PRACTICAL ECOLOGY
ecological restoration & consulting

FRANKSTON FAUNA LINKAGES AND CROSSING STRUCTURE DESIGN

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Prepared for Frankston City Council

Frankston City

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CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

Background

Practical Ecology Pty Ltd was engaged to undertake a study of existing and potential fauna linkages within Frankston and adjoining municipalities to maintain or restore connectivity for aquatic, ground-dwelling and arboreal fauna. The study was to also identify barriers to achieving connectivity for fauna and provide details for different structural designs to overcome them. The study objective was to provide a prioritised approach to creating fauna linkages and connectivity structures within Frankston with the intention of reducing threats to declining fauna populations and building functioning and sustainable fauna populations resilient to climate change.

The retention, enhancement, and creation of linkages can reduce the impacts of habitat fragmentation including isolation and smaller patch size. Within an urbanised landscape, fauna crossing structures are also an integral component of providing connectivity for fauna and the successful functioning of a habitat linkage network. Together, linkages and crossing structures facilitate daily and dispersal movements of fauna, connect populations so they can exchange individuals and genes, decrease the risk of extinction due to declining populations or temporary reductions in suitable habitat, and facilitate the functioning of critical ecosystem processes such as seed dispersal and pollination.

A key outcome of this study was to identify and prioritise habitat linkages and locations for fauna crossing structures to assist in a staged implementation process. For crossing structures, key objectives were to provide a suite of standard specifications for different structures to overcome barriers to faunal movement, broad recommendations for future monitoring of the use and success of these structures, approximate installation costs, working examples of where structures have been successfully installed, and their general maintenance requirements with the aim of being incorporated into asset renewal projects. The study was also to provide a greater understanding of local fauna use and movement in addition to parameters for linkages to meet fauna connectivity requirements.

The study was to build on prior work undertaken on fauna linkages within the south-east region of Melbourne and existing knowledge of linkages and fauna sensitive road design. Specifically the study was to prioritise the conservation significance of linkages largely following criteria used in a previous study of connectivity within the south-east of Melbourne (McCaffrey and Henry 2010). The study engaged a large number of individuals, community groups, land managers, and agencies from the initial stages through to the development of the report. A questionnaire was distributed and two workshops held with land managers and community groups to refine the methodology and collect valuable local knowledge on fauna within Frankston. In addition, the report was externally peer-reviewed by a consultant scientist with the Australian Centre for Urban Ecology (ARCUE; Dr R. van der Ree).

The report is divided into three main sections. The first section presents the existing and proposed linkages identified by the study and resulting higher priority corridor linkages based on an assessment against a large number of criteria. Recommended parameters for corridor creation or enhancement are also provided along with management recommendations and on-ground actions to achieve corridor implementation. The second section presents recommended locations for fauna crossing structures and provides details on different types of fauna crossing structures, including appropriate situations for their use, technical specifications, maintenance requirements, approximate costs and case study examples. Management and monitoring recommendations are also provided. The third and final section recommends two major corridors and two supplementary corridors for urgent implementation. Detailed specifications are provided along with estimations of likely target fauna use. Recommended on-ground actions to implement these corridors are also provided, including specific habitat and connectivity requirements of 30 target fauna species.

Target fauna groups (5) and species (30) were identified to focus and inform recommendations for linkages and fauna crossing structures. Two additional fauna groups were added to those within the original project brief (i.e. aquatic, ground-dwelling and arboreal fauna). These were semi-aquatic fauna (mainly frogs) and woodland birds, two groups which are different from all others based on a unique set of habitat and connectivity requirements.

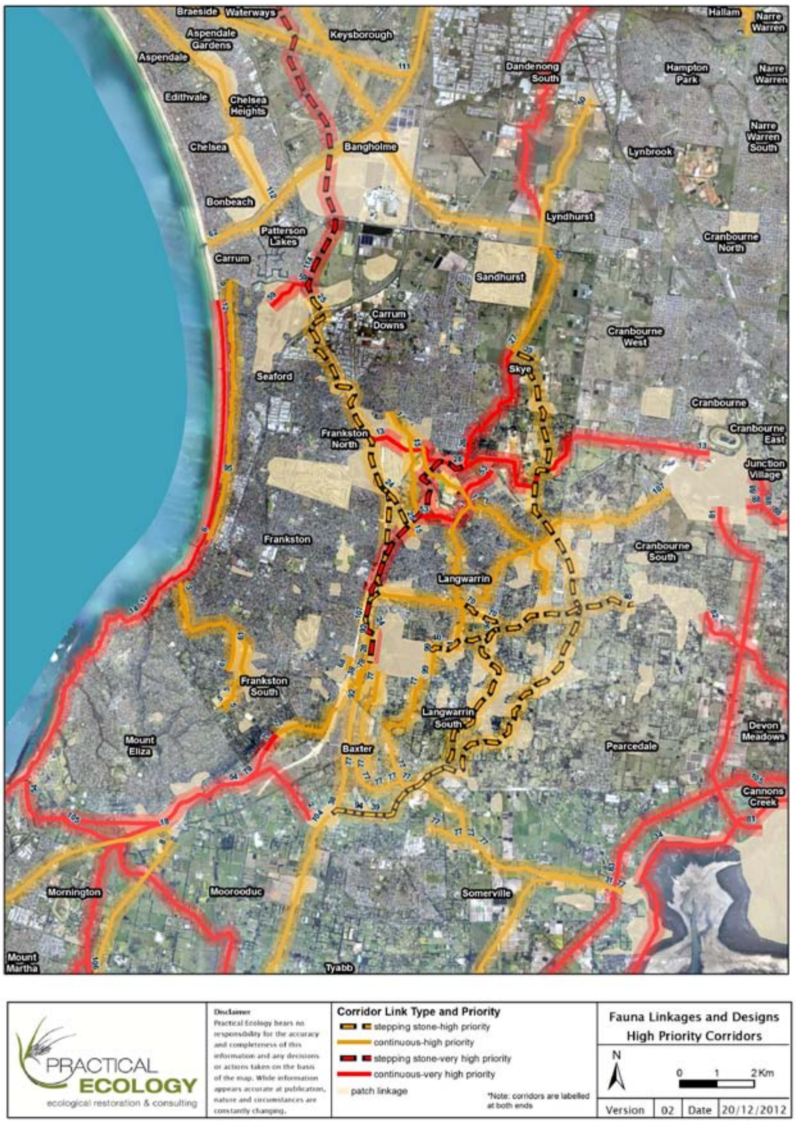
Summary of Findings and Recommendations

A large number of linkages (187) were identified and assessed against criteria to provide recommendations for priority linkages to implement. Criteria belonged to one of three groups which assessed the i) conservation significance of the linkage, ii) potential barriers to implementation (i.e. feasibility), and iii) opportunities for successful implementation. Quantitative assessment of criteria was undertaken in a Geographic Information System (GIS) environment. Patch type linkages were assessed along with corridor type linkages although these were not the main focus of the study and results for these are provided in an appendix. Ninety-one corridors and 96 patch type linkages were assessed as part of the study. Corridors were assessed as belonging to one of three main current ecological and connectivity functions: terrestrial, riparian, or aquatic.

Based on the resulting scores from the analysis, 18 corridors were assessed to be of Very High priority, 30 of High priority, and 43 of Medium-Low priority. Four Very High priority corridors and 12 High priority corridors are located entirely with the Frankston LGA providing local scale connectivity for fauna. An additional four Very High priority corridors are shared with adjoining municipalities providing larger landscape-scale connectivity. Higher priority linkages were ones that linked with habitat outside of Frankston and run through largely agricultural land. Corridors linking larger areas of core habitat were nearly always of higher priority.

Higher priority corridors are recommended for implementation over the long-term to achieve a high level of connectivity for fauna populations within Frankston and adjoining municipalities. These are shown in the reproduced map below (Figure 7). Together, these higher priority corridors serve to form a network of linkages, providing connectivity among all core areas of fauna habitat identified by the study and most ‘node’ habitat patches.

Higher priority linkages should be the focus of greater resources and effort in protecting and enhancing existing fauna habitat values but also the creation of new habitat.



A review of corridor parameters is provided including recommended widths, buffers, and fire protection zones for corridor linkages. Corridor widths required to achieve connectivity requirements of different target fauna is also provided. For each linkage, the report details information to guide the implementation and management of linkages including: specific habitat values of the linkage, faunal groups likely to utilise and benefit from the linkage, land tenure, and major barriers to successful implementation. This is followed by recommended actions to be undertaken for the long-term implementation of linkages and the protection of existing habitat and linkages. Recommendations are made for Council allocation of resources in the protection and enhancement of habitat and critical fauna resources such as hollow-bearing trees.

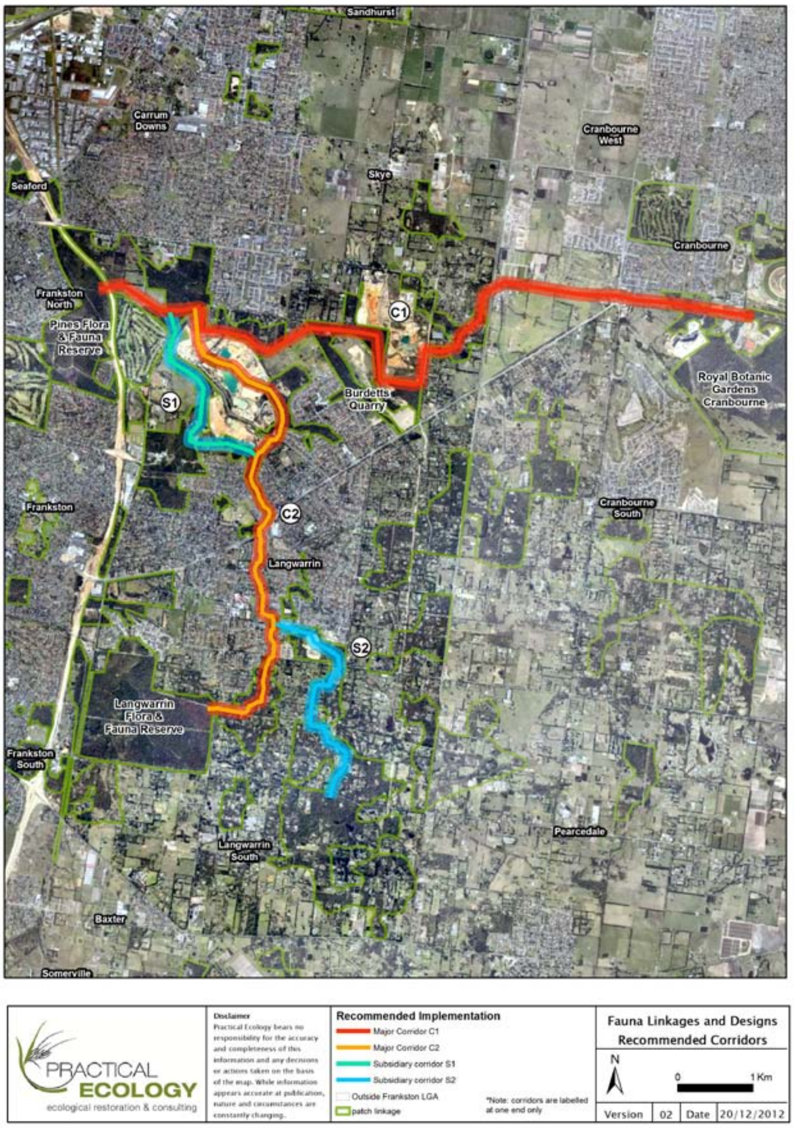
Two higher priority corridors for more urgent implementation are also recommended. These major fauna corridor are the:

<u>Pines Flora and Fauna Reserve to Cranbourne Botanic Gardens Corridor</u>

and the

<u>Boggy Creek Corridor</u> linking the Pines Flora and Fauna Reserve to Langwarrin Flora and Fauna Reserve.

Two supplementary corridors are also recommended to enhance connectivity for target fauna species. These provide additional connectivity to fauna habitat and populations within Studio Park and woodland habitat within Langwarrin ('Langwarrin Woodlands'). These corridors are shown below (Figure 29).



Specific on-ground actions for achieving linkage parameters were produced for these two corridors recommended for urgent implementation. Detailed information for each linkage is provided including a description, the target fauna species likely to use the linkage and the benefits to each species, and key threats to achieving connectivity along the corridor and solutions to overcome these threats. Recommended buffer zone, core habitat, and fire protection zone widths are also provided in addition to land ownership along each corridor. Specifications for habitat creation and restoration based on target fauna habitat requirements are provided for each of the two corridors. The latter was informed by a detailed review of target fauna habitat requirements and potential distribution and movement patterns within Frankston. Approximate costs are also provided for on-ground actions required to achieve the linkage parameters.

A large number (121) of potential locations for the provision of fauna crossing structures was compiled and initially assessed against quantitative spatial datasets and associated criteria. As part of this process, the study reviewed observations of fauna records within Frankston and also compiled and analysed records of fauna casualties to inform recommended locations for fauna crossing structures. Observations of target fauna species and casualty records were used to refine the type of structures recommended at each location. Higher priority locations were subsequently assessed based on whether they were required at the current point in time and feasible to implement.

Fifty-three locations were considered of Very High or High priority for implementation, although only 23 of these are likely to be required at the current point in time. Nine of these higher priority locations were considered not to be feasible based on engineering, cost, and/or ecological constraints.

Higher priority and feasible crossing locations are recommended for the installation of fauna crossing structures within the near future. Other locations should be considered as part of long-term planning for improving habitat connectivity for fauna, with any new road or infrastructure development, and the realisation of higher priority corridor linkages. Monitoring of crossing structure effectiveness should also be undertaken and according to recommendations to further inform future plans and on-ground management.

Major recommendations of this report are:

- To pursue the implementation of higher priority linkages over the long-term to form a network of linkages providing high connectivity among habitat patches and fauna populations;
- Implement in the near future two urgently required corridors and two supplementary corridors according to recommended specifications;
- To protect and enhance all existing habitat and critical habitat resources (e.g. hollow-bearing trees) along higher priority corridors and within patch linkages as a matter of high importance; and
- Pursue the implementation of fauna crossing structures at currently required locations within the short-term and at other high urgency locations as required.

1. INTRODUCTION

Practical Ecology Pty Ltd (Practical Ecology) was commissioned by Frankston City Council to provide a study of existing and potential fauna linkages and recommended locations for fauna crossing structures within Frankston. The overarching aim of the study was to maintain and restore connectivity for aquatic, ground-dwelling and arboreal fauna. The study was also to identify major barriers to connectivity and provide details on different fauna crossing designs that facilitate fauna to overcome major barriers to movement. The intended purpose of the study was to guide a prioritised approach to implementing fauna linkages and crossing structures within Frankston. This was to address the issues of declining fauna populations, maintenance of sustainable populations, and increase ecosystem resilience in the face of climate change.

1.1 Project Background

The study was to build on previous work undertaken on linkages and fauna connectivity requirements within the south-east Melbourne region (McCaffrey and Henry 2010) as well as existing knowledge on fauna linkages and fauna sensitive road design. The provision of connectivity for fauna is recognised under the need to “protect and preserve biodiversity and enhance the natural environment” recognised in the Frankston City Council Plan and under Frankston 2025 Community Vision that “Wildlife corridors connect natural areas across the city creating ecosystem linkages”. The need for building linkages to connect faunal populations and address fragmentation of natural systems is recognised in Victorian government documents such as ‘Securing our Natural Future: A white paper for land and biodiversity at a time of climate change (2009) and at the Commonwealth level in ‘Australia’s Biodiversity Conservation Strategy 2010-2030 (National Biodiversity Strategy Review Task Group 2009).

Faunal linkages are of increasing importance where habitat loss and fragmentation has been most severe. Frankston has lost up to 90% of its pre-European remnant vegetation, much of it to the process of urbanisation but also agricultural activities. Whilst still supporting significant biodiversity values and several large patches of remnant fauna habitat, increasing urbanisation in Frankston and the surrounding landscape is threatening the persistence of faunal linkages and creating greater resistance to faunal movement and population exchange. Isolation of faunal population to a few islands of habitat is a very real possibility unless linkages are established to connect what remains and land put aside for conservation purposes. Several recent studies have pointed to inadequate levels of habitat connectivity within the south-east region of Melbourne (Cardinia Environment Coalition 2008; DSE 2011; McCaffrey and Henry 2010; McCaffrey, Henry and Goodman 2010; O'Malley 2011; O'Malley et al. 2012; PPWCMA 2009; Schmidt, Renowden and Quin 2008) and call for the establishment of faunal linkages or biolinks to address this issue.

1.2 Study Objectives

The overarching study objective was to identify and prioritise faunal linkages and crossing structure implementation within Frankston and adjoining areas to assist in improving and restoring structural and functional ecological connectivity. The study was to build on previous studies of linkages within Frankston and adjoining municipalities such as McCaffrey and Henry (2010), Ecology Australia (2006) and other relevant studies. In particular, the study was to build on methods for prioritising linkages used in McCaffrey and Henry (2010). The study had a number of key objectives in order to satisfy the overarching project aim.

These objectives were:

- A comprehensive study of existing and potential linkages within the municipality and into adjoining municipalities to maintain or restore connectivity for aquatic, ground-dwelling and arboreal fauna, including identifying barriers to connectivity and providing details on different fauna structural designs to overcome barriers to faunal movement.

- Identification of existing and potential habitat links within the Frankston municipality and into adjoining municipalities (building on McCaffrey and Henry 2010, Ecology Australia 2006, and other flora and fauna studies).

- Linkages prioritised for conservation significance to assist in a staged implementation process using largely the criteria used in McCaffrey and Henry (2010).

- Provide details of recommended linkages and key parameters.

- Locations and prioritisation of where fauna connectivity structures are required within the municipality with the aim of being incorporated into asset renewal projects.

- A suite of standard specifications of different types of fauna connectivity structures to overcome barriers to faunal movement.

- Working examples of where fauna connectivity structures have been successfully installed in other locations.

- Broad recommendations for future monitoring of the use and success of fauna connectivity structures.

In regards to crossing structures, this study is focused on providing advice on achieving connectivity for fauna, not on reducing mortality. Measures to reduce mortality such as barrier fencing can reduce landscape/local connectivity of habitat for fauna. As a result, exclusion fencing is only recommended in this report when used in conjunction with a fauna crossing structure.

1.3 Consultation

Extensive liaison with stakeholders was undertaken through email correspondence, two questionnaire surveys, and two workshops. The first questionnaire targeted land managers within the broader study area and sought to identify major priorities, concerns, or issues concerning faunal connectivity that land managers may have or be aware of that was of relevance to the study. The second questionnaire sought to understand similar concerns and issues the community may have in regard to faunal connectivity but also to collate any additional information community members may have in regard to fauna connectivity, faunal records, and fauna mortality or injury within Frankston.

The first of the two workshops sought expert opinion from land managers on a preliminary list of potential corridor routes, criteria for assessing the conservation significance and prioritisation of linkages, and methods for identifying priority locations for recommending fauna crossing structures. Land managers were also asked to provide an estimate of the relative importance of different values or characteristics that define the conservation significance of a linkage. These estimates were used in determining the weightings for criteria for conservation significance (Table 2).

The second workshop with broader community members sought feedback on planned methods, a preliminary list of linkages, along with local knowledge on faunal movement, areas of high faunal mortality/injury, and species distributions, amongst several other topics.

Consultation with community members and land managers has been extensive and engaged a large number of individuals, experts, and organisations. For example, several organisations, companies, and researchers from three different states were engaged in developing specifications for faunal crossing structures.

