18 m. Moderate number of potential den trees. Narrow riparian band with continuous canopy. Silver Wattle to 5 m (10% cover).	
10b	River Red-gum canopy to 10 m. No potential den trees recorded. No wattles.	
10c	Continuous River Red-gum canopy to 18 m. Moderate number of potential den trees. Silver Wattle to 5 m (5% cover).	

Sub-patch	Description	Photograph
10d	Continuous River Red-gum canopy to 25 m. High number of large and hollow-bearing trees. Silver Wattle to 5 m (15% cover). Evidence of gliders feeding on exudates from Silver Wattle branches.	
10e	Not accessible due to private property. Riparian River Red-gum forest along the Murray River. Habitat suitability has been determined based on an average of this habitat type assessed in other areas.	No photograph
11a	Black Box woodland with scattered River Red-gum, all to 8 m tall. Previously cleared. No large or hollow-bearing trees observed. Understorey dominated by Pale-fruit Ballart with 1% cover of Golden Wattle and Silver Wattle.	

Sub-patch	Description	Photograph
11b	River Red-gum canopy to 18 m. Canopy gaps approximately 5 m. High number of potential den trees. Silver Wattle to 6 m (5% cover).	
12a	River Red-gum and scattered Black Box canopy to 18 m with canopy gaps of approximately 10-15 m. Silver Wattle in understorey to 5 m (5% cover). Many large and hollow-bearing trees.	
12b	Regenerating River Red-gum with scattered Black Box to 10 m with very sparse large and hollow-bearing trees. Continuous (but low) canopy. Scattered Silver Wattle in understorey (<5% cover).	

Sub-patch	Description	Photograph
12c	Continuous canopy of River Red-gum and Black Box to 15 m . Moderate number of large and hollow-bearing trees. No wattles in understorey.	
13a	Mixed continuous canopy of River Red-gum and Black Box to 18 m. Many large and hollow-bearing trees. No wattles in understorey.	
13b	River Red-gum and scattered Black Box and Grey Box canopy to 20 m with canopy gaps of approximately 10-30 m. Silver Wattle in understorey to 6 m (10% cover). Many large and hollow-bearing trees.	

Sub-patch	Description	Photograph
14a	River Red-gum canopy to 15 m. Stags and large trees with many hollows present. Silver Wattle to 6 m (10% cover).	
14b	Paved / grassy ground layer with River Red-gum and Black Box to 20 m. Moderate number of large and hollow-bearing trees. Canopy gaps 10 - 30 m.	
14c	Mixed continuous canopy of River Red-gum and Black Box to 18 m . Many large and hollow-bearing trees. Silver Wattle to 6 m (10% cover) in understorey. Red Ironbark planted along Boundary Road was in flower during time of survey.	

Sub-patch	Description	Photograph
15	Riparian vegetation along the Campaspe River. Canopy of River Red-Gum to 25 m. Moderate number of large and hollow-bearing trees. Silver Wattle to 8 m (5%) in an understorey dominated by woody weeds. Canopy gaps across the Campaspe River less than 20 m.	

Appendix 2: Important habitat trees

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
1	3	Stag	15	>100	Good	Poor	Good	
2	3	River Red-gum	18	80-100	Poor	Good	Good	
3	3	River Red-gum	15	40-60	Moderate	Good	Good	
4	3	River Red-gum	20	>100	Moderate	Good	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
5	10a	River Red-gum	18	60-80	Poor	Poor	Good	
6	10a	River Red-gum	15	>100	Good	Poor	Good	
7	10a	River Red-gum	15	>100	Good	Moderate	Good	
8	11b	River Red-gum	18	80-100	Good	Moderate	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
9	14a	River Red-gum	20	80-100	Good	Poor	Good	
10	1a	River Red-gum	18	>100	Good	Poor	Good	
11	1a	River Red-gum	15	80-100	Good	Poor	Good	
12	1a	River Red-gum	15	60-80	Good	Poor	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
13	9b	River Red-gum	18	60-80	Poor	Poor	Good	
14	9b	River Red-gum	20	80-100	Good	Moderate	Good	
15	9b	River Red-gum	18	80-100	Good	Moderate	Good	
16	9e	Grey Box	18	60-80	Good	Good	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
17	9e	Grey Box	18	60-80	Good	Good	Good	
18	9e	Stag	18	80-100	Good	Poor	Good	
19	15	River Red-gum	25	80-100	Good	Good	Good	
20	15	River Red-gum	20	>100	Good	Moderate	Good	