1.4 Study Area

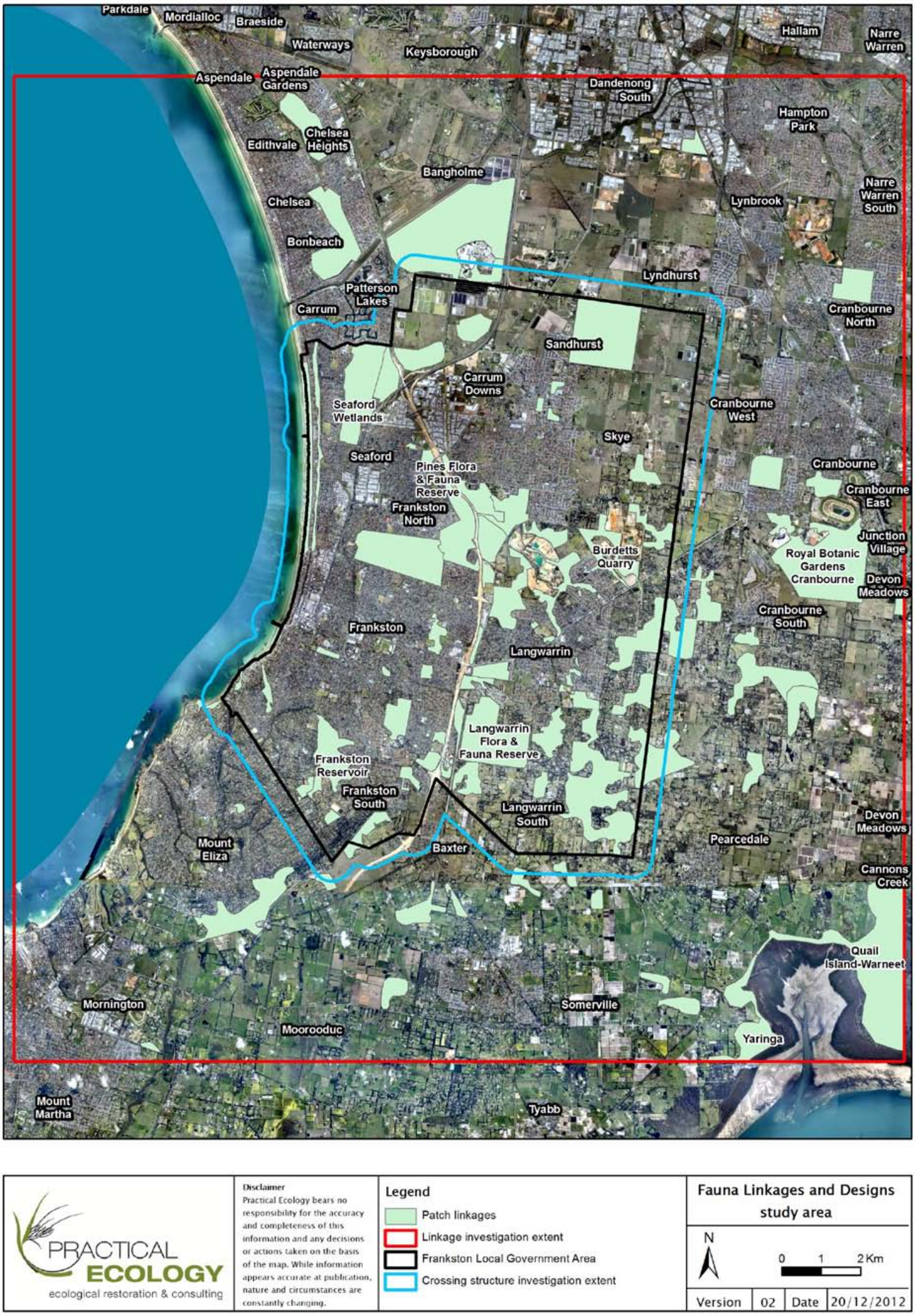
The project area encompasses all land, both public and private, within the Frankston City Council municipal boundaries. The investigation and recommendations was also to consider adjoining municipalities bordering Frankston Council. Adjoining municipalities include:

- City of Casey
- City of Kingston
- Mornington Peninsula Shire
- City of Greater Dandenong

The study considered these adjoining municipalities when proposing potential landscape-scale linkages. Due to the project constraints and relevance to Frankston City Council, detailed investigation was focused on linkages within 5 kilometres of Frankston City Councils boundary (Fig. 1). An investigation of potential faunal crossing structure implementation extended 500m beyond the boundary of Frankston City Council to account for barriers such as roads that were in close proximity or running parallel to the municipality boundary. The study area is located in the Port Phillip and Western Port region and the Gippsland Plains Bioregion (DNRE 1997). The municipality and surrounding region supports many patches of important faunal habitat, which can be considered as 'linkage patches' that increase the permeability and utilisation of the landscape by fauna. The most common ecological vegetation classes (EVCs) predicted to occur prior to European settlement were Grassy Woodland, Heathy Woodland, Plains Grassy Woodland, and to a lesser extent Plains Grassy Wetland and Swampy Riparian Woodland.

Natural fauna habitat types within the municipality include forests, heaths, woodlands, grasslands, scrubs, wetlands, tree canopies, flooded pastures, open water bodies, rivers and creeks, estuaries, and sandy and rocky shores. Human modified habitats of particular value to fauna also include golf courses, gardens, farm dams, water treatment ponds, vegetated drains, farmland, and scattered trees.

Figure 1. Study area and extent of investigations



1.5 Ecological Background

The fragmentation, isolation, and loss of habitat are strongly associated with declining populations of fauna species and overall losses in fauna diversity worldwide. Widespread clearing of native vegetation in Australia since European settlement is implicated in the extinction of many fauna species. For example, Australia has the highest recorded number of mammal extinctions in the world with 27 mammals having become extinct in the last 200 years. Nationally 390 fauna species are considered at threat of extinction and 250 fauna species considered to be threatened in Victoria by the Department of Sustainability and Environment. Major reasons for these declines include habitat loss, fragmentation, and degradation caused by clearing of native vegetation for agriculture, urban development, and timber harvesting but also grazing, weed invasion, inappropriate fire regimes, and alteration of water flows and temperature regimes in rivers and water-bodies. In Australia, the introduction of numerous exotic species such as rabbits, foxes, cats, and trout, has had a profound impact on native fauna populations. While rabbits are known to compete with native fauna for food resources and degrade their habitat, predation of native fauna by foxes and cats is implicated as major cause in the extinction or decline of many fauna species, particularly ground-dwelling species.

Urbanisation and primary production activities (e.g. agriculture and timber extraction) have a large impact on biodiversity and fauna communities. These processes result in the loss, modification, and fragmentation of fauna habitat but also in more hostile landscapes for fauna to persist in or move through. The processes of urbanisation is particularly relevant to fauna within the City of Frankston and results in:

- an overall reduction in the amount of habitat available to fauna
- smaller patches of habitat of with a much reduced capacity to support a diversity of fauna species
- isolation of areas of habitat and resident populations of fauna and subsequent decline in resilience to wildfire, droughts, climate change, and disease
- barriers to the movement of animals (daily, seasonal or migratory) such as roads, impervious residential or commercial environments and other infrastructure
- greater threats to fauna such an increased predation from exotic predators (i.e. cats and foxes) and collisions with vehicles

Two important consequences of habitat fragmentation are decreasing habitat patch size and increasing isolation which in turn leads to small fauna populations more vulnerable to local-extinction. Sensitivity of fauna to habitat fragmentation and urbanization varies among species based largely on their habitat requirements, movement abilities, and sensitivity to threatening processes (e.g. fox predation). Where areas of habitat are isolated they have a reduced capacity to be re-colonized by fauna after events such as wildfire, droughts, or disease outbreaks that may cause the local-extinction of fauna species. Consequently, connectivity between areas of habitat and resident populations is important for ensuring the survival of native fauna population in Frankston and adjoining areas.

Landscapes have different capabilities to support a diversity of fauna species and healthy resident populations resilient to changes in environmental conditions such as droughts, fire, or climate change. For example, heavily urbanised landscapes are a much lower capacity to support healthy and diverse fauna communities than grazed pastoral landscapes, which in turn have a much lower capacity than ‘natural’ landscapes supporting large areas of native vegetation. Similarly, these landscapes differ in the diversity and ease with which fauna species can move through them to travel between suitable areas of habitat or maintain breeding events (i.e. 'permeability'). Frankston supports a mixture of these types of landscapes although it is largely a peri-urban landscape dominated by residential and commercial developments, particularly in the west, with some agricultural land in the west. Increasing urbanisation within Frankston and surrounding municipalities has previously been identified as a key threat within the study area to fauna populations (Cardinia Environment Coalition 2008; McCaffrey and Henry 2010; O'Malley 2010). Previous studies covering the study area have identified the need for improved connectivity of faunal habitat and populations (Cardinia Environment Coalition 2008; McCaffrey and Henry 2010; PPWCMA 2009). These include improved connectivity for specific threatened species, such as the Southern Brown Bandicoot (DSE 2011, O'Malley 2010).

A solution to habitat and population isolation in the provision of habitat links. Habitat links provide connections between areas of habitat which would be otherwise isolated. They facilitate the movement of animals between areas of habitat and contribute to more resilient fauna communities. Translocation of animals (or 'assisted migration') may assist in mitigating declines in genetic health of populations. However, this approach is species-specific, costly over the long-term as translocation programs must operate indefinitely into the future, and does not provide an integrated connectivity solution that services many fauna species. Also, it does not manage other threatening processes causing population decline and is generally considered in Australia a last resort measure when all other conservation measures have failed.

Habitat connectivity and linkages for fauna are important as they:

- Facilitate daily, seasonal, or migratory movements of animals
- Connect populations so they can exchange individuals and genes or supplement declining populations with new individuals
- Facilitate the re-colonisation of unoccupied habitat after local extinction or after periods in which habitat is temporally unsuitable (i.e. after drought, flood, or fire)
- Increase gene flow among populations and reduce the risk of in-breeding
- Increase the permeability of the landscape to fauna, allowing them to exploit more areas of suitable habitat including crucial habitats for completion of life cycles
- Provide habitat refuges for fauna from introduced predators (i.e. foxes and cats)
- Provide habitat in their own right across a landscape for fauna to utilise
- Help species survive climate change and other changes in environmental conditions such as drought, flood, and fire
- Facilitate the functioning of crucial processes for a healthy ecosystem such as seed dispersal and pollination via animal vectors

Habitat links are defined as an arrangement of habitat that facilitates the movement of organisms (e.g. animals) or continuity of ecological processes through a landscape. Generally, they facilitate movement of animals between larger non-linear areas of core habitat (i.e. 'habitat patches') that can support resident populations. In this study, these areas are referred to as '**core**' or '**node**' habitat patches (see APPENDIX 8 for detailed definition). Habitat links (e.g. corridors) serve to link core and node habitat patches to create a 'habitat network'. Habitat links also serve to increase the overall cover of habitat within a landscape and available for fauna to utilise for foraging and refuge.

Habitat links can be composed of:

Habitat Corridor – a linear strip of vegetation (i.e. many more times longer than wide) that is composed of continuous (or nearly so) habitat between two larger areas of habitat or to important habitat features important for completion of their life-cycle or reproduction. Continuous corridors of habitat are generally required for ground-dwelling fauna and more fragmentation sensitive species.

Stepping Stones – a series of one or more isolated patches of habitat which provide resources and refuge which assists in animals moving between areas of habitat or between important habitat elements for completion of life-cycles or reproduction. Stepping Stone linkages can generally provide connectivity for more mobile fauna species (e.g. birds) less sensitive to gaps in habitat and urbanisation.

An additional integral component to habitat links and improved connectivity of fauna habitat and populations is the provision of crossing structures to overcome barriers to movement. Crossing structures are required where there are barriers to movement and where habitat is impractical to create (such as roads). Crossing structures can be used in combination with exclusion fencing (i.e. keeping animals off roads) to reduce mortality, but the latter is not the focus of this study.

1.6 Fauna in Frankston

1.6.1 Fauna Species and Groups in Frankston

Bird species comprise a large proportion (%) of total vertebrate species diversity within Frankston and account for the greatest proportion of individual records (Figure 2). This pattern is consistent with elsewhere due to the high diversity of species within this group. Mammal (including ground-dwelling and arboreal) and reptile species also contribute a significant portion of vertebrate diversity although Figure 2 (B) suggests they are comparatively less rarely observed or abundant. Nine of the 26 mammal species recorded in Frankston are microbats. Comparatively fewer frog and fish species are recorded in Frankston reflecting the relative diversity within these groups more broadly in south-east Australia.

Among the most commonly recorded bird species were the Red Wattlebird, Magpie-lark, Brown Thornbill, Australian Magpie, Superb Fairy-wren, Pacific Black Duck, Grey Fantail and White-browed Scrubwren. The Short-finned Eel, Common Galaxias, Spotted Galaxias, and Dwarf Galaxias were amongst the most commonly recorded fish species while frog species more frequently observed included the Common Froglet , Southern Brown Tree Frog, and Southern Bullfrog (or 'Banjo Frog'). Amongst the most commonly recorded mammals was the Swamp Rat (18% of records), followed by the Common Ringtail Possum (14%), Koala (12%), Common Brushtail Possum (8%), Black Wallaby (7%), and Short-beaked Echidna. The Garden Skink, Blotched Blue-tongue Lizard, and Weasel Skink were amongst the most commonly recorded reptile species.

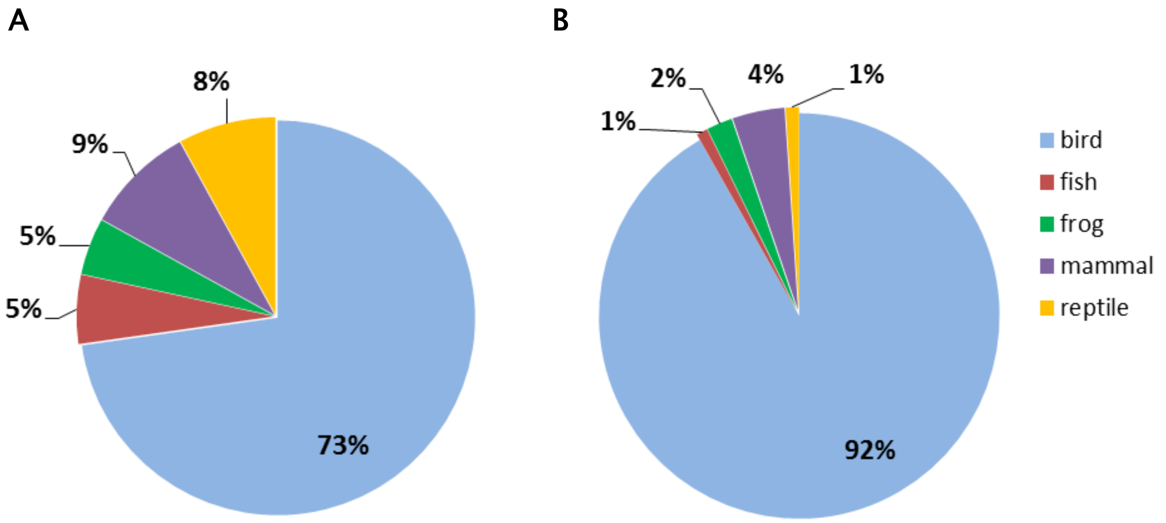


Figure 2. Analysis of compiled fauna species records for Frankston LGA including the A) percentage (%) of total vertebrate species diversity represented by each of five broad fauna groups and the B) percentage (%) each fauna group contributes to the total number of vertebrate fauna records.

It should be noted, however, that records can be biased towards birds due to their day-time (diurnal) activity, conspicuous nature (i.e. more easily observed), and the ability of non-specialists to identify species correctly. The night-time activity patterns (i.e. nocturnal) of many of our mammal species means they are less rarely observed by people while reptile, fish, and frog species are often difficult for the non-specialist to both observe and identify. Consequently, records for these groups are more reliant on surveys by professional zoologists (see Section 2.3.5 for further details). Records also do not accurately reflect the relative abundance of different animals. It is possible for a species to be frequently recorded but have a very low abundance and vice versa. For example, Black Wallabies and Long-necked Turtles are rarely observed but may be more abundant than records would suggest.

1.7 Report Structure

The report is divided into four major parts. The first part (Section 2) summaries the methods used in this study with full details of analysis methods for prioritising linkages provided in APPENDIX 8.

The second part (Section 3) presents results of a detailed spatial analysis of fauna linkages within the study area and subsequent prioritisation. This section prioritises habitat linkages (i.e. corridors) and recommends higher value linkages for long-term implementation. It is not intended that all higher prioritised are implemented in the short term but rather that the results are used as long-term tool to guide decision making. Prioritised linkages (High and Very High priority) may be used to guide future decisions and investment for achieving connectivity for fauna over a long time-frame (>25 years). These results are followed by recommended parameters and design principles for corridor linkages and actions to be implemented for improving connectivity for fauna across Frankston (Section 3.5). Detailed descriptions and recommended parameters for linkages are provided in

The third part (Section 4) of the document first presents several analyses relating to determining priority locations and type of crossing structures required within Frankston and immediately adjacent land. Detailed descriptions of different fauna crossing structures and associated management recommendations are also provided. It should be noted that this section is focused on implementation of crossing structures to improve habitat connectivity for fauna, not on reducing road mortality. Measures to reduce road mortality may also reduce habitat connectivity for fauna, such as the use of barrier fencing to stop animals moving onto roads.

The fourth and final section presents two fauna corridors recommended for urgent implementation and provides descriptive information, design recommendations, works specifications, land ownership within the linkage, and broad costings for each linkage. These are intended for pursuing in the immediate future. Also provided are estimations of what fauna are likely to use each linkage, the habitat values of the linkage, and key threats to connectivity and solutions to overcome these threats.

2. METHODS

2.1 Identifying and prioritising linkages

2.1.1 Introduction

Two main groupings of fauna linkage were used in the analysis: 'corridor' linkages and 'habitat patch' linkages. Although the analysis below was also applied to habitat patches, prioritisation and implementation of corridor linkages were the focus of the project as opposed to the management of patches. However, the results of the analysis applied to habitat patches are presented in APPENDIX 5 for additional future reference. The method employed provides a municipal-wide assessment of fauna habitat connectivity and can be used to inform planning and management across the entire LGA over a long-period (>25 years).

Mapping of existing or proposed corridor linkages involved digitisation in GIS software. In most cases, each corridor linkage connected two or more existing habitat patches. However, a change in the type of linkage (i.e. whether an aquatic, riparian, and terrestrial linkage) or connectivity function (e.g. a corridor linking two habitat patches or an off-branch of a riparian corridor increasing overall permeability of the landscape) required a new corridor segment be created. This approach was required by the analysis method so that linkages were assessed against relevant criteria and to fairly compare linkages to one another. As such, a habitat link between two distant core patches, for example, could be composed of two or more connecting corridor linkages (e.g. one aquatic and one terrestrial), each having a different score or rank priority.

Achieving habitat and resource connectivity for fauna can vary depending on the species concerned. For example, fauna capable of flight (i.e. birds and microbats) may overcome landscape features (e.g. buildings or deep water-bodies) which constitute a complete barrier to ground-dwelling fauna. Similarly, ground-dwelling fauna species may require relatively continuous areas of habitat to move about a landscape, while for flight-capable fauna a series of habitat patches distributed across a landscape (i.e. 'stepping stones') may be sufficient to achieve connectivity. Depending on the distances a fauna species can move (i.e. how mobile it is), distances between suitable habitat patches may also limit the level of connectivity. For example, a swamp wallaby may be capable of moving across areas of cropland between suitable areas of habitat but a small rodent species may be capable of moving only short distances across hostile environments. Consequently, the distribution and arrangements of habitat across a landscape influences the level of connectivity for differing groups of fauna and fauna as a whole.

To ensure connectivity could be achieved for a broad range of fauna groups and species, a surrogate species/group approach was adopted in identifying and prioritising linkages and crossing structures and in providing recommendations for implementation. Several species from four fauna groups were selected (ground-dwelling, woodland birds, semi-aquatic, and aquatic) based on their different habitat and connectivity requirements (see APPENDIX 8: Table 8). Surrogate species were selected in an attempt to have a suite of reference species for which to provide connectivity for, including both common and threatened species, and species varying in their sensitivity to habitat fragmentation and urbanization. The intention was that if connectivity could be achieved for these target (i.e. 'surrogate') species, then a broad range of other species are also likely to benefit.

2.1.2 Steps in analysis

A number of steps were involved in identifying and prioritising important fauna linkages. These steps are illustrated in the diagram shown in Figure 3. Each step and resulting outputs are described briefly below with more detailed methods provided in APPENDIX 8.

The overall approach was to identify a large number of both existing and potential future fauna linkages and then assess them against unique criteria to produce a score for each linkage. Criteria belonged to three groups representing their 1) biological importance ('Conservation Significance': Figure 31), 2) degree of difficulty in implementing ('Feasibility': Figure 32), and opportunities for implementation ('Opportunity': Figure 33).

The combination of scores in each of these criteria (see APPENDIX 4) were then used to provide a priority rank (i.e. 'Low' to 'Very High') for each linkage. All the linkages assessed and ranked in this way are illustrated in Figure 30. Linkages determined to be of High or Very High priority linkages are recommended for future consideration in achieving connectivity for fauna across the municipality. These linkages can be used to guide future decisions and investment for achieving fauna connectivity over a long time frame (>25yrs). Results of analysis were used to inform the recommendation of two urgent fauna corridors for implementation in the near future and subsequent on-ground works and management.

Step 1: Needs and objectives were defined by Frankston City Council. Further refinement was achieved through stakeholder and community engagement and reviewing biological information (i.e. species records and habitat information) within Frankston and adjoining areas.

Step 2: A large number of existing and future potential fauna linkages were identified informed by a) previous investigations of biological connectivity within the region, b) models of fauna habitat connectivity covering the study area (O'Malley *et al.* 2012), c) habitat mapping, d) needs of target fauna species, and e) community and land-manager consultation. Starts and ends of corridor linkages were defined by connections to larger patches of habitat or by a change in the type of linkage it provided (i.e. whether it was an aquatic, riparian, or terrestrial corridor).

Step 3: Fauna linkages were assessed against criteria largely based on McCaffrey and Henry (2010) but developed further in this study and reviewed by stakeholders and land-managers. All criteria were also calculated quantitatively in GIS software. Criteria were developed for three categories: Conservation Significance, Feasibility, and Opportunity.

> **Conservation Significance**: the biological value of the linkage in providing connectivity and habitat for fauna (Figure 31)
>
> **Feasibility**: the difficulty of implementing the linkage to achieve functional connectivity for fauna considering existing infrastructure and land tenure (Figure 32)
>
> **Opportunity**: factors increasing the chance of successfully implementing a linkage (Figure 33)

Step 4: Assess all linkages against criteria within each category, resulting in scores (between 1 and 100) for each linkage in the three categories above.

Step 5: For each of the three categories, linkages were first ordered according to their score. Linkages were then assigned a rank score (1-4) based on whether they were in the top quarter (1) of scores, 2nd quarter of scores (2), 3rd quarter of scores (3), or fourth and last quarter (4) of scores. This calculation was undertaken for each of criteria categories separately so that each linkage had a rank score between 1 and 4 for each one of the three categories.

Step 6: The rank score achieved in each of the three categories were then summed together to provide a final priority score for each linkage. Consequently, this final score ranged between 3 (i.e. 1+1+1 in each category) and 12 (i.e. 4+4+4).

Step 7: The method used in Step 5 was re-applied in this step but on the final summed priority score, resulting in linkages being assigned a rank between 1 and 4. This rank provided a basis for assigning a Low (4), Medium (3), High (2), or Very High (1) priority to each of the linkages.

Step 8: Based on the results of the linkage analysis and considering the needs of target fauna, two fauna corridors for urgent implementation were determined (Figure 29). Each is composed of one or more of the corridor linkages identified and ranked in Steps 1 to 7 and consequently incorporate one or more types (i.e. aquatic, riparian, or terrestrial) of corridor linkage. These two corridors are recommended for focused on-ground efforts in the immediate future.

Step 9: Detailed recommendations and specifications were developed for the two urgent fauna corridors guided by the needs of target fauna and best practice.

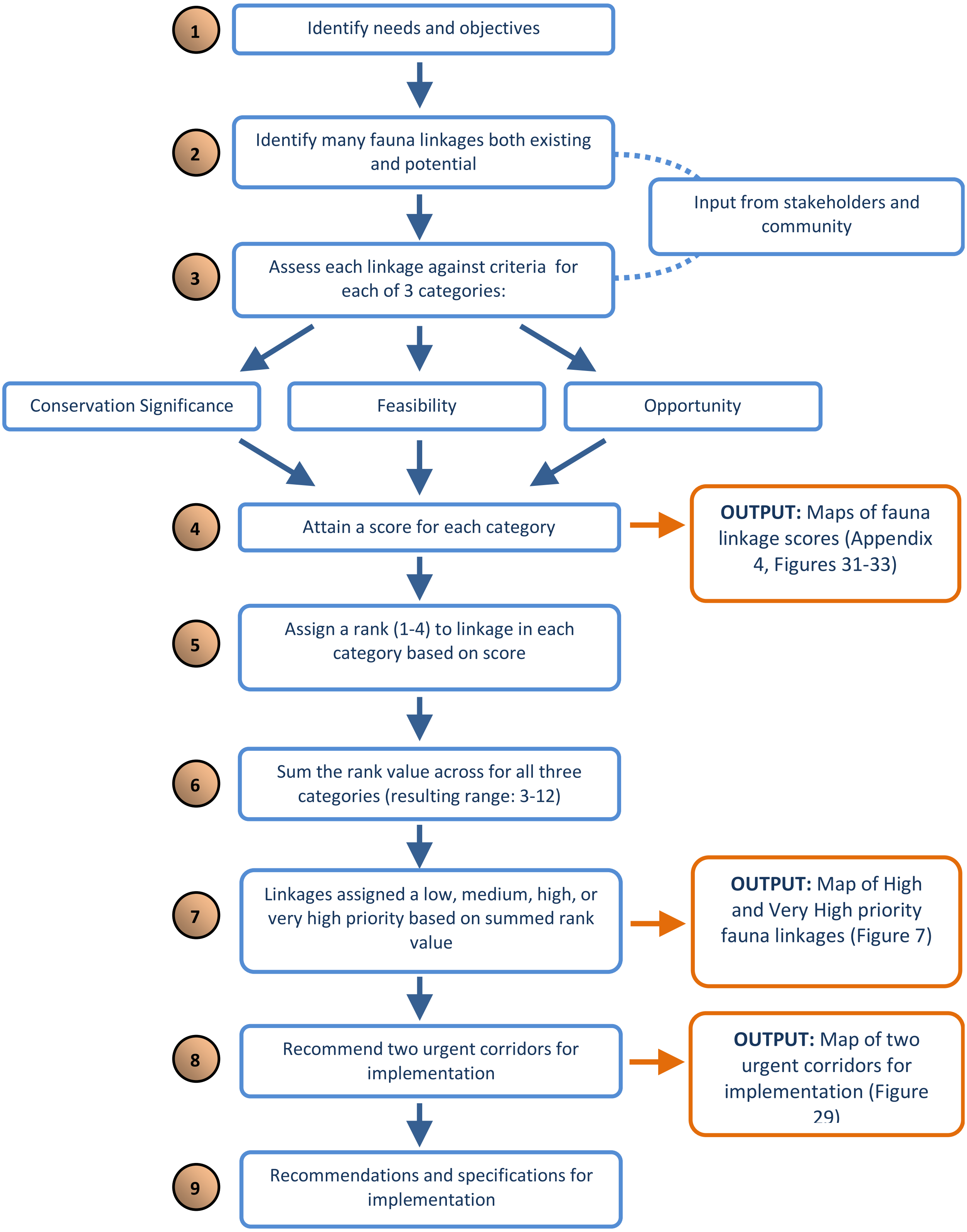


Figure 3. Analysis steps in the identification and prioritization of fauna linkages.

2.1.3 Recommending two high urgency fauna corridors

Once linkages were prioritised, two high urgency fauna corridors were subjectively identified for implementation in the near future (Section 5, Figure 29). Primary criteria was that each provided a connection between two or 'core' areas of fauna habitat and that a significant proportion of the linkage was located with Frankston LGA. Additional criteria included the:

- Score and priority of the component corridor linkages (i.e. assessed corridor segments)
- Diversity of fauna groups and target fauna species benefitting from the linkage
- Biological and habitat value of the core areas potentially connected
- Level of increased overall connectivity provided to fauna (including target fauna species)
- Diversity of fauna habitats connected and incorporated
- Feasibility in attaining a high quality linkage over the long-term

As this identification did not require segmenting of linkages by type (i.e. aquatic, riparian or terrestrial), each of these two corridors was composed of one or more of the linkages assessed in the prioritisation analysis (i.e. Figure 3).

2.2 Identifying and prioritising locations for fauna crossing structures

Several information sources and processes were used to estimate locations requiring wildlife crossing and their relative prioritisation. Roads for example, can be a major barrier to movement and habitat connectivity for many fauna species and can be mitigated by the installation of fauna friendly crossing structures. Similarly, roads and other artificial in-stream structures can be a major barrier to fish dispersal or migration. Although some actions can be sought to improve landscape permeability on private land, improvements in connectivity can be most readily attained by improving the permeability of roads in locations where they dissect patches of habitat or habitat linkages. Land with limited or little habitat for fauna also constitutes a barrier to faunal movement, although habitat provision is the appropriate method of facilitating movement rather than any structures. Structures are only used in circumstances in which habitat cannot be restored at locations where fauna habitat connectivity is required, such as roads.

2.2.1 Step 1: Selecting locations for consideration

Locations for the provision of crossing structures were included if they satisfied any one of the following criteria:

- Intersection between a high priority fauna linkage and any road;
- Sections of roads bordered on both sides by areas of low resistance (e.g. native vegetation);
- Identified 'hotspots' of wildlife casualties based of analysis of collated data from several sources;
- Identified in-stream barriers in a Melbourne Water GIS database
- Intersections between aquatic corridors and any major road

Information sources included:

- Identified extant and proposed fauna linkages;
- FCC, DSE, Wildlife Victoria, and Wildlife Carers (primarily 'Animalia Wildlife Shelter') supplied data on wildlife casualties in the LGA;
- Consultation with the community and wildlife carers
- Landscape resistance to fauna movement maps (O'Malley *et al.* 2012; see Section 2.3.4 below); and
- Native vegetation maps and roads layer including FCC supplied traffic counts

2.2.2 Step 2: Assessing where crossing structures are most needed

Prioritisation of locations for implementing fauna crossing structures is a combination of three major considerations:

i) the abundance of animals within the local neighbourhood;

ii) frequency of animal movement events within the local neighbourhood; and the

iii) risk of injury or mortality to animals in the surrounding area.

Localities supporting a high density of animals or high frequency of animal movement events in the local neighbourhood would have a high level of prioritisation, but only where there is resistance to movement either through animals being unsuccessful in crossing (i.e. there is a high risk of mortality/injury) or where animals avoid an attempt to cross a barrier (i.e. called a 'perceptual barrier' such as where traffic volume is high and animals avoid attempting to cross a road). Strong barriers to movement are considered to be largely major roads although residential areas with cats and dogs or high levels of pedestrian traffic or inhospitable/exposed areas may also put an animal at higher risk of mortality or be a perceptual barrier. These areas equate to ones estimated to have high level of resistance for faunal movement and occupation. Traffic volume and speed along roads is implicated as a major factor in mortality rates and reference was made to a traffic count database for council-managed roads supplied by Frankston City Council.

Partly, locations requiring crossing structures for improving connectivity across barriers can be informed from fauna casualty records which indicate where animals may be attempting to move across barriers (e.g. roads) or hostile environments (e.g. residential areas). A large number of such records (>1300) were collated (largely sourced from 'Animalia' but also Wildlife Victoria and DSE) and entered into GIS software. The density of wildlife casualty incidences across Frankston LGA was predicted using a smoothed kernel density estimate in GIS software (Geospatial Modelling Environment, Beyer 2012). A separate analysis was undertaken for each of three major fauna groups: ground-dwelling vertebrates, birds, and arboreal fauna. The average of these density estimates was calculated and clipped to a 50% isocline. The resulting spatial dataset was used to infer 'hotspots' of wildlife injury or mortality (i.e. casualties).

As mentioned earlier, placing crossing structures only at locations currently experiencing wildlife injuries may be short-sighted and used alone, may be biased towards certain fauna groups in which mortality/injury is more readily detected through incidental methods. Consideration should also be given to locations where larger, higher quality fauna habitat intersects high risk/resistance landscape features such as roads. The focus of crossing structures for this study is primarily to increase functional connectivity (see Section 7: Glossary) among habitat patches and the populations of fauna they support. Locations for crossing structures should therefore be aligned with long-term plans for providing connectivity in the form of ecological restoration of patch links and implementation of higher priority corridor linkages.

Taking these considerations into account, locations were first scored by criteria intended to reflect the likely abundance of animals and frequency of movement events. Criteria were:

- Average resistance to movement within a 200m radius of locality;
- Total area (ha) of habitat patches on either side of road at the locality;
- Maximum Conservation Significance score of intersecting fauna linkages; and
- Average wildlife mortality/injury density estimate.

Standardised (1-100) estimates of these criteria were summed and rescaled to range between 1-100. The resulting score was then multiplied by a factor (0.5-1.0) representing the likelihood of a successful crossing occurring across the barrier (i.e. the permeability of the road). An exception was for locations not associated with road barriers such as in-stream aquatic barriers for which scores were calculated without reduction by any factor (i.e. multiplied by 1.0).

Roads were scored as follows:

- Freeway/highway: 1.0 (wide width and high traffic volume)
- Major roads: 0.8 (moderate width and medium to high traffic volume)
- Minor roads: 0.5 (narrow width and lower traffic volume)

The overall calculation used in ArcGIS was:

([ResMN] + [NV_average] + [Max_ConSc_] + [MORTMN]) x [RoadSc]

(average resistance + average total native vegetation[1] + maximum Conservation Significance score + average mortality/injury density value) x road risk factor score

Resulting scores (re-scaled to vary between 0 and 100) were used to rank crossing structure locations (from 1 to 4). Locations were assigned an overall rank of Very High (1), High (2), Medium (3), Low (4) based on rank order within quartile ranges i.e. the first quarter of locations in rank order were assigned a 'Very High' priority.

The resulting rank seeks to address locations where crossing structures are most needed to provide connectivity for fauna. However, future efforts in restoring connectivity and habitat for fauna must also be considered. Crossing structure locations for High or Very High corridors should be considered as of similar priority for implementation over the long term, even if current conditions do not warrant their construction at the present point in time.

2.2.3 Step 3: Assessing the feasibility and the timing of implementation

Subsequent re-analysis involved filtering High and Very High urgency crossing locations to only include those involving existing major roads. On-ground assessments were undertaken of High and Very High urgency locations and subjectively assessed for feasibility in implementing a fauna crossing structure at the locality. This assessment involved a subjective determination of whether A) the crossing structure was feasible from an engineering perspective and from an B) ecological perspective in their being sufficient conditions and land (i.e. for habitat creation to either side of structure) for a functional crossing structure.

The high priority locations were further filtered according to whether they are required at the present point in time. This was undertaken to distinguish locations where there are current barriers to

1 Based on an average between DSE modelled extent native vegetation GIS dataset and Ecology Australia (Ecology Australia 2006) on-ground mapping of a select number of locations within Frankston. The first dataset largely over-estimates the extent of intact remnant vegetation while the latter was largely focused on higher quality areas of habitat and potentially underestimated in some cases, the extent of native vegetation.

movement (e.g. roads) currently restricting movement of fauna between areas of suitable habitat. These locations are required at the current point in time to improve connectivity for fauna.

Consequently, a location was deemed as 'currently' requiring a crossing structure if it met the following conditions:

i) bordered on both sides by larger areas of fauna habitat (i.e. patches or corridors) AND

ii) intersects a road of wider width and/or higher traffic flow AND

iii) along (or within close proximity to) a High or Very High priority corridor

These were then re-evaluated by on-ground inspection of locations considering the current habitat present and also the results of fauna casualty analysis (i.e. casualty hotspots).

2.2.4 Step 4: Determining the type of crossing structure required at higher priority locations

The type of crossing structures required at any one locality was determined using several criteria. Initially, the ideal type(s) of crossing structure(s) recommended at any one locality was determined by the following criteria or calculations:

- Overpasses for intersections between higher priority linkages and freeways or major highways;
- Box culvert underpass structures for intersections between higher priority linkages and major roads;
- Rope-bridges where high tree cover occurs within 200m of proposed crossing structure location; and
- Fish-passage structures or removal of barriers for any identified fish barrier identified in a Melbourne Water GIS dataset or intersections between roads and aquatic corridors or waterways.

These were re-assessed based on the:

- Target fauna records and casualty records near the locality;
- habitat present within the local area; and
- feasibility considering ecological and engineering constraints

Fauna records (focusing on target species) and casualty records within 500m of locations for potential implementation of crossing structures were collated and reviewed. Records associated with nearby patches of habitat were also visually inspected to determine what groups or target species connectivity could be achieved for and the connectivity objective of any associated corridor linkage. Attention was given to target species which require a certain type of crossing structure such as records of Black Wallabies which require larger-sized box culverts compared to other target ground-dwelling vertebrates. The desirable type of crossing structure at each locality was determined in this way. This was followed by an assessment of the types of crossing structures which could be feasibly and practicably installed at the locality considering engineering constraints, cost, and constraints on creating a functional habitat linkage at the locality within the near future. These assessments were constrained to Very High and High urgency locations.

Types of crossing structures for ground-dwelling fauna movement differ largely in size and the number of different fauna groups or species connectivity is achieved for (see Table 2 and Table 3). For ground-dwelling faunal movement, crossing structure types vary from land-bridge at the higher connectivity scale to smaller-sized underpasses (e.g. small pipe structures; Table 2) at the lowest end of the scale, following a decreasing level of potential connectivity for fauna groups.

Not all locations identified by this study (APPENDIX 6) should be immediately addressed. Rather, this information should be used to guide road development and structure placement into the future. Ideally, crossing structures should be considered *before* roads (or upgrades) or other developments become a barrier to faunal movement.

2.3 Fauna Linkage Parameters and Crossing Structure Design

2.3.1 Fauna Linkage Parameters

McCaffrey and Henry (2010) undertook an extensive review of corridor, buffer, and core widths for Fauna Linkages for the study area and parameters are largely taken from this recent study. A review of recent literature in the intervening time (2010-2012) was undertaken along with reference to recent reports. The benefit of different corridor widths was updated to include aquatic fauna (e.g. Dwarf Galaxias) while parameters for birds and frogs were also included. The major documents guiding parameter specifications included:

- Bennett, F. A. (2003) Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN, Gland Switzerland, Cambridge, UK.

- Danger, A. & Walsh, C. J. (2008) Management options for conserving and restoring fauna and other ecological values of urban streams in the Melbourne Water region. A report to Melbourne Water., Report for Melbourne Water by Department of Resource Management and Geography, University of Melbourne, Melbourne.