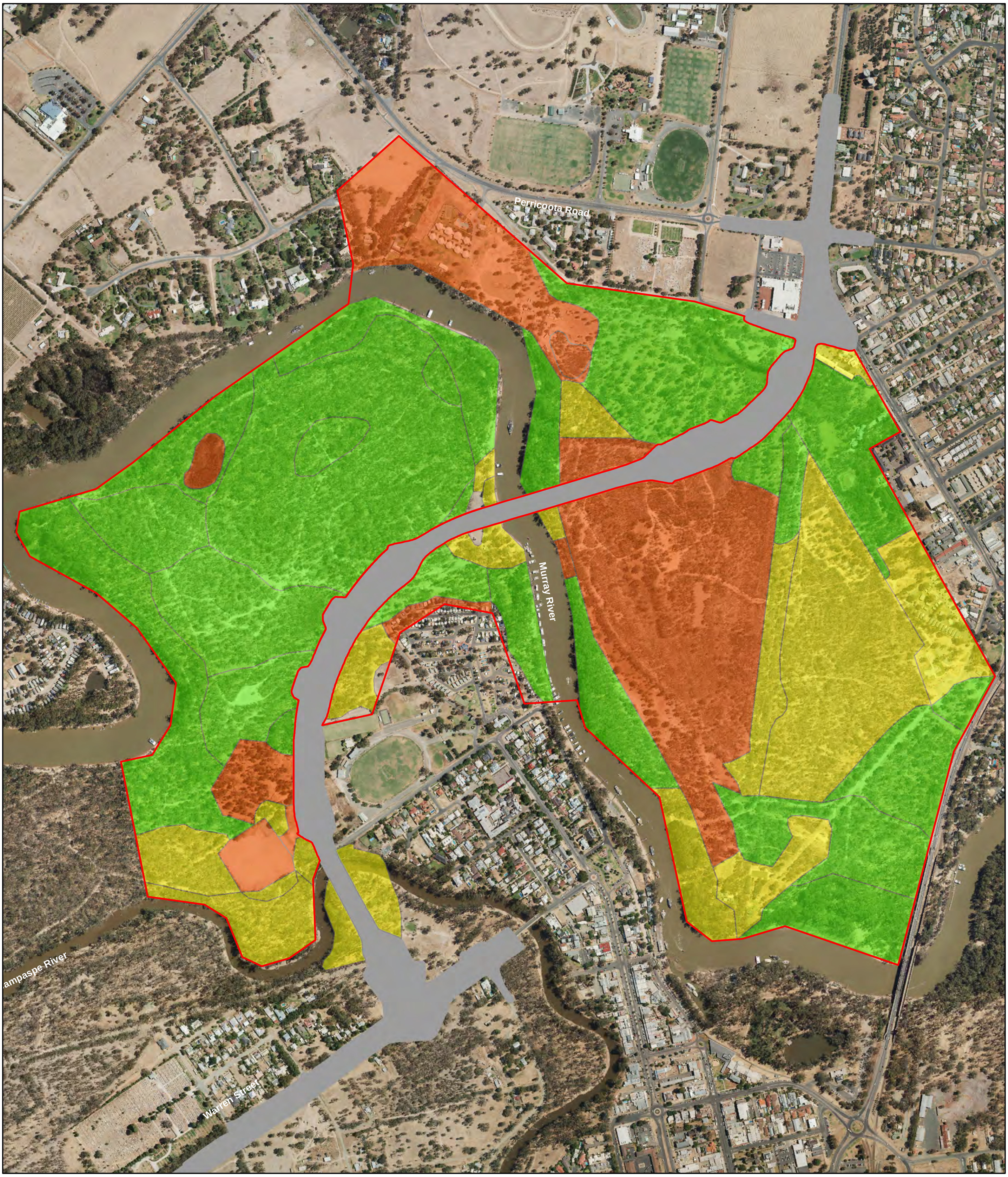
Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
21	8a	River Red-gum	20	80-100	Good	Moderate	Good	
22	8a	River Red-gum	20	80-100	Good	Moderate	Good	
23	5a	Black Box	18	40-60	Good	Moderate	Good	
24	5a	Grey Box	18	60-80	Good	Good	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
25	5b	River Red-gum	20	60-80	Good	Moderate	Good	
26	8a	River Red-gum	25	80-100	Good	Moderate	Good	
27	15	Stag	20	80-100	Good	Poor	Good	
28	15	Black Box	25	60-80	Poor	Moderate	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
29	8a	River Red-gum	25	60-80	Good	Moderate	Good	
30	4a	River Red-gum	20	40-60	Moderate	Poor	Good	
31	4a	Grey Box	18	80-100	Moderate	Good	Good	
32	4b	Grey Box	18	40-60	Moderate	Good	Good	