- Department of Sustainability and Environment (2011) Sub-regional species strategy for the Growling Grass Frog. Victorian Government Department of Sustainability and Environment.

- Hansen, B., Reich, P., Lake, S. & Cavagnaro, T. (2010) Minimum width requirements for riparian zones to protect flowing waters and to conserve biodiversity: a review and recommendations - with application to the State of Victoria. Report to Department of Sustainability and Environment by School of Biological Sciences, Monash University, Clayton, Victoria.

- McCaffrey, N., Henry, J. & Goodman, Z. (2010) Assessment of Potential Biolinks in the Botanic Ridge Precinct: Habitat Linkages to the Royal Botanic Gardens Cranbourne. Report for Royal Botanic Gardens Melbourne by Practical Ecology Pty Ltd, Preston, Victoria.

- McCaffrey, N. & Henry, J. (2010) Ecological Connectivity Plan for the South-east region of Melbourne. Practical Ecology Pty Ltd, Preston, Victoria.

- O'Malley, A. (2011) Southern Brown Bandicoot Sub-Regional Strategy: technical report and recommendations. Report produced by Practical Ecology Pty Ltd for the Department of Sustainability and Environment, Melbourne.

2.3.2 Crossing Structure Design

Crossing structure design was sourced from the following documents:

- Bax, D. (2006) *Karuah Bypass Fauna Crossing Report*. Report to Roads and Traffic Authority (NSW) by Thiess Pty. Ltd., Sydney.
- Kapitzke, R. (2010) *Culvert Fishway Planning and Design Guidelines*. James Cooke University, Townsville, QLD.
- Queensland Department of Main Roads (2000) *Fauna Sensitive Road Design. Volume 1 - Past and Existing Practices.*, Queensland Department of Main Roads, Planning, Design and Environment Division, Brisbane.
- Queensland Department of Transport and Main Roads (2010) *Fauna Sensitive Road Design. Volume 2 - Preferred Practices*. Queensland Department of Main Roads, Planning, Design and Environment Division, Brisbane,
- McCaffrey, N. & Ewing, A. (2011) *Assessment of measures to mitigate habitat fragmentation across a transport corridor*. Report for the Peninsula Link project - Linking Melbourne Authority, prepared by Practical Ecology Pty Ltd, Preston, Victoria.
- van der Ree, R., Clarkson, D. T., Holland, K. G., N. & Budden, M. (eds.) (2008) *Review of mitigation measures used to deal with the issues of habitat fragmentation*. Report for Department of Environment, Water, Heritage, and the Arts (DEWHA), Contract no. 025/2006, Published by DEWHA.
- Veage, L. A. & Jones, D. N. (2007) Breaking the Barrier: Assessing the Value of Fauna-friendly Crossing Structures at Compton Road. Brisbane City Council, Griffith University, Brisbane.

2.3.3 Geographical Information Systems

The majority of data processing and analysis were undertaken in ArcGIS 9.3 and ArcGIS 10. Specific data processing was undertaken using Quantum GIS V.1.7.0 "Wroclaw" (QGIS 2011; http://qgis.osgeo.org), a free, open source multipurpose GIS platform, and Geospatial Modelling Environment or Hawth's Tool extension (Beyer 2012).

2.3.4 Faunal Movement Resistance Mapping

Resistance maps developed for Melbourne Water in a separate study (O'Malley *et al.* 2012) and covering the study area assisted in informing where crossing structures were needed within Frankston. The study uses a faunal group approach including ground-dwelling mammals, woodland birds, frogs, and fish. This approach involves combining several spatial datasets representing features in the landscape representing barriers or conduits to faunal movement and/or occupation for different fauna groups. For example, a conduit for fish would be a waterway, while a barrier may be a weir or poor water quality. For ground-dwelling mammals, a conduit may be native vegetation while a significant barrier may be a major highway. Maps represent the summation, with weighting, of several landscape features representing barriers or conduits to movement and/or occupation. In themselves, these resistance maps are a coarse representation of likelihood of occupation and/or movement through the landscape for each surrogate group. The end result is a map of high to low areas of resistance to faunal movement. As a result, these maps assist in identifying areas important to facilitating movement within each surrogate group, or inversely, where there are significant barriers to movement or occupation.

2.3.5 Limitations of species and fauna casualty records

Species records were used in a number of analyses and were also used to make inferences on fauna movement within Frankston and potential use of corridors. The collated records used are compiled through time by a combination of incidental observations and survey work. There are inherent limitations of using such data. Firstly, records span a large number of years with cut-offs in the analysis and interpretation ranging from 50 to 10 years, so that records may not give a reliable picture of where animals are distributed at the present point in time. Land-use changes and losses and/or fragmentation of habitat can have large impacts on fauna over short periods of time. Secondly, not all areas have been surveyed and those that have vary in the frequency of people visiting sites and making observations. For example, it is expected that records are likely to be strongly biased towards public recreation and conservation reserves compared to private land. Ideally fauna surveys should be undertaken across a large number of evenly distributed (i.e. grid) point locations within a relatively short period of time.

Taking into account the distribution and quality of habitat can be used in combination with records to provide a more reliable indication of where species are likely to occur. However, fauna often rely on specific habitat features such as large old hollow-bearing trees or specific groundstorey features such as litter and hollows logs. This information is lacking for much of the land across Frankston, limiting the reliability of inferences made on potential fauna use of an area and potential movements. Private land in the east of Frankston has been subject to little fauna surveys or habitat mapping.

Some species are also more easily observed than others such as birds active during the day-time compared to nocturnal mammal species that sleep in hollows during daylight hours. This could result in records suggesting the latter species is less widely distributed or abundant in an area than in actual fact. Detailed tracking (i.e. radio-telemetry) or genetic studies are required to make accurate inferences on movement of fauna species at the individual or population level respectively. Studies such as these and further fauna surveys would provide greater insights into fauna movement across Frankston.

Casualty records

Fauna casualty data was used with caution as it has significant limitations where information is collected on an ad-hoc basis. For example, records are strongly biased towards larger and more conspicuous animals and where human population density or traffic is higher (i.e. more people to observe a dead animal). Also, species may differ in the likelihood of being visible to observers after a fatal collision with a vehicle: some fauna species are more likely to remain directly on the road or roadside while others are likely to travel further away beyond the point of collision and from human observers. The type of vegetation at the fatality point will also influence records, with animal carcases less likely to be observed in dense vegetation versus gravel roadsides. Also, records often lack the identification of species (i.e. ‘possum’) and where they do, identification to the species level by non-experts must sometimes be handled with care.

3. FAUNA LINKAGES: PRESENT CONNECTIVITY AND FUTURE OPPORTUNITIES

A large number of linkages (n=187) within Frankston and adjoining municipalities were identified and individually digitised in GIS software for spatial analysis (Figure 6; APPENDIX 8). Ninety-six (96) of these were habitat patches (Figure 4) and 91 were corridors (Figure 5). Over half of the linkages (104) assessed are located entirely within Frankston with remainder providing larger landscape connectivity (Figure 30).

3.1 Existing fauna connectivity

In investigating connectivity for fauna within the study area, 131 existing linkages facilitating structural connectivity were identified. Of these, 96 were patch linkages (Figure 4) and 35 were corridor linkages (Figure 5). Eighteen were assessed as aquatic or riparian corridors with the remainder (17) being terrestrial corridors. Over half of these existing terrestrial corridors run along roadsides or railway lines (n=9).

A small number of core areas are extent within the investigation extent (n=9) compared to less fragmented (n=17) and more fragmented (n=21) node linkages. Stepping stone type linkages represented the greatest number (n=47) of linkages although a large proportion were small in size compared to the other types of patch linkages. These results show that more fragmented fauna linkages are generally more frequent within the study area compared to more intact areas of fauna habitat. Conversely, less fragmented and larger types of patch linkages are relatively rare within the study area extent and therefore, of high importance. Core areas are largely isolated from one another with continuous corridor linkage (i.e. not a stepping stone type) non-existent within the study area pointing to poor structural connectivity among the most important areas of fauna habitat.

3.2 Potential corridor linkages

An additional 56 corridor linkages were proposed in improving connectivity for fauna within the study area (Figure 6). Linkages were largely proposed for providing structural connectivity among core areas and nodes but incorporating stepping stone patch linkages where practicable. Of proposed linkages, the majority (50 out of 56) were assessed as terrestrial corridors with the remainder potential aquatic or riparian linkages. Of the terrestrial corridors, nearly half are ‘stepping stone’ type corridors.

The large number of stepping stone type corridors largely represents the low feasibility of implementing continuous corridors across Frankston LGA due to heavily urbanised nature of many areas and the high level of habitat fragmentation and infrastructure barriers already present. Proposed continuous corridors (terrestrial, riparian, and aquatic) were more commonly proposed outside Frankston LGA or at the fringes in the east, north-east, and south-east, due to lower levels of urbanisation, dominance of agricultural land and associated lower cover of permanent infrastructure (i.e. houses, buildings etc.). An exception was an area located at the centre of the municipality (between Ballarto Rd and Cranbourne-Frankston Rd) which is largely undeveloped, supports little existing permanent infrastructure and is dominated currently by quarries and larger node and core area linkages. Several continuous-type corridor linkages were proposed for this area and assessed against other linkages. Elsewhere within Frankston, urban infrastructure barriers greatly restrict the potential for continuous habitat type linkages for less mobile and more fragmentation sensitive ground-dwelling fauna.

3.3 Linkage scale

A number of corridor linkages were considered to provide (existing or potential) landscape scale connectivity (Figure 30, APPENDIX 1). Landscape scale linkages were ones identified from a modelling study of fauna connectivity across the Port Phillip and Westernport Region for Melbourne Water (O'Malley et al. 2012; see APPENDIX 8, Sections 8.1 and 8.2.2). Largely these are proposed linkages (Figure 6) as opposed to existing ones. They provide connectivity between larger (>10ha), higher-quality fauna habitat patches at a landscape or regional scale. These linkages can provide structural connectivity to large patches of fauna habitat to the south in the Mornington Peninsula (i.e. Mt Eliza Regional Park and Devilbend Reservoir), to the south-east along the Western Port coastline (i.e. Yaringa, Quail Island, and Hastings patches), to the east (Royal Botanic Gardens Cranbourne, Koo Wee Rup patches), the north-east (Edithvale Wetland and Braeside Park patches), and north towards the foothill habitats of the Dandenong Ranges.

Figure 4. Existing patch linkages supporting fauna habitat and providing landscape permeability. For definitions of different patch types see APPENDIX 8.

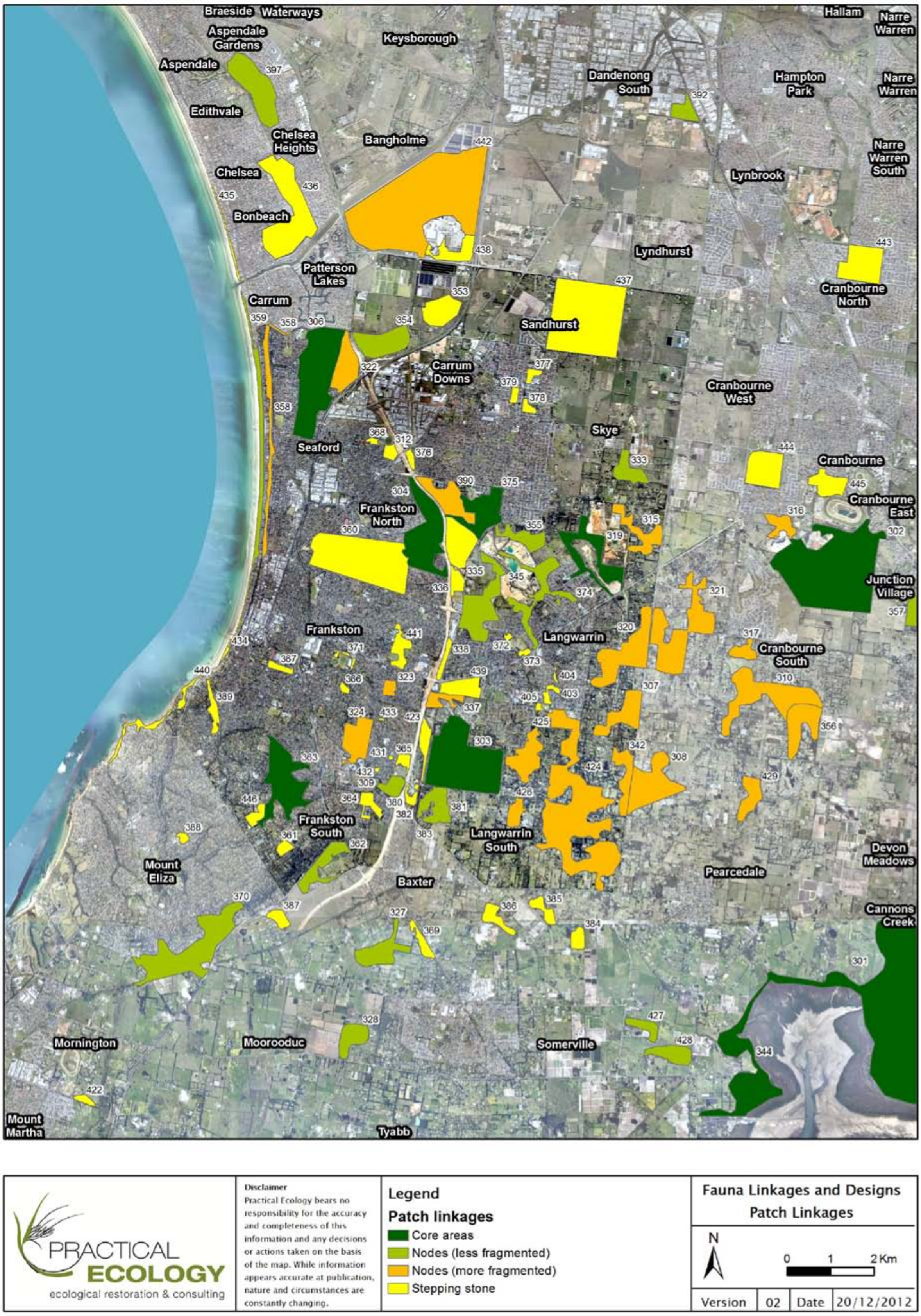


Figure 5. Types of **existing** corridor linkages assessed by the study against Conservation Significance, Feasibility, and Opportunity criteria (see Section 8.1). Shown with all other existing patch linkages (green) assessed in the study.

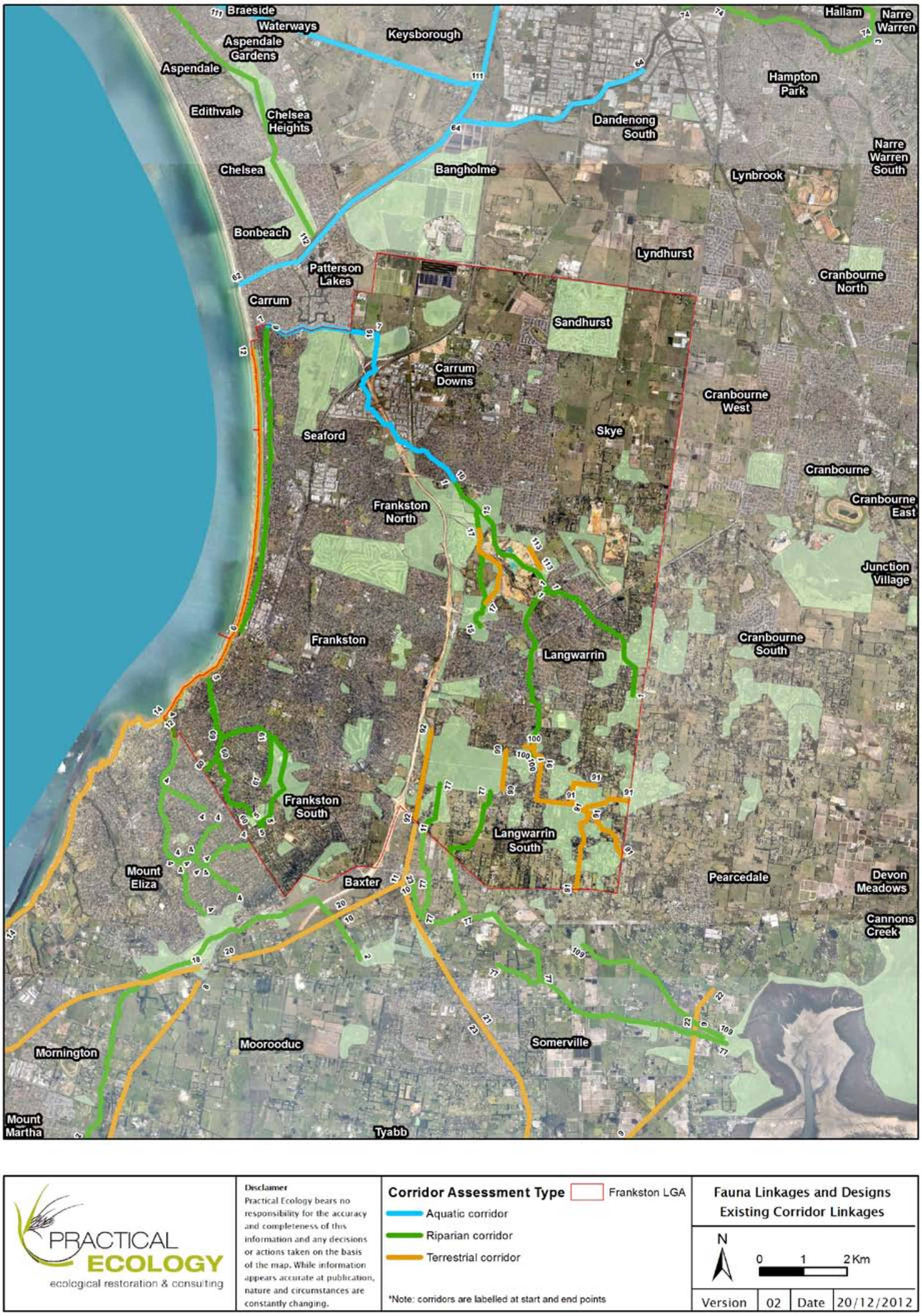
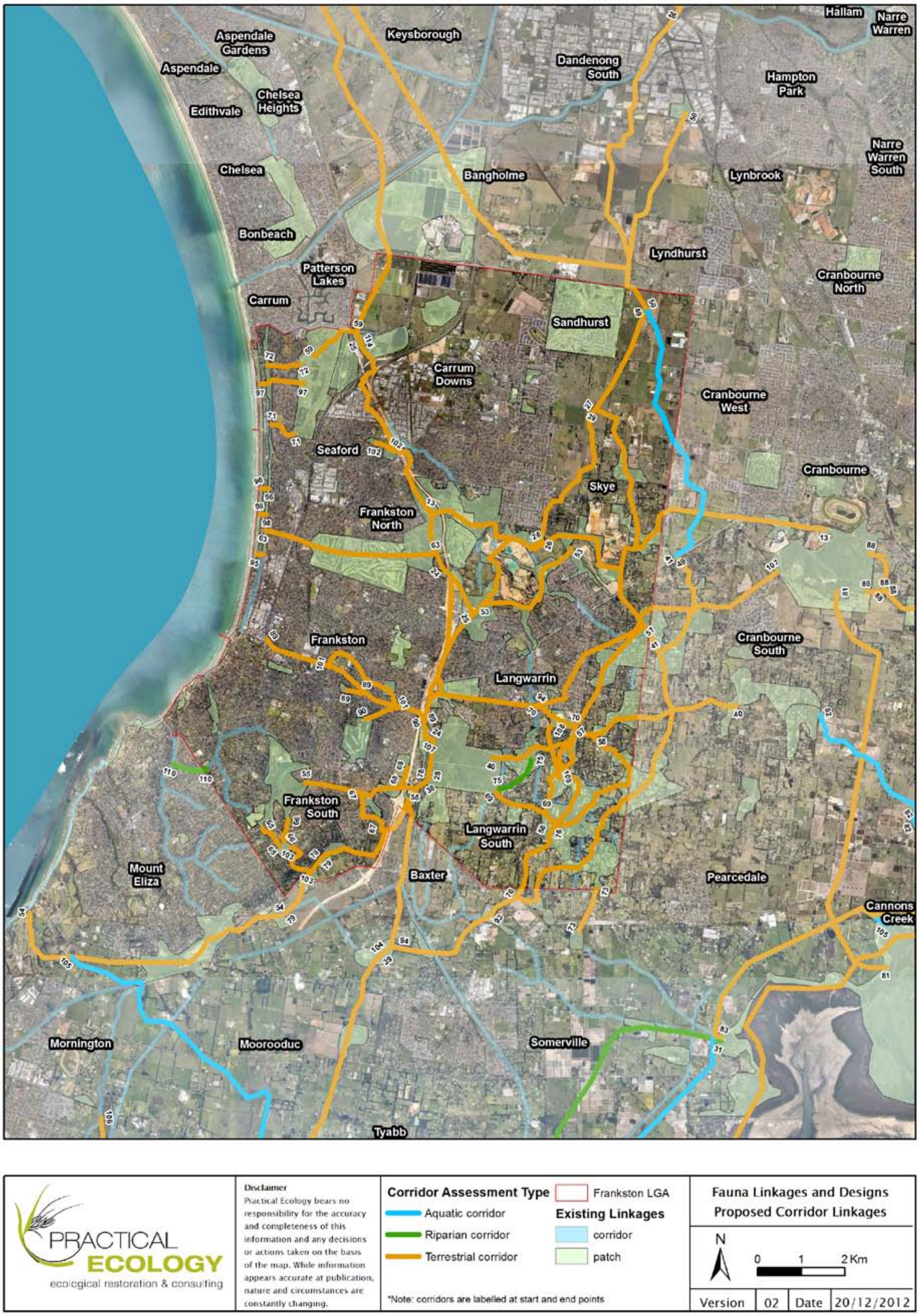


Figure 6. Types of **proposed** corridor linkage segments assessed against Conservation Significance, Feasibility, and Opportunity criteria with the overall aim of improving landscape permeability for fauna. Shown with all other existing (light blue) and patch linkages (green) assessed in the study.



3.4 Fauna Linkage Priority

The rank priority of linkages was assessed separately for patch and corridor type linkages. This means that corridors were only compared to other corridors and patches only to other patches. Corridor linkages assessed as having a High or Very High rank priority are illustrated in Figure 7 below. Results of the analysis are given in Table 7 (APPENDIX 3) including the status, type (e.g. riparian or terrestrial linkage), scores, and priority ranking of each linkage assessed. Full results (i.e. scores) for each linkage under the criteria of Conservation Significance, Feasibility, and Opportunity are provided in APPENDIX 4. The assessed priority of patch linkages are given in APPENDIX 5 and illustrated in Figure 34. Corridor linkages are presented in the main report as they are the focus of the current investigation, as opposed to the management of patches. Detailed descriptive information including values, threats, and barriers to connectivity are provide for all higher priority linkages in 0 (APPENDIX 2).

3.4.1 Priority of Corridor Linkages

Corridor linkages connecting the larger core areas were generally of higher priority as were landscape scale linkages (Figure 30) running through largely agricultural/Green land. Very High priority ranking of corridors placed greater emphasis on linking Frankston core areas to those outside the municipality through land with lower levels of urbanisation. The recommended High and Very High Priority linkages together form a corridor network which would provide a high level of connectivity for fauna.

Within Frankston, higher priority corridors generally connected larger core habitat areas such as Langwarrin Flora and Fauna Reserve ('Langwarrin FFR'), the Pines Flora and Fauna Reserve ('Pines FFR'; core area and associated nodes), Seaford Wetlands, Frankston Reservoir, but also the Langwarrin Woodlands nodes. Also of higher priority were landscape scale corridors linking these large areas of core fauna habitat to ones outside of Frankston such as the Royal Botanic Gardens Cranbourne (RBGC), Western Port coastline core area, northern sections of the Melbourne Water treatment plant, the northern foothills of Dandenong, and several core areas south in Mornington Peninsula Shire.

Very High priority *continuous* corridors largely within Frankston included the Pines Flora and Fauna Reserve–Burdett's Quarry to RBGC link (ID# 13), the Burdett's Quarry core area to Studio Park node link (ID# 53), the Melbourne Water Eastern Treatment Plant to Seaford Wetlands link (ID# 59), and the Frankston–Seaford Foreshore link (ID# 12). *Stepping stone* corridors of Very High priority only included one link connecting Langwarrin Flora and Fauna Reserve to nodes in Frankston north (ID# 28).

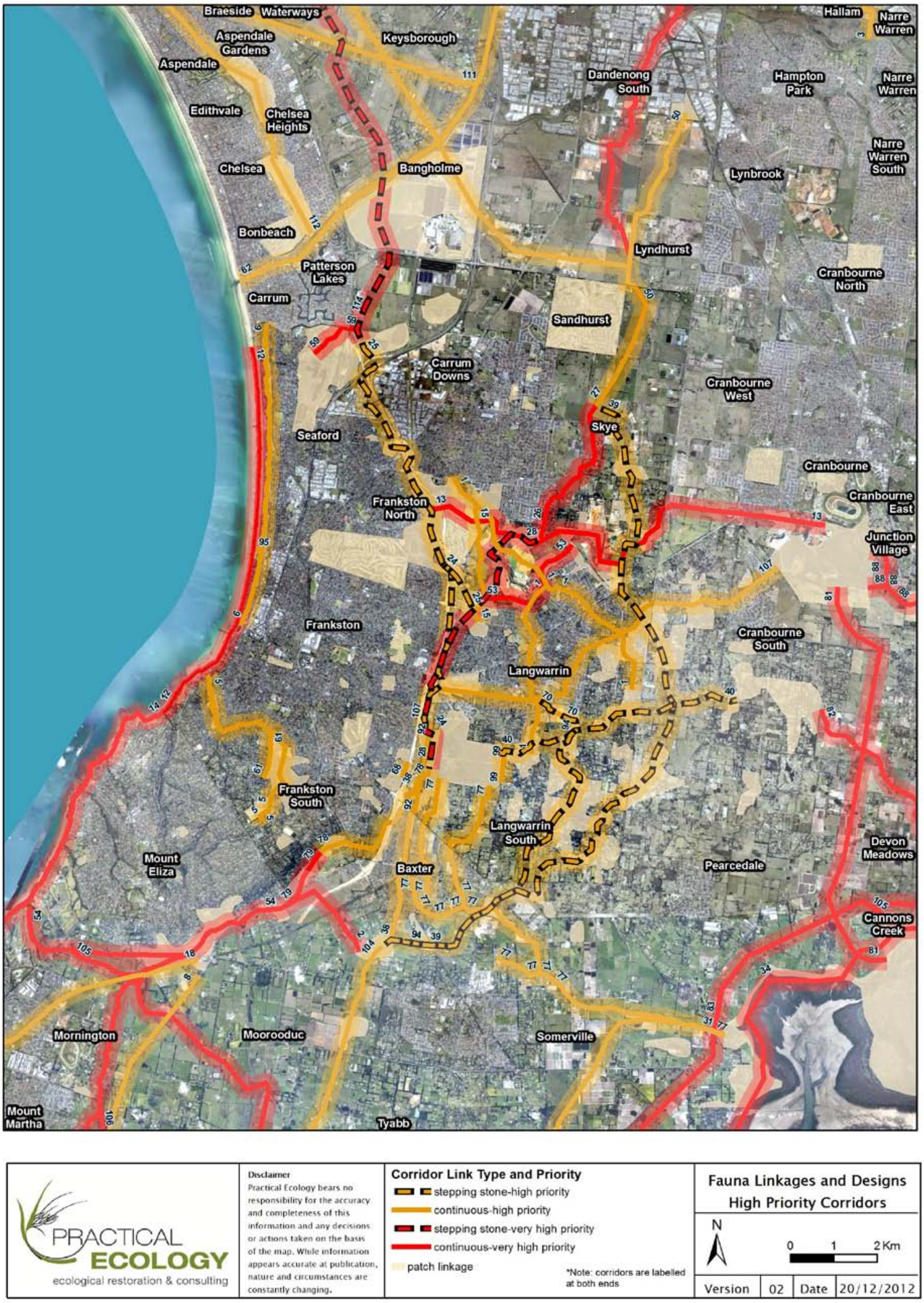
High priority *continuous* corridors within Frankston included the Kananook Creek link (ID# 6), the Boggy Creek link (ID# 1), linkages along Sweetwater Creek to Frankston reservoir (ID# 61 and 5), a narrow potential corridor between Langwarrin FFR and the RBGC in Cardinia Shire (ID# 107), and a short link between the Pines FFR and Studio Park node (ID# 15). High priority *stepping stone* corridors included the Studio Park to Seaford Wetlands link (ID# 25), the Boggy Creek to Langwarrin Woodland link (ID# 94), Pines FFR to Langwarrin FFR link (ID# 24), and a potential corridor connecting Langwarrin FFR to Sweet Wattle node in Cardinia Shire (ID# 40).

High Priority corridors beginning in Frankston but largely in adjoining municipalities included ones connecting Langwarrin FFR and Langwarrin Woodlands to the large core habitat areas along the Western Port coastline (ID# 31, 39, 77) and also to the south in Mornington Peninsula Shire (ID# 38, 79). Similarly, corridors linking the Seaford Wetlands and core-node habitat areas in the north of Frankston to large areas of habitat to the north were of higher priority. A Port Phillip foreshore corridor (ID# 14) continuing the Frankston-Seaford Foreshore link (ID# 12) was also of higher priority. These are largely proposed (i.e. not existing) linkages required to achieve larger landscape connectivity for fauna and between more significant areas of fauna habitat within the region. Overall, greater emphasis was placed on connecting Langwarrin FFR, the Pines FFR, the RBGC, and Quail Island-Warneet nodes and core areas along with northward, Port Phillip coastline, and south-west links.

Noteworthy higher priority linkages entirely outside Frankston, but important for achieving larger landscape-scale connectivity for fauna, included several potential linkages running south-west or south from Frankston, the south-east RBGC to Koo Wee Rup link (ID# 88), the RBGC to Western Port coastline link, and the Western Port coast link (ID# 34)

The prioritised linkages (High and Very High urgency linkages) should be used to guide future decisions and investment for achieving fauna connectivity over a long time frame (>25yrs). Immediate focus should be on corridors which can be implemented largely by efforts within Frankston LGA although long-term planning should involve consideration of corridors in adjoining municipalities to achieve larger-scale landscape connectivity for fauna. A large proportion of higher priority corridors are proposed ones which require the establishment of habitat for fauna over a long time-frame. Two corridors recommended for urgent implementation are detailed in Section 5 below.

Figure 7. Identified corridors of High or Very High priority where relative rank was determined by comparison to all other corridor linkages. Corridor ID numbers include labels at either end of corridor route.



3.5 Fauna Linkage Design Principles, Parameters, and Actions

This section provides advice on fauna linkage design principles, parameters, and actions to achieve the linkage parameters. The latter includes both planning decisions and on-ground actions for implementing proposed linkages (Figure 6) and improving existing ones (Figure 5). A broad investigation of possible mechanisms for linkage implementation is also provided in this section along with on-going overarching management recommendations for the entire linkage network. Detailed descriptive information, priority rank, and recommended parameters for each linkage is provided in APPENDIX 2. More specific parameters are provided for a smaller number of corridors recommended for more urgent implementation (see Section 5).

3.5.1 Remnant vegetation management

Following the Triple R or biodiversity trinity (Buchanan 1989; DSE 2003) of bush regeneration, the first priority within linkages is to protect and enhance existing remnant vegetation. These can serve both as stepping stones for fauna and also as island seed sources for the natural regeneration of any adjacent cleared land.. The second priority should be restoration of lower quality remnants, followed by rehabilitation of the most degraded remnants. Promoting higher floristic diversity will increase the structural complexity of habitats along with increased food and shelter resources that are more seasonally stable.

3.5.2 Habitat components

A large proportion of proposed landscape scale linkages of recommended high priority have very little remnant vegetation. In these circumstances the priority would be on reserving land for conservation purposes, followed by broad scale revegetation. Higher floristic diversity will increase food and shelter resources for fauna. Along with the provision of habitat structural complexity (e.g. logs, litter, hollows, groundcover species, shrubs, and trees), these two factors may be the most important for positive outcomes for fauna in revegetation projects (Bennett, Kimber and Ryan 2000b). The provision of tree hollows through time is particularly important for arboreal fauna and many bird species. However, higher costs associated with increasing floristic diversity must be weighed against any potential gains and the specific circumstances of implementing each linkage, for example the available pool of finances and resources.

Restoring vegetation along corridors can be guided by standards developed for two corridors for urgent implementation detailed below (see Section 5) which are based on target fauna species habitat and connectivity requirements (Table 13). More detailed decisions on floristic composition of revegetation works can draw from relevant Ecological Vegetation Class (EVC) predicted to previously occur within an area (Oates and Taranto 2001). Predicted mapping should be used in conjunction with more detailed local information including historical survey information, geology, soil type, and rainfall. Local remnant vegetation should also be referred to when deciding on species to be included in any revegetation or rehabilitation works. In the shorter-term, a combination of common species should be selected that will have high recruitment success and provide important structural habitat components. As mentioned earlier, broad habitat components include:

- groundcover species (ideally species which produce a more dense ground cover);
- shrubs;

- canopy trees and hollows;
- logs and litter;
- water-bodies (ephemeral or permanent) such as wetlands, ponds, and lakes;
- wet depressions;
- in-stream aquatic environments (e.g. rivers and creeks).

The first four are some of the basic structural components of most non-aquatic habitats such as woodlands, forests, heaths, and grasslands. Ideally, for forest and woodland restoration, revegetation of the three major habitat strata (indigenous groundcover, shrubs, and trees) should occur in the first instance as this avoids cost issues with easily establishing an indigenous groundcover when a shrub or tree cover is already established. However, where there are financial constraints, direct seeding of a shrub and tree cover may be the only initial feasible option in the short-term. Establishing shrub and tree species in combination with providing structural connectivity for frugivorous bird species can facilitate the natural dispersal of fleshy-fruited indigenous flora species within a linkage. Frugivorous bird species are important seed dispersers for fleshy-fruited species and the provision of roosting sites can aid in re-colonisation of sites by these plants. Similarly, ground-dwelling vertebrates, particularly mammals such as the Black Wallaby, may be important vectors for indigenous grass seeds and fungi. These examples can be viewed as positive feedback in establishing linkages capable of providing connectivity for a broad range of fauna, which in turn can aid revegetation efforts.

Existing linkages should also be assessed for the presence of these important habitat components and where lacking, investment should be made into restoring the habitat component. The addition of basic habitat components should be pursued through time in each linkage that is committed to being established by multiple government agencies and the broader community. Appropriate benchmarking prior to any restoration/revegetation works followed by monitoring is also essential for the long-term success of such works and is discussed in more detail below. At larger spatial scales, the restoration of riparian and wetland areas has been considered a priority biodiversity objective in implementing wildlife corridors (Bennett 1990; Bennett 2003; Parsons 2005; Semlitsch and Jensen 2001). Primarily this is because riparian areas may support higher biodiversity values and greater habitat resources for fauna. In addition, wetlands are rare in current landscapes and are crucial to the lifecycle of many fauna, including migratory and wetland bird species. This would apply to landscape-scale connectivity for fauna over tens of kilometres. Restoring riparian linkages connecting larger core patches in Frankston and also in providing connectivity for fauna to more distant core areas outside Frankston should be given some priority. However, inclusion of terrestrial linkages is also important for providing the greatest range of habitats for the greatest number of fauna species.

A detailed review of target fauna species (Table 8) habitat requirements (Table 13) was undertaken to provide guidance on required specifications for habitat creation within the recommended corridor linkages. These are provided in Section 5.3 and should guide the provision of habitat along the recommended corridors. Estimated distribution and movement patterns of target species within Frankston (Table 12) should also guide on-ground works and objectives for the implementation and management of corridor and patch linkages.

3.5.3 Corridor Width

The general consensus on corridor dimensions is that wider corridors with a higher interior (area) to edge ratio are better. Consequently, there is no one size of corridor that is optimal (Bennett 1990) and the widest possible width is recommended to be pursued in all cases. Increases in these two characteristics are considered to improve the likelihood of providing functional landscape connectivity for fauna. An optimal width is one where connectivity is maintained for the species it is intended to provide connectivity for (Bennett 2003). However, there is very limited evidence for species specific responses to different corridor widths in varying landscape contexts (i.e. rural versus urban) in Australia. Nonetheless, wider areas also confer greater resistance to edge effects (see Glossary Section 7) as well as adjacent land uses and issues such as erosion, pollution, light and sound pollution. Possibly the most important is greater resistance to weed invasion due to a reduction in disturbed edge environments in which weed species are highly competitive due to their adaptation to disturbed environments.

Consequently, wider linkages are also more easily maintained and have a higher likelihood of good quality fauna habitat being established which can support resident fauna populations. More narrow corridors of habitat are still important for animal dispersal (see Glossary in Section 7) as well as providing food resources and shelter (Bennett, Kimber and Ryan 2000a), and in some specific cases may support resources lacking or of higher value than those in wider linkages or interior patch habitats. Target fauna groups selected for this study include both urban tolerant and edge or fragmentation sensitive species which may have varying responses to different corridor widths (Table 1). However, an apparent trend in this assessment (Table 1) is that wider corridors are likely to greatly increase the number of species of target fauna capable of using a linkage. Consequently, the widest possible corridor width should be pursued wherever practicable, to provide connectivity for the greatest number of fauna species and guilds.

Within the study area, additional consideration must be given to requirements for:

- Buffers from edge effects
- Core habitat corridor widths required to facilitate functional connectivity for fauna
- Fire break and fuel modified area requirements
- Open space planning

The first three of these considerations determines the component parts of a corridor linkage cross section. Hence, a corridor consists of an:

i) inner ‘core’ habitat presumed to be uninfluenced by edge effects and offering the highest quality habitat for fauna;

ii) a buffer area for negating any edge effects but consisting of the same habitat/vegetation provision as the core; and

iii) in some cases, an outermost zone for public open space and/or fuel-load reduction (fire management). This zone can also incorporate an access management trail and any fencing required.

Buffer widths: to counter edge effects, recommended buffer widths in the literature vary from 30m for remnant vegetation (Dostal 2000) to 1000m to reduce any edge effect from roads (Forman et al.

2003). However, a recommended average across studies equates to 50m (Gardner 1998; Matlack 1994; Paton 1994). For some linkages in which the total corridor width is restricted to <50m, edge effects will extend throughout the entire width. In such circumstances, a reduced function should be expected largely confined to facilitating rarer longer-distance dispersal events for fauna with greater movement capabilities (i.e. birds and some arboreal species). Habitat provision within such corridors is restricted to more urban tolerant fauna species. Implemented buffer widths should be monitored across different vegetation types to assess whether the provided width is sufficient. This is due to different vegetation types possibly being more prone to edge effects such as weed invasion than others. This will also differ according to site specific conditions such as former land use (i.e. soil nutrient levels), adjacent land uses, and the type of land rehabilitation or revegetation committed to.

Total corridor width: Recommended minimum corridor widths from the literature vary from 50m to 1000m. Recommended widths vary based on fauna groups or function. Eighty metres is recommended for birds in general (Parsons, Major and French 2006), although 100m is recommended for development-sensitive birds and between 300 to 600m wide for forest-interior birds (Mason et al. 2007). For semi-aquatic species a width of 92.6 - 164m wide is recommended (Semlitsch 1998) and a >200m width for forest-dependent arboreal mammals (Lindenmayer 1994). Widths of 50-60m have been recommended for linear strips of habitat (Lambeck 1999) up to at least 350m for corridors through terrestrial environments (Doerr, Doerr and Davies 2010). A corridor width of >200m has been previously recommended in the study area for sensitive ground-dwelling fauna, although more narrow widths can function for rare dispersal events in agricultural landscapes and ones in which predation pressure is lower (O'Malley 2011).

3.5.3.1 Recommended width specifications

The total recommended width of corridor linkages is defined by an estimate of the maximum attainable considering existing infrastructure (e.g. buildings, roads etc). 0 (APPENDIX 2) provides recommended (i.e. desirable) minimum buffer widths, core widths, and the average overall maximum corridor width attainable for each investigated corridor linkage when considering ecological requirements of target fauna, landscape context and existing infrastructure. An evaluation of target fauna group and representative species has been undertaken (Table 7) and shows that species will vary in their response and utilisation of different corridor widths. Estimates of minimum corridor widths required for most indigenous fauna species are lacking in the scientific literature. As a result, only a best-guess approach informed by available information is possible. The following corridor components and specifications (illustrated in Fig. 10) are recommended for providing connectivity for the greatest number of fauna groups:

Open public space/fire management zone: ~10-80m on either side (20-160m)

- This zone may be largely required only in urban or peri-urban situations or where dwellings are situated close to a corridor.
- Highly modified zone largely consisting of mown areas and isolated clumps of shrubs and sparse tree canopy cover. This zone will have some but limited value for fauna, principally urban-tolerant bird and arboreal mammal species that can make use of scattered trees and isolated patches of shrubs. However, even where an entire corridor length consists of habitat to the specifications of this zone, important structural connectivity can be provided for these common species which in turn provide important services in ecosystem function and overall health within a fragmented landscape.

- The width dimensions are based on specifications for buildings in an area covered by a Wildfire Management Overlay under the Victorian planning scheme (clause 44.06 and 52.47). Width may be less where an overlay does not apply or where there are no existing or proposed buildings. Consultation with the CFA is required on a case-by-case basis along with an assessment of slope, vegetation type and the position in respect to existing or proposed dwellings.

Buffer zone: 50m minimum on either side (100m)

- Consisting of the same habitat provision as core habitat but acknowledging a lower attainable quality due to edge effects. Depending on the adjacent land uses (e.g. whether roads, freeways, residential land, agricultural land) fauna utilisation may vary from similar to that in the core habitat to a much reduced utilisation. Largely differences will be in the types of fauna groups and species utilising buffer (edge) versus core (interior) habitats based of their sensitivity to edge effects. Edge-sensitive species are likely to make less use of habitat within a buffer zone than edge-tolerant species.

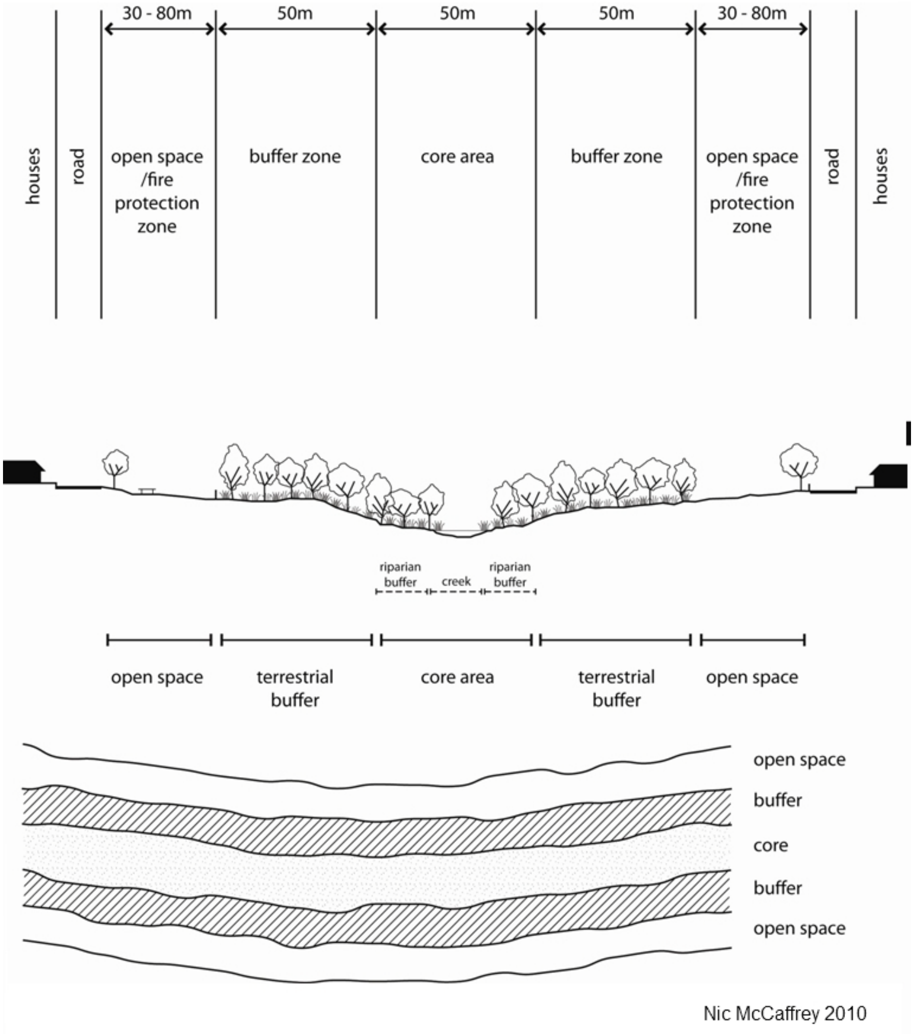
Core habitat zone: ≥50m minimum (100m for riparian habitats)

- This is a minimum width for attempting to provide core habitat for resident populations of urban-intolerant (or edge-sensitive) fauna. Lower widths may still facilitate rare, longer-distance dispersal events by edge-sensitive species. Linkages incorporating wetland areas are recommended to have a core width of >100m and should be informed by the local topography and site-specific survey information. Riparian habitats should have a minimum setback width of at least 50m from the bank edge wherever practicable (>100m total core width), with setbacks of up to 200m more desirable. Riparian linkages provide connectivity for an overall greater number of fauna guilds and species and a greater corridor width is required to incorporate a greater range of food resources and microhabitats for fauna species.

- The core zone supports the highest quality fauna habitat within the corridor footprint and the greatest range of microhabitats and environments for animals to exploit. All fauna guilds should be able to make some use of the core habitat zone, although the number of species will likely increase with greater corridor width due to a wider array of microhabitats and microclimates incorporated along with satisfying home range/foraging requirements of different fauna species (see Glossary in Section 7).

A visual representation of corridor design is shown below in Figure 8. Further recommendations and guidance can be taken from detailed specifications for two urgent corridors for implementation in the near future provided in Section 5.

Figure 8. Indicative cross-section profile of a typical corridor with a 50m core width. Note that a minimum open space/fire protection of <30m may be possible in some circumstances (e.g. grassland environments). This zone is recommended to incorporate a service track for maintenance and where required, can also incorporate any required fencing of the corridor.



3.5.3.2 Estimated use of different corridor linkage widths by target fauna species

Table 1. Summary of corridor linkage characteristics and use by target fauna species for different corridor linkage widths. Adapted and updated from McCaffrey and Henry (2010). Estimates are based on broad assumptions of fauna species use within a largely rural landscape. The 'likelihood of use' by selected fauna species in an urban context is likely to be different; with use reduced by at least one width category (i.e. ≥100m becomes ≥50m).

Fauna Group	Reference Subgroup	Width of corridor			Broad Habitat Features
		<50m	**≥100m**	**≥200m**	
		− Simple floristic and structural diversity − Does not provide interior habitat; all edge habitat − Suitable for resilient species, edge specialists, exotic or invasive species − River with little riparian set-back, or structural diversity within or surrounding water − Drainage lines with remnant native vegetation, but narrow and often subject to edge effects − Simple creek line or drainage lines with little or no veg. surrounding or within water − Drainage line with no vegetation or concreted	− Slightly more floristic and structural diversity − Does not provide interior habitat, all edge habitat − Greater number of micro-habitat types − Suitable for common adaptable species − River with some riparian set-back and some veg. and structural diversity within water − Creek line with some riparian vegetation and some structural diversity within and surrounding water − Drainage lines are not concreted, have some native vegetation such as reeds and grasses	− Greatest amount of structural and floristic diversity − May accommodate disturbance sensitive species and interior species − May provide some interior habitat − Rivers with 100m either side riparian set-back and higher diversity of structural features within and surrounding water − Creeks with greater area of riparian vegetation and higher structural diversity within and surrounding water − Drainage lines are part of larger vegetated corridors	
Arboreal	**Mammals**				
	Feathertail Glider	Could utilise if trees and understorey is present, however unlikely to provide habitat.	Could utilise for moving through the landscape between patches of habitat only if trees are present.	May utilise this for moving through a landscape or foraging for resources. Will only exist in mature forest with hollows and tall trees.	Requires hollows for nesting, spend most of their time in tree canopy above 15 to 20m. Prefer complex and mature forest. This species can glide up to almost 30m however generally will only glide a gap of 15m. (Information from Van Dyck and Strahan 2008).
	Koala	Could utilise for short link.	May be able to utilise if preferred habitat trees are present, however would not provide enough habitat to reside in.	May utilise if preferred habitat trees are present, could provide part of home range.	Has preferred feeding tree species which vary regionally. Has a home range of between 1 and 50ha according to resource availability. Information from Van Dyck and Strahan 2008).
	Common Ring-tail Possum	Good chance of at least some use both as habitat and as dispersal corridor where appropriate habitat is present (i.e. taller shrubs and Eucalypt tree canopy cover).	High likelihood of use where taller continuous shrub cover and canopy cover is present.	Greatest likelihood of supporting healthy resident populations.	Is found in a variety of habitats where shrubs are dense and form tangled foliage which can be used for the construction of dreys (nests) but can also form suboptimal nests in cavities of buildings.

Fauna Group	Reference Subgroup	Width of corridor			Broad Habitat Features
		<50m	**≥100m**	**≥200m**	
	Sugar Glider	Could utilise if trees are present.	Could utilise for moving through an environment providing trees are present. Could possibly forage within a corridor of this size if it is connected to larger habitat patch.	Preferable for this species, it is known to occur in linear strips provided there are enough hollows and food resources. Is known to occur in young forests provided there are nest boxes/hollows present.	Requires hollows for nesting, can only glide up to 50m, gaps beyond this require moving on the ground exposing it to predation. Food resources include sap, pollen and nectar, invertebrates and invertebrate exudates. (Information from Van Dyck and Strahan 2008).
Terrestrial	**Mammals**				
	Southern Brown Bandicoot	May utilise simple corridors for short distances in rural landscapes provided there is enough cover and protection from predation. Much less likely to be successful in urban or peri-urban landscapes unless corridor is predator-proofed.	Could possible utilise, again provided there is ample understorey/ground cover and exotic predator exclusion through fencing.	This is best suited for Southern Brown Bandicoot. This species has high sensitivity to disturbance, habitat loss and predation. Populations have undergone large range retractions and many are isolated and existing in sub-optimal habitat.	Requires specific habitat features such as dense understorey vegetation and suitable soil substrate for foraging. Home range varies from 05 to 5ha. (Information from Van Dyck and Strahan 2008).
	Black Wallaby	Could utilise relatively thin corridors in rural landscapes where some areas support dense shrub and groundcover (Di Stefano et al. 2009; Law and Dickman 1998). Less likely to utilise in urban and peri-urban landscapes and where high levels of human traffic. The species has a high potential to disperse across modified agricultural landscapes and barriers (Paplinska et al. 2009)	Would utilise these corridors provided it had thick vegetation cover in a large part of the animal's home range within urban to peri-urban landscapes. High likelihood of use in rural landscapes where a dense shrub/groundcover is present within a portion of the animal's home range.	This would be preferred corridor size for this species. It shows a preference for thick understorey cover, and wide corridors would provide habitat for healthy populations of the species and possibly increase gene exchange.	The Black Wallaby is commonly found in vegetation with a dense understorey for sheltering, however it will venture into more open areas for feeding. (Information from Van Dyck and Strahan 2008).
	Short-beaked Echidna	Would utilise these corridors for foraging or dispersal.	Would utilise these corridors for foraging or dispersal.	Would utilise these corridors for foraging or dispersal.	Short-beaked Echidnas are found throughout Australia in most habitat types. They require thick shrubs, hollow logs or abandoned burrows to shelter in and the presence of ant or termite nest which they feed on. (Information from Van Dyck and Strahan 2008).
	Swamp Rat	Would utilise these corridors, however requires dense ground cover for protection.	Would utilise these provided there was thick vegetation present.	These corridors could be utilised, again provided there is thick ground cover.	The Swamp Rat is dependent on thick ground and understorey vegetation for protection. It creates burrows underground, and in swampy areas above round but under a thick cover of sedges and tussock grasses. (Information from Van Dyck and Strahan 2008).
	Agile Antechinus	Could possibly utilise for short distances.	Could utilise for moving between habitat patches and some foraging provided there is vegetation cover and invertebrates present.	This size corridor is most suited to the Agile Antechinus. This species requires enough cover from predators and forages both in canopy trees and through the	The Agile Antechinus are found in a variety of habitats including forest, woodland and heathland. This species is hollow dependent and males have a home range of approximately 1ha. (Information from Van

Fauna Group	Reference Subgroup	Width of corridor			Broad Habitat Features
		<50m	≥100m	≥200m	
				understorey and ground level.	Dyck and Strahan 2008).
Terrestrial	**Reptiles**				
	Blotched Blue-tongue Lizard	Less likely to support resident populations but where a diverse range of microhabitat are present, including logs or dense vegetation providing some protection from exotic predators, use will be higher. Of greater use as a dispersal corridor.	High likelihood of use dependent on the quality of ground level habitat and densities of exotic predators.	Very high likelihood of use dependent on the quality of ground level habitat and densities of exotic predators.	A wide variety of lowland habitats in within cool temperate south-east Australia. Feeds on a wide variety of food items, including plants, insects, and sometimes fungi. Requires dense vegetation/logs/rocks as refuges from exotic predators where they are in higher density (i.e. urban areas).
	Glossy Grass Skink	Could possibly utilise if there was a dense ground storey layer, along water courses or drainage lines. Glossy Grass Skinks were found in a ditch in a modified roadside in PSP 13 (surrounded by farmland) (Mal Legg pers. comm.).	Could possibly utilise if there was a dense ground storey layer, along water courses or drainage lines.	Most suitable for this species provided there is dense ground cover within wet or swampy areas.	The Glossy Grass Skink is found in damp heathy and swampy areas with a dense ground cover (M. Legg pers. com.).
	Lowland Copperhead	Use primarily as dispersal corridors where a dense grass cover is present and some wet areas. More likely along riparian linkages.	Higher chance of use where appropriate habitats are present including dense grass/sedge cover and healthy food resources such as semi-aquatic fauna (i.e. frogs) and ground-dwelling mammals.	Highest potential to support healthy populations where appropriate habitats are present including dense grass/sedge cover and healthy food resources such as semi-aquatic fauna and ground-dwelling mammals.	Associated with wetlands and freshwater or moist low-lying areas in dry sclerophyll forests, woodlands, and heaths. Prefers tussock grass habitats
	Swamp Skink	Unlikely to utilise.	Robertson (cited in Marr et al. 2009) recommends a corridor width of 100m for long term sustainability of this species.	This could provide dispersal routes and habitat.	This species is generally found in dense tussock grass and wet heathy areas associated with watercourses or swampy areas. It requires diverse structural complexity on the ground for basking, hunting and protection from predators (M. Legg pers com.).
	Tree Dragon	Unlikely to utilise.	Could utilise for dispersal and foraging.	Could potentially utilise for foraging and dispersal if preferred habitat is present.	This species is partly arboreal and is found in woodland with dense understorey and heathy areas. It requires hollows, dense vegetation or rocks for sheltering. (Information from Wilson & Knowles 1988 and M. Legg pers. com.)
	White-lipped Snake	Could possibly utilise for dispersal.	Could utilise for dispersal and foraging.	Could utilise for foraging and dispersal. Needs structural diversity for basking and foraging.	This species prefers dense vegetation and is often found in wetter areas. This species could utilise any corridor provided there is structural diversity on the ground for protection from predators. (Information from Wilson and Knowles 1988)
Birds	**Woodland Birds**				
	Crested Shrike-tit	Possible dispersal movements over	Could possibly utilise if adjacent to large	Could utilise if the corridor was	Are sensitive to urban development.

Fauna Group	Reference Subgroup	Width of corridor			Broad Habitat Features
		<50m	≥100m	≥200m	
		shorter distances	remnant patch for short foraging trips or moving small distances from one habitat patch to another.	generally undisturbed habitat. However it is more likely to utilise if it is connected to large remnant patches.	Generally occur in large remnant patches. Very few are recorded in re-growth from logging, however have been recorded in regrowth from fire. (Information from Higgins and Peter 2002).
	Dusky Woodswallow	Could utilise this corridor for short movements between habitat patches or for foraging.	Often found along edges of habitat patches so could utilise this type of corridor for movements and foraging.	This type of corridor could provide habitat if it is a preferred habitat type of open dry forest and is close to remnants or large scattered trees.	Can remain in disturbed habitat if there is large remnant scattered trees present. Mostly an insectivorous species requires this food resource to be present. (Information from Higgins et al. 2006).
	Eastern Yellow Robin	Possible dispersal movements over shorter distances	May utilise if suitable habitat is present if dense shrubby understorey is present.	Could provide habitat if there were preferred habitat features present such as shrubby dense understorey and structural diversity such as fallen timber.	This species is sensitive to fragmentation and disturbance. May not occur even in remnant if understorey is significantly disturbed. Thus requires mature woodland with dense undisturbed understorey. (Information from Higgins et al. 2006).
	Varied Sittella	Unlikely to utilise.	Possibly some use for shorter distance dispersal events.	Could use as habitat although wider >300m corridor are likely to be required considering home range size, sensitivity to edge habitats, and possible requirement for co-operative breeding.	Largely inhabits eucalypt woodlands and forests, particularly areas supporting tree-hollows, dead branches, rough-barked trees (stringy-barks/ironbarks) but also paperbarks and a shrubby or grassy understorey. Considered sedentary and resident with few longer-distance movement recorded and a home range of 13-20 ha. Insectivorous and forages in the crowns of trees amongst bark, branches and sometimes among foliage (Higgins and Peter 2002).
	Rufous Whistler	Could utilise for short movements between habitat patches.	May utilise for movement between patches or foraging. May depend on surrounding land use and quality of vegetation present.	Could make up part of home range if the preferred habitat is present.	This species is found in a wide range of habitat types, generally with shrubby understorey. May be sensitive to disturbance such as logging and urbanisation. (Information from Higgins et al. 2006).
Semi-aquatic	**Frogs**				
	Common Froglet	Can utilise, especially for dispersal, but also for habitat where day-time shelter micro sites are present and damp areas or water-bodies/waterways are available.	Likely to support populations of the species where appropriate habitat is present.	Highly likely to support populations of the species where appropriate habitat is present.	Common and one of the most widespread of frog species. Inhabits low-lying environments in damp, grassy forest and woodland but also agricultural and residential landscapes in wet/damp situations. Requires water-bodies or slow-moving waterways to reproduce.
	Southern Toadlet	Could utilise for dispersal and foraging if appropriate habitat available.	Could utilise for dispersal and foraging.	Could utilise as part of home range.	This species is found in wet depression on the ground within leaf litter in drainage line. Habitat includes forest woodland, shrubland, grassland and heath. (Information from Hero et al. 1991).
	Southern Bullfrog	Can utilise, especially for dispersal, but	Can support large populations where	Optimal width where suitable	Very common species inhabiting a wide range

Fauna Group	Reference Subgroup	Width of corridor			Broad Habitat Features
		<50m	**≥100m**	**≥200m**	
		also for habitat where day-time shelter micro sites are present and damp areas or water-bodies/waterways are available	suitable habitat is present.	habitat is present and increases the chance of wet/damp micro sites being incorporated within a habitat mosaic in non-riparian corridors, facilitating dispersal and movement between larger areas of suitable habitat capable of supporting populations.	of wet environments. Particular preference for grassy areas around water-bodies, dams, or water-ways. Common in woodlands and forest but also agricultural and residential landscapes where habitat is present. Prefers soft-loamy soils, litter and under logs for burrowing.
	Southern Brown Tree Frog	Unlikely to utilise.	Could possibly utilise if there is sufficient native vegetation for protection, shelter micro sites (rocks, logs etc) and foraging and damp areas or near water.	Could utilise provided there is moist damp areas and sufficient cover.	This species is terrestrial and semi-arboreal. Are generally found in damp areas and tadpoles are aquatic. It is found in a variety of habitats such as; wet and dry forest, grassland, shrubland, rainforest and woodland but depends on the presence of water. Requires rocks, logs and other ground-level debris for sheltering during the day and habitats with low vegetation to forage during the night. (Information from Hero et al. 1991).
Semi-aquatic	**Reptiles**				
	Common Long-necked Turtle	Will move through open areas. Could utilise a simple corridor over shorter distances (<400m) provided there are underpasses under roads or other hazardous structures	Will move through these corridors as well but dependent on provision of aquatic habitats, however have mortality risks associated with roads	High potential for use as terrestrial habitat if aquatic habitat is also present. Barrier to migration is cited as an obstacle to improving connectivity for this species (Danger and Walsh 2008).	Snake-necked turtles are carnivorous eating fish, tadpoles, crustaceans, invertebrates and carrion. They can travel long distances terrestrially. However this species requires either temporal or permanent water for part of its life-cycle (Wilson and Swan 2008)
Aquatic	**Fish**				
	Dwarf Galaxias	Can utilise for dispersal events dependent of waterway health. Riparian setbacks of >40m in low intensity land use contexts can provide improved food and habitat resources. Less likely to be used in an urban context.	Higher potential to support populations of the species through providing improved food and habitat resources along with in-stream biodiversity, although dependent on in-stream water quality and urban storm-water impacts.	Highest potential to support populations of the species in an urban context. Dependent on water quality.	Generally found in cool, slow moving creeks, drainage lines and shallow wetlands that are not impacted by storm water or poor water quality. Benefits from lower water temperatures that their main competitor Eastern Gambusia *Gambusia holbrooki* is intolerant of. May also aestivate in ephemeral water-bodies.
	Common Galaxias	Can utilise degraded urban streams <50m setback for dispersal events and may possibly use landlocked water-bodies as breeding refuges from predation and competition with exotic fish species. Riparian setbacks of >40m can provide improved food and habitat resources.	Higher potential to support populations of the species through providing improved food and habitat resources along with in-stream biodiversity where not on steep slopes or lower-order streams. May benefit from higher water quality (Hansen et al. 2010).	Highest potential to support populations of the species in an urban context dependent on high water quality and provision of in-stream habitat features and resources.	Can utilise waterways with higher water temperatures than other Galaxiid species and does not require fast-flowing waterways. Populations may persist in landlocked water-bodies but will migrate upstream after spawning if given the opportunity. Less likely to occur in the presence of exotic brown *Salmo trutta* or rainbow trout *Oncorhynchus*

Fauna Group	Reference Subgroup	Width of corridor			Broad Habitat Features
		<50m	≥100m	≥200m	
					mykiss. The exotic Eastern Gambusia *Gambusia holbrooki* are not a competitive threat until *G. holbrooki* abundance is high (i.e. ratios above 3:1) (Information from Danger and Walsh 2008).
	Southern Pygmy Perch	May utilise for dispersal events dependent of waterway health in rural landscapes. Riparian setbacks of >40m in low intensity land use contexts can provide improved food and habitat resources. Use less likely in an urban context.	Higher potential to support populations of the species through providing improved food and habitat resources along with in-stream biodiversity, even in high intensity land use contexts, where not on steep slopes or lower-order streams (Hansen et al. 2010)	Highest potential to support populations of the species in an urban context. Dependent on water quality.	This species is threatened by increased urbanisation. The Southern Pygmy Perch requires abundant aquatic vegetation in which it can hide and target prey species. It resides in wetlands or slow moving waterways. Water quality is an important factor is determining persistence and is likely sensitive to urban stormwater impacts. It may also be threatened by competition from exotic fish species.
	Tupong	Can utilise for dispersal events dependent of waterway health and landscape context. Riparian setbacks of >40m in low intensity land use contexts can provide improved food and habitat resources. Less likely to be used in an urban context.	Potential to support populations of the species through providing improved food and habitat resources along with in-stream biodiversity but dependent on higher water quality, in-stream habitat features and densities of exotic predators (Hansen et al. 2010).	Highest potential to support populations of the species in an urban context where microhabitat requirements are present such as logs and rocks, overhanging banks and soft substrate.	This species is most abundant in slow-flowing waterways where microhabitat features of leaf litter, benthic debris (i.e. logs), overhanging banks, or sandy substrates are present. Consequently, they are sensitive to poor sediment quality in waterways. It is found in estuaries where it breeds and throughout many freshwater river systems in Victoria. General threats are barriers to movements, loss of habitat, and poor sediment quality. (Information from Danger and Walsh 2008).

3.5.4 Management recommendations and on-ground actions for all existing linkages

Protection and enhancement of existing linkages is recommended as being of highest priority. The following management recommendations apply to all existing linkages:

- Secure land for conservation purposes wherever practicable
- Protect existing remnant vegetation and canopy cover
- Improve habitat quality through weed control, supplementary plantings (to increase structural complexity of habitat), retaining and fostering the development of hollow-bearing trees, and retention and/or introduction of logs
- Ensure plantings are composed of a mix of flora species producing a range of food (e.g. nectar, fleshy fruits, seeds, tubers) and habitat (grasses, sedges, shrubs, trees) resources
- Manage and reduce threatening processes (e.g. erosion, rabbits, exotic predators, weed infestations)
- Widen habitat linkages wherever possible based on recommended width specifications
- Avoid urban development or further fragmentation of identified existing linkages
- Reduce the number of trails within existing reserves and avoid implementing new ones
- Undertake ecologically sensitive small-scale mosaic burning regimes
- Reduce speed limits and traffic volumes on roads adjacent to existing linkages
- Implement fauna crossing structures at recommended locations (see Section 4.1)
- Reduce the impacts of cats and dogs surrounding higher priority linkages by restricting ownership or implementing and enforcing curfews.
- Undertake control of foxes and cats where required.

3.5.5 Management recommendations and on-ground actions for all proposed linkages

Within each proposed linkage, the following on-ground actions and planning decisions are recommended:

- Secure for conservation purposes land supporting remnant vegetation and improve habitat quality of extant remnant vegetation within proposed linkages
- Wherever practicable, secure land along the general alignment route of high and very high priority linkages for conservation purposes
- Liaise with adjacent Councils and other management authorities to implement corridor linkages and the enhancement of patch linkage

- Pursue the implementation of proposed high and very high priority linkages through the planning scheme and landowner incentive schemes
- Avoid development or further fragmentation of identified existing linkages, particularly further subdivision within 500m of any high or very high priority linkage
- Investigate landholder interest in having revegetation/rehabilitation of fauna habitat undertaken on their property through a questionnaire survey (or similar means) of landowners along higher priority corridors and associated patch linkages.
- Pursue the revegetation of cleared land and the restoration/rehabilitation of remnant vegetation
- Attempt to secure land or provide incentives to landholders along priority corridor routes that will eventually achieve continuous habitat
- Implement fauna crossing structures at recommended locations (see Section 4)
- Manage and reduce threatening processes (e.g. erosion, rabbits, exotic predators, weed infestations) within linkages and adjacent land
- Reduce the impacts of cat and dogs surrounding higher priority linkages by restricting ownership or implementing and enforcing curfews.

3.5.6 Management recommendations and on-ground actions applicable to all linkages and land within Frankston

The following recommendations for providing higher landscape permeability for fauna within and between linkages should be implemented by Council:

Habitat

- Work with landholders to protect and enhance indigenous vegetation on their properties
- Establish and support Landcare Groups with a particular focus on landholders within the Langwarrin and Skye area
- Develop programs that support landholders to set aside habitat for wildlife on their properties such as the Land for Wildlife Program
- Use incentive programs for landholders to retain and enhance fauna habitat on their properties including scattered eucalypts, large old logs, fallen timber, and in particular, hollow-bearing trees.
- Undertake surveys for hollow-bearing trees and also request this information through the planning permit process. Develop a database of significant fauna habitat trees and pursue their protection.
- Encourage the control of environmental weeds by landholders within node habitat patches

Fencing

- Encourage and support the replacement of barbed-wire fencing with 3 or 4-line plain wire fencing (particularly on rural and peri-urban properties), with priority to land within 500m of any High or Very Priority linkages. Barbed wire fencing can be a severe hazard to wallabies and arboreal mammals, restricting their movement more than plain wire fencing

- In new developments or planning applications require the use (or replacement of barbed-wire fencing) of 3 or 4-line plain wire fencing between private parcel boundaries wherever practicable.

- Discourage the use of solid fencing designs except where this may reduce movement of fauna onto roads and allowances have been made for faunal movement elsewhere on a property that align with recommended linkages and provide safe and reasonable passage for faunal movement.

- Where plain-wire fencing is impracticable in higher density developments, require fencing with bottom-gaps (>15cm) to allow passage of smaller-sized ground dwelling animals. Also encourage the use of non-metallic fencing that can be climbed by arboreal species or alternatively, the installation of climbing poles at fence corners or in proximity to existing continuous canopy cover (i.e. bases of large trees that bridge property boundaries) Encourage and support landowners to retro-fit existing infrastructure. Ensure the installation location of climbing poles or fence bottom-gaps are aligned with existing areas of habitat.

Critical Habitat Components

- Protect all existing hollow-bearing trees wherever possible. Hollows are a critical habitat component for many Australia fauna including numerous target fauna

- Ensure that Council arboriculture works are planned to maintain a continuous canopy cover along all existing or potential linkages. Avoid any gaps >20m and pursue the planting of indigenous trees were canopy habitat is lacking or significant gaps occur. Prioritise canopy tree planting away from existing road easement wherever practicable.

- Use simple fauna-friendly arboriculture techniques to facilitate the development of hollows in indigenous trees in all Council works. One simple technique involves not cutting larger limbs (>15 cm diameter) off at the trunk base but leaving at least a 50cm spar. Preference should be given to larger limbs with a wider angle to the trunk base (i.e. more horizontal or downward angled to ensure any formed hollow does not fill with water. Ensure this requirement is also explicit in all planning permit requirements on private land. More time intensive branch hollow creation using a chainsaw should also be encouraged (see http://vtio.org.au/Content/downloads/).

- Collect hollow logs and large diameter logs (currently without hollows) from felled trees and install in areas where they are absent. Large hollow logs are extremely rare in the landscape and have several important functions including critical shelter, breeding, and predator protection values. These will take time to accumulate for use in potential or existing linkages as well as within larger fauna underpasses.

3.5.7 Potential planning mechanisms to achieve implementation of linkages

There are many different paths and combinations of techniques that can be applied to achieve the implementation of recommended linkages and associated on-ground works. These include planning controls, management agreements, inter-agency coordinated works, and incentive schemes. A recommended list of options available to Frankston City Council, adapted from McCaffrey and Henry (2010), includes:

- Reviewing the current Environmental Significance Overlay (ESO) and Significant Landscape Overlay (SLO) to reflect all areas of existing significant native vegetation, tree canopy habitat, and other significant fauna habitats (e.g. wetlands).

- Explore methods to protect or implement some higher priority linkages through the Victorian planning scheme or similar mechanisms and also for requiring provisions to reduce additional infrastructure barriers to movement or further loss of habitat connectivity for fauna

- Rezoning of land via planning scheme amendments to appropriately reflect the conservation value of existing linkages and facilitate the implementation of proposed linkages.

- Using a Public Acquisition Overlay informed by prioritised linkage network to secure highly important land.

- On-title agreements for private and public land: Trust for Nature Covenants (S.173; P&E Act; S.69 CFL Act) or Section 172 agreements (offset sites) under the Victorian planning scheme.

- Private landowner incentives for retention or creation of fauna habitat (e.g. Landcare, Land for Wildlife, Trust for Nature Covenants).

- Tracking native vegetation offset sites through development applications to guide further opportunities for further prioritisation of investments.

- Through subdivision and planning permit systems and increasing Open Space requirements for any larger-scale development applications.

- Using the construction of new roads or road upgrade proposals to implement fauna barrier fencing along roads which are adjacent to high priority habitat linkages and also fauna crossing structures at recommended locations (Section 4 Figure 11).

- Pursueing opportunities to restore fauna habitat on crown land (e.g. in VEAC remnant vegetation study) and service easements.

- Pursueing the protection of existing linkages and the implementation of proposed linkages through State and Federal legislative requirements for planning applications.

- Liaise with other major public authority land managers within Frankston such as Melbourne Water to implement linkages on public land.

- Further update the current Municipal Strategic Statement (MSS) identifying fauna linkages to reflect the results of the current study and any other new information.

- Applying for grants to undertake management works and aligning Council works with those of other projects or organisations (e.g. the Mornington Peninsula & Western Port Biosphere Reserve, Melbourne Water's Healthy Waterway Strategy).

3.5.8 Ongoing Management

Once linkages have been committed to, management plans should be prepared to implement on-ground works on public and private land. For each linkage, management plans should detail:

- The achievable goals of each linkage and benchmark objectives
- Prioritised management actions to restore or rehabilitate fauna habitat in the short and long-term
- Management actions to control threatening processes for fauna such as exotic predators and competitors, weed infestation, and barriers to movement
- Monitoring guidelines
- An overarching management plan for implementation is also required. Revegetation of proposed linkages is most cost-efficient at increasing scales and therefore should be coordinated across multiple proposed linkages rather than a piecemeal approach. Pest control must also be undertaken and coordinated across the entire linkage network.

3.5.9 Knowledge Base

Further information on fauna distribution, abundance, and movement would help further support the goal of improving connectivity for fauna across Frankston and within the region. In addition, a better understanding of habitat quality and the distribution of critical habitat components (such as hollow-bearing) trees will be important for protecting existing connectivity and planning for future enhancement. To assist in further developing a sound information base on which to make management decisions, the following recommendations are made:

- Undertake surveys and develop a GIS database for significant fauna trees – large old hollow-bearing trees. Every remaining hollow-bearing tree or log within the study area is of very high value for fauna, as are larger tree classes or dead trees (future logs) that have the potential to develop hollows in the short-term (next 50 years).
- Undertake further fauna surveys in neglected areas and targeted towards less frequently detected species (e.g. gliders, frogs, and reptiles) with a focus on private land in the east of Frankston.
- Encourage and support studies of animal movement (i.e. radio-telemetry or genetic based studies) within Frankston.
- Through the above recommendations, attempt to develop a better understanding of critical habitat trees across Frankston for arboreal mammals (e.g. sugar gliders), hollow-dependent birds, and microbats (i.e. maternal roost trees)

- Develop a Significant Habitat Tree Register and pursue implementation through the Victorian Planning Scheme. The City of Banyule has successfully implemented a similar such scheme, enacted as a Schedule under their Environmental Significance Overlay.

4. PROVISION OF STRUCTURAL CONNECTIVITY: FAUNA CROSSING STRUCTURES

4.1 Introduction

Installation of fauna crossing structures is an essential component to the implementation of any fauna habitat linkage network, facilitating the reconnection of major areas of fauna habitat severed by roads and urbanisation. In turn, structural connectivity allows individual animals to safely expand foraging ranges, the dispersal of animals (i.e. population exchange), and gene flow. Through achieving functional connectivity for fauna, essential ecosystem processes facilitated by animals such as pollination, seed/spore dispersal, and insect regulation can also be maintained, both within and outside Frankston.

4.1.1 Why do we need fauna crossing structures?

Habitat connectivity is essential for functional movement of fauna. Many species, including those that are arboreal, terrestrial, or aquatic in habit, require passage to and from breeding and/or foraging habitat, which may be disconnected from other areas in which they generally reside within. Barriers, such as roads or weirs/dams will require fauna crossing structures to enable functional movement throughout the wider landscape. These structures are essential to provide linkages between discrete areas of suitable habitat, particularly within an urban environment, or where busy, high-volume roads bisect areas of high quality habitat.

It has been shown that roads and traffic have major and far-reaching impacts on wildlife and habitat (Ramp et al. 2005). In particular, roads are a significant cause of wildlife mortality (Alexander 1998), and create a physical barrier to animal movement and dispersal (Barnett, How and Humphreys 1978; Taylor and Goldingay 2003; van der Ree et al. 2009), fragment habitat and populations (Glista, DeVault and DeWoody 2009; Simmons et al. 2010), alter animal behaviour, (Koenig, Shine and Shea 2001; 2002; Queensland Department of Main Roads 2000), and facilitate dispersal of weeds and feral animals (Seabrook and Dettmann 1996). A recent literature review of the impacts of roads on wildlife (Fahrig and Rytwinski 2009) found that the negative effects of roads and traffic on the distribution and abundance of terrestrial vertebrates (i.e. not aquatic) far outnumbered positive effects.

To counter the effect of roads as barriers to fauna movement, there are a range of fauna crossing structures that are currently in use throughout Australia (Bax 2006; Kapitzke 2010; Taylor and Goldingay 2003; Veage and Jones 2007). These structures are largely classed into two types: overpasses and underpasses. Overpasses include land bridges and canopy (rope) bridges, and underpasses include box (or archway) culverts, pipe culverts and fishways (van der Ree et al. 2008), (Queensland Department of Main Roads 2000). These structures are discussed in further detail below.

4.1.2 Proof of concept: do crossing structures facilitate movement of fauna across barriers?

Provision of fauna crossings (e.g. fauna culverts, canopy and land bridges, and fishways) has been shown to be particularly successful for facilitating movement in some ground-dwelling mammals (Taylor and Goldingay 2003), arboreal mammals (Goldingay, Rohweder and Taylor 2012; Goosem, Weston and Bushnell 2005; Weston et al. 2011) and fish (Kapitzke 2010) in Australia. In a recent literature review (van der Ree et al. 2008), wildlife crossing structures were found to be effective in increasing the permeability of roads at the individual level (during periods of monitoring) by allowing individuals to move safely across roads. In the northern hemisphere, culverts combined with exclusion fencing have also facilitated road crossings by turtles (Aresco 2005), lizards, and amphibians (Taylor and Goldingay 2003; Woltz, Gibbs and Ducey 2008).

In the review undertaken by van der Ree et al. (2008), of various monitoring studies on the effectiveness of a range of fauna crossing structures, it was clearly shown that land bridges and bridge underpasses provided the highest level of functional connectivity, as a wide range of fauna were detected using these structures, followed by culverts; canopy (rope) bridges were largely used by arboreal mammals. In addition to functional connectivity provided by fauna crossing structures, fauna exclusion barriers/fencing also greatly reduced road mortality, as shown in Veage and Jones (2007), where road kill numbers detected dropped from 13 individuals prior to the construction of the fauna exclusion fencing, to two and three in the four months and two years post construction, respectively. Incidentally, it was deemed likely that the last three road kills could be attributed to a hole deliberately cut into the fence (Veage and Jones 2007). This further supports the hypothesis that fauna exclusion fencing, in conjunction with fauna crossing structures, does provide a safe, functional connectivity option for fauna within a local landscape.

In New South Wales, large culverts (2.4 m wide, 1.2 m high and 18 m long) combined with fauna-exclusion fencing have been successful in facilitating movement of bandicoot species, wallabies (potentially the Black Wallaby *Wallabia bicolour*), rodents (potentially Swamp Rats *Rattus lutreolus* and Bush Rats *Rattus fuscipes*), and small mammals across a 2.5 km stretch of the Pacific Highway (Taylor and Goldingay 2003). The uncertainty of species use in the latter study was due to sand-pads being used to quantify frequency of culvert which does not allow certain identification of fauna at the species level. A similar study in south-east Queensland (Bond and Jones 2008) also suggest fauna crossing structures may facilitate movement of some fauna across a road barrier (Compton Road). Rodents, bandicoots, and reptiles were the most frequent fauna found to traverse the fauna underpasses. Native fauna species most likely associated with tracks in sand-pads included the Bush Rat, Common Dunnart *Sminthopsis murina*, Common brushtail possum *Trichosurus vulpecular*, Short-beaked echidna *Tachyglossus aculeatus*, Swamp Rat, Yellow-footed antechinus *Antechinus flavipes*, and Common ringtail possum *Pseudocheirus peregrines*. Although use of sand-pads excluded the possibility of identifying species of reptiles using culverts, most tracks were considered to be those of medium-sized reptiles. This study also found Black Wallabies and Eastern grey kangaroos *Macropus giganteus* to continuously use a land-bridge structure. Providing a road underpass for a population of Mountain Pygmy Possum *Burramys parvus* has reduced the negative effects of roads on population viability (van der Ree et al. 2009; van der Ree et al. 2007), which is particularly important for threatened species whose populations are either small or isolated.

Also, a recent study found that mitigating road mortality was the most effective management solution to increase population persistence of Common Wombats *Vombatus ursinus* in an area of south-eastern Australia (Roger, Laffan and Ramp 2011). Crossing structures combined with exclusion fencing has been shown to be highly successful in reducing overall roadkill (Bond and Jones 2008) in south-east Queensland and for Koalas in north-eastern New South Wales (Semeniuk et al 2010).

4.1.3 Structure of this section

The first part of this section prioritises locations at which fauna crossing structures are required within Frankston followed by the type of structures recommended for implementation. The second part of the section provides detailed specifications for these different types of fauna crossing structures. The third part provides recommendations for the implementation and monitoring of crossing structures. Results of on-ground feasibility assessments and timing of implementation are provided in APPENDIX 6 while detailed specifications for different types of crossing structures is provided in APPENDIX 7 including context of use, suitability, fauna requirements, details, and costs.

This information is intended to be incorporated into asset renewal projects by Frankston City Council. Fauna crossing structures must be considered as part of pre-planning stage for roads or other infrastructure barriers such as urban developments. Retrofitting may be possible but is generally more costly.

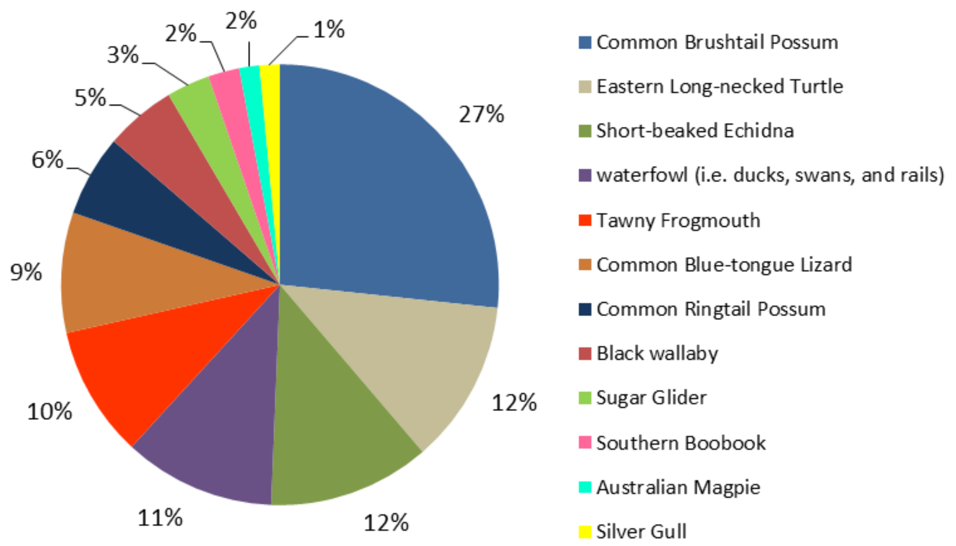
4.1.4 Results of wildlife mortality/injury analysis

Records of fauna casualties can provide useful insights for informing required locations and types of crossing structures within an area. An analysis of fauna casualty records suggested that some species are more prone to injury in urban environments also may be more impacted by road barriers than others (Figure 9). Ground-dwelling and arboreal mammals accounted for a large proportion of casualties. Slower moving reptiles were also over-represented such as the Blue-tongue Lizard and Eastern Long-necked Turtle. Of birds, owl and waterfowl species were over-represented, possibly due to these animals either hunting ground-dwelling prey where they come into contact with vehicles or more frequently making ground movements than other bird respectively. These results suggest a mix of crossing structures which provide safe passage for ground-dwelling and arboreal animals may provide the greatest benefit to improving connectivity for fauna.

Several 'hotspots' of high wildlife mortality/injury were identified from the analysis of collated data (Figure 10). An obvious pattern was high wildlife casualty in areas where major roads intersected land supporting larger areas of higher quality fauna habitat. Casualties were highest along McClelland Drive, particularly along Langwarrin FFR and adjacent patches of fauna habitat and again along the same road where it passes between the Pines FFR and habitat supported within Studio Park and quarry sites of the Boggy Creek node. High casualties were also observed along roads adjacent to higher quality habitat patches and where habitat corridors intersected roads. The latter was observed in association with Skye Road and The Peninsula Country Golf Club and also at points where Boggy Creek intersects with Cranbourne-Frankston Road. A similar hotspot was associated with residential land and associated roads near Robinsons including Golf-Links Road, Robinson Road, and Frankston Golf Club. Several discrete hotspots of fauna casualties were also associated with the Nepean Hwy and adjacent Frankston-Seaford Foreshore.

Other areas included areas adjacent to fauna habitat along Sweetwater Creek, along Moorooduc Highway adjacent to Baxter Park, to the east and west of Frankston Reservoir, where the Mornington Peninsula Freeway dissects wetland fauna habitats, and along Ballarto Road where agricultural land or remnant vegetation occur at both sides of the road. Within the Langwarrin Woodlands area, higher casualty rates were observed along North Road and Robinsons Road where they intersected higher quality, more intact remnant vegetation and associated fauna habitats. Interestingly, many of these locations are very similar to ones predicted from intersections between high conservation significance linkages and major roads.

A



B

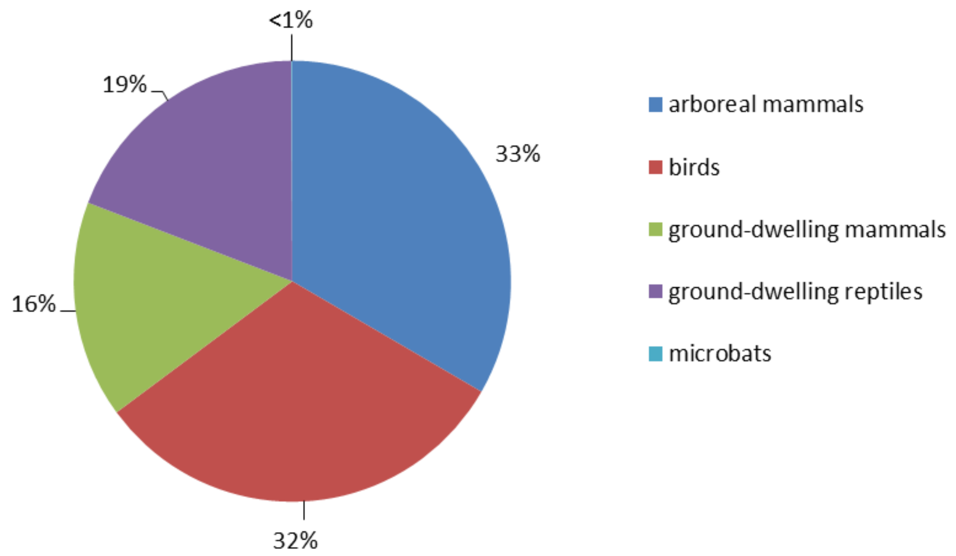


Figure 9. Recorded fauna casualties within Frankston LGA including A) species or species groups accounting for 90% of casualty records and B) records according to five fauna groupings. Note that data is not comprehensive and was not collected or collated in an unbiased and systematic way (see Section 2.3.5).

Figure 10. Identified 'hotspots' of high wildlife casualties within the investigation area.

4.2 Recommended priority and type of crossing structures

4.2.1 General Methods

Detail methods for identifying and scoring crossing structure locations are provided in Section 2.2, but a summary is provided below.

The general approach to prioritisation of crossing structures for improving faunal connectivity was to first identify a large number of possible candidate locations largely based on:

- Intersections between high priority linkages or habitat patches and significant barriers to movement (e.g. roads)
- Locations in which road casualties of animals was estimated to be high (i.e. 'hotspots') inferring current movement of fauna
- Locations identified through consultation with land managers, local naturalists and wildlife carers

These locations were then prioritised using a range of criteria reflecting the current need for a crossing based on current faunal movement (as inferred from casualty data) and habitat distribution. The final ranking of locations (from 'Low' to 'Very High' urgency) also accounted for the priority of any intersecting higher priority corridor so that overall connectivity would be achieved in the long term.

Subsequent re-analysis involved filtering High and Very High urgency crossing locations to only include those involving existing major roads or ones with higher traffic volume. On-ground assessments were undertaken of High and Very High urgency locations and subjectively assessed for feasibility in implementing a fauna crossing structure at the locality (see APPENDIX 6). Feasibility accounted for engineering constraints due to existing infrastructure (e.g. buildings, amenities etc), sufficient land, and cost but also the feasibility from an ecological perspective in their being sufficient land for habitat creation at either end of the structure. Results of these assessments are provided in APPENDIX 6.

The type of crossing structures required at any one locality was determined using several criteria. Initial recommendations were based on the significance of the barrier (e.g. a freeway or minor road with high traffic volume) and the level and type of inferred movement of fauna at the locality (e.g. arboreal fauna crossing whether extensive canopy exists). Records of target fauna species and casualty records, including the results of the 'hotspot' analysis for ground-dwelling, arboreal, and bird fauna was also consulted. These were then re-evaluated by on-ground inspection of locations considering the current habitat present, existing infrastructure, and feasibility in implementing.

4.2.2 Crossing structure priority

A large number (n=121) of locations for the provision of crossing structures were identified and assessed against as range of criteria in GIS software. Thirteen of these locations were determined to currently support fauna crossing structures based on information supplied by Linking Melbourne Authority (for crossing the Peninsula Link freeway). Of the remaining 108 locations, 27 were considered of Very High priority for implementation based on the results of the analysis. A further 26 locations were considered of High priority for implementation and the remaining 55 of Medium to Low priority. Details of Very High and High priority locations are provided in APPENDIX 6. Higher priority fauna crossing locations (n=53) are largely concentrated in the eastern half of Frankston where larger areas of fauna habitat intersect with major roads. These include around Langwarrin FFR, the Pines FFR and associated Boggy Creek and quarry areas, and the Langwarrin Woodlands (from Langwarrin South to Cranbourne South).

Of higher priority locations (Very High and High), 9 were not considered feasible to implement based on ecological, cost, and/or engineering constraints. Of the feasible locations (n=44) for crossing structure implementation, 20 locations were considered as being required at the current point in time, with the remaining 24 to be pursued in the future with the implementation of recommended corridors and creation of habitat.

Twenty locations are recommended for the urgent implementation of crossing structures at the current point in time (APPENDIX 6 and Figure 11). Fifteen of these are of Very High urgency for implementation based on scoring. Most structures are associated with larger areas of fauna habitat in the east of Frankston. A single location outside of the study area and Frankston municipality was recommended (Figure 11: #124) for pursuing due to its potential importance in facilitating wider connectivity for some target fish species.

Only High and Very High locations (APPENDIX 6) should be seriously considered over the long-term for implementation although this may change based future developments, habitat creation or loss. Of these High and Very High locations, not all need to be immediately addressed (i.e. considered in the near future). However, this information is useful for informing future developments and should be used as to guide road development, structure placement, and habitat corridor implementation over the long term (>25 years). Ideally, crossing structures should be considered *before* roads (or upgrades) or other developments become a barrier to faunal movement.

4.2.3 Crossing structure type

A variety of crossing structures are recommended for locations currently requiring improved connectivity for fauna (Figure 12 and APPENDIX 6). Large box-culverts are recommended for 8 locations, smaller box-culverts for 7 locations, and rope bridges for 12. Fish passages are recommended at two locations although these could potentially be overcome by removal of in-stream barriers. The recommended type of crossing structure should be re-assessed on a case-by-case basis at the detailed planning stage to account for changes in conditions. Council should consider the implementation of larger crossing structures wherever practicable.

As a general rule, crossing structure types implemented at any one locality for facilitating terrestrial faunal (i.e. not aquatic; includes ground-dwelling mammals, woodland birds, and frogs) movement should be:

- The recommended crossing structure type, or the next structure level down (refer to Table 2), where practicable.
- For each locality where a certain class of underpass is recommended but not practicable due to engineering constraints (as assessed in further detail by an engineer e.g. underground services/utilities) and associated costs, the number of crossing structures required must be increased by the number of size classes down-scaled. For example, where a 'large box culvert (underpass-type 1)' is recommended but not feasible, two 'small box culverts' (underpass-type 2, or three 'large pipe culverts (underpass-type 3) etc should be

installed as a minimum standard. Ideally a mixture of smaller and larger structures should be implemented to facilitate connectivity for a greater number of different-sized fauna. Where this is not practicable, there may be a significant reduction in the level of structural connectivity for fauna facilitated.

- Serious consideration must be given to the impacts of down-scaling ‘underpass’ type structures between culvert type to pipe culverts, particularly in regard to connectivity for larger-sized mammals (e.g. wallabies) across major roads.

Figure 11. Locations currently required for urgent implementation of fauna crossing structures. Shown with the High and Very High urgency corridors, along with existing freeways, major roads, and culverts and crossing structures for the Peninsula Link freeway. Shown with crossing structure ID# – refer to table in APPENDIX 6 for further details.

Figure 12. Feasible types of fauna crossing structures for higher priority locations currently requiring ones. Where the recommended type of crossing structure cannot be attained refer to Section 4.2.3 for options and additional requirements. Shown with crossing structure ID# - refer to table in APPENDIX 6 for further details.

4.3 Fauna crossing structure design

4.3.1 Types of different fauna crossing structures

Different fauna groups need crossing structures that can accommodate their requirements for unimpeded or safe passage. Connectivity versus the level of perceived or real threats that individual fauna face also determines the type of structure that will be required at any given location, or within a larger area. For instance, land bridges or bridge underpasses can provide connectivity for most fauna groups across, or beneath, major freeways while concrete pipes may be sufficient for small mammals on smaller country roads. Consideration of fish is required to ensure that they are able to gain passage to upper reaches of waterways, and these can sometimes be done in conjunction with (or adjacent to) fauna passages for terrestrial (and arboreal) fauna.

4.4 Crossing Structure Specifications

The table on the next page provides an overview of the main categories of fauna connectivity structures and their types. The broad arrow ascending the left column shows the functional connectivity that each of the main types of structures can potentially provide, and these should be implemented in that order where possible, in order to cater for a broader range of fauna subgroups. Further details for each structure are provided in APPENDIX 7 and recommended types of structures at priority locations is given in APPENDIX 6, with ones for urgent implementation illustrated in Figure 12.

Table 2. Types of fauna crossing structures and structural connectivity

Structural connectivity	Category	Sub-category	Type (also map legend)
	General (terrestrial) fauna crossing structures		
	Overpass	Land bridge	Overpass – type 1 (T1)
	Underpass	Bridge underpass	Underpass – type 1 (T1)
		Large box culvert	Underpass – type 2 (T2)
		Small box culvert	Underpass – type 3 (T3)
		Large pipe culvert	Underpass – type 4 (T4)
		Small pipe culvert	Underpass – type 5 (T5)
	Fish crossing structures)		
n/a	Underpass	Wet box culvert	Fish passage

Structural connectivity	Category	Sub-category	Type (also map legend)
		Wet pipe culvert	
		Rock ramp fishway	
		Cascade fishway	
	Arboreal crossing structures		
n/a	Overpass	Rope bridge (box)	Rope bridge
		Rope bridge (platform)	
	Other	Glider pole	Glider pole

4.4.1 Land bridges

4.4.1.1 Description

Land bridges (also known as 'eco-duct overpasses') are a type of overpass structure, which allow fauna to move over a road, along a connecting corridor of habitat. Generally, this type of structure is effectively a bridge over a road, covered with soil and planted vegetation, and further enhanced by the addition of other habitat features, such as rocks and logs (van der Ree et al. 2008) and (Queensland Department of Transport and Main Roads 2010)

Land bridges are likely to provide the most effective connectivity for a wide range of terrestrial, avian and arboreal fauna, including frogs, reptiles, and invertebrates which require terrestrial connectivity, and arboreal mammals which have difficultly gliding over wide roads, such as gliders (Queensland Department of Main Roads 2000). They are also the only form of crossing structure likely to reduce road mortality and increase connectivity for less urban tolerant indigenous bird species.

4.4.1.2 Context of use

Land bridges are best suited for fauna crossings across large, busy roads and where connectivity for bird species or macropods is highly desired. Macropods (e.g. Black Wallaby) have been found to more readily use land-bridges than culverts (Hayes and Goldingay 2009). They are particularly desirable in areas where there are large, high quality areas of fauna habitat bisected by busy roads, such as freeways and multi-lane highways. While land bridges are generally highly effective, they are likely to be very expensive to implement and take longer to establish than other connectivity structures. Hence, they should be implemented for major road barriers to providing connectivity among key core area fauna habitats and priority landscape-scale linkages.

4.4.1.3 Technical Specifications

An example for specifications for a land bridge in Queensland (Queensland Department of Main Roads 2000) is given below:

- Arched and hourglass in shape
- 70 metres long, 20 metres base-width and 50 metres wide mid-width
- Minimum required height above the road class (e.g. 6 m minimum clearance for a national highway)
- Vehicular tunnel height = 5.4 metres high
- Slope of batters of each side is 1:3
- Covered in soil, vegetation, other habitat features
- Fauna exclusion fencing on roadside is keyed onto the land bridge to encourage fauna movement in this direction

Such a land bridge would require deep layer of soil for regeneration of trees to provide functional upper canopy connectivity for arboreal mammals.

Figure 13. Land bridge, Compton Road, near Brisbane