Tree #	Sub-patch	Species	Height (m)	DBH (cm) class	Den quality	Foraging quality	Habitat connectivity	Photograph
33	4b	Grey Box	15	60-80	Good	Good	Good	

Appendix 3: Den habitat quality mapping



0 125 250 500 Metres

Legend

Study area

Midwest Alignment

Den habitat quality

Good

Moderate

Poor

Appendix 3: Den habitat quality

Project: Murray River Crossing Echuca

Client: Roads and Maritime Services

Project No.: 8194	Date: 8/07/2015	Created By: M. Ghasemi / E. Ebsworth

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Solutions — PO Box 337, Camberwell, VIC 3124, Australia — www.ecologicalresearch.com.au

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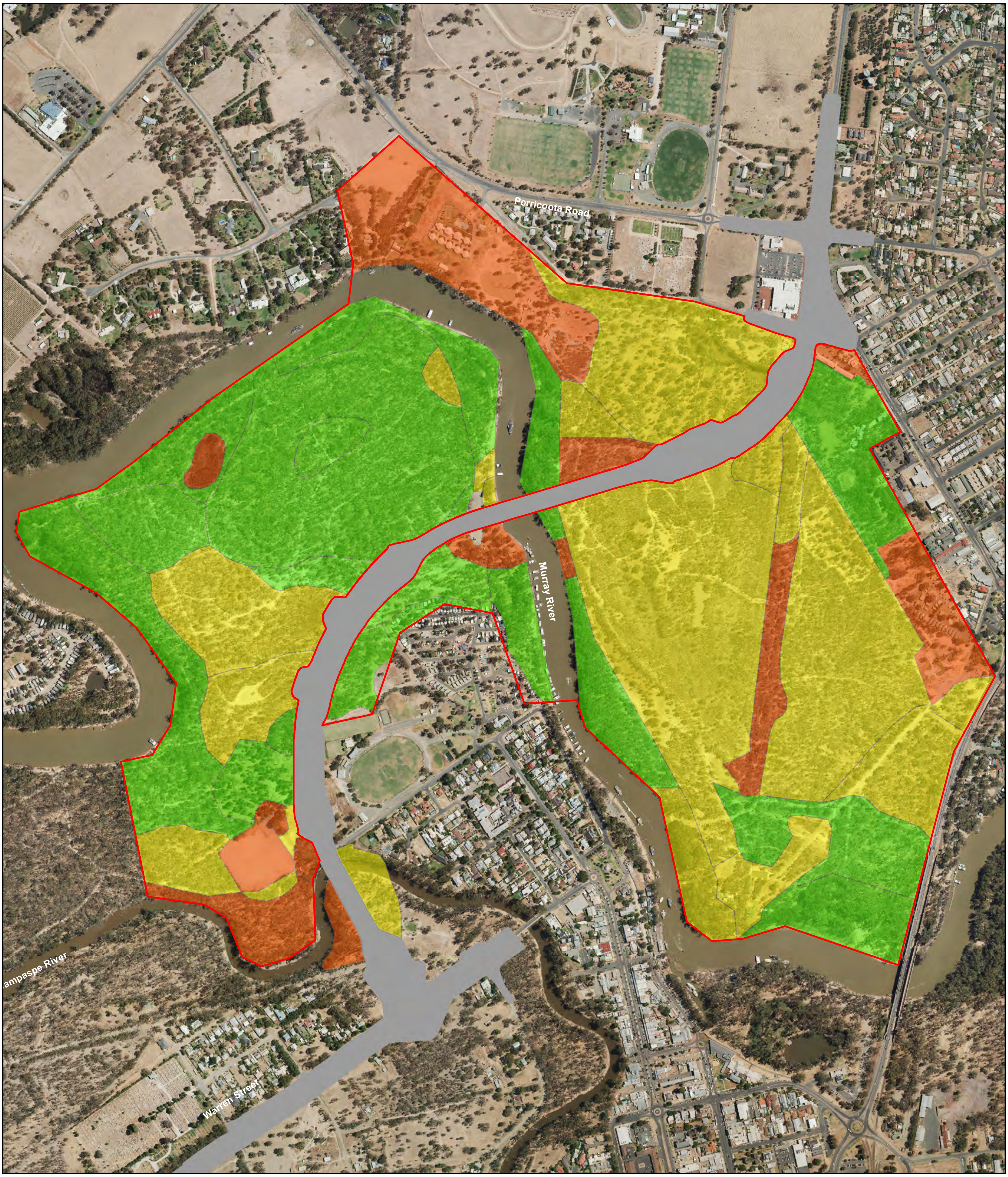
Appendix 4: Foraging habitat quality mapping



Metres
0 125 250 500

Legend

Study area

Midwest Alignment

Foraging habitat quality

Good

Moderate

Poor

Appendix 4: Foraging habitat quality

Project: Murray River Crossing Echuca

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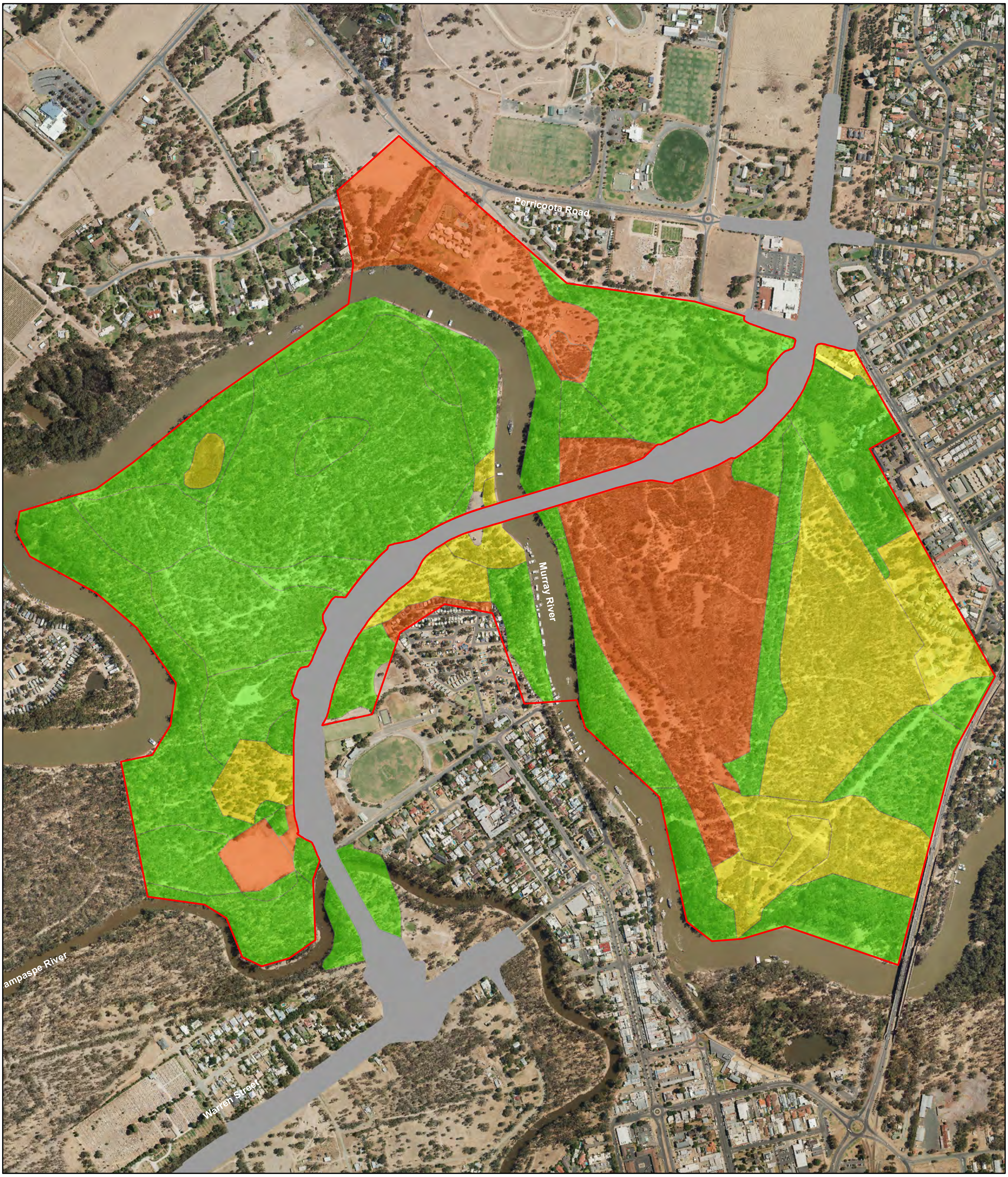
Appendix 5: Habitat connectivity mapping



Legend

- Study area
- Midwest Alignment

Habitat connectivity

- Good
- Moderate
- Poor

Metres
0 125 250 500

Appendix 5: Habitat connectivity

Project: Murray River Crossing Echuca

Client: Roads and Maritime Services

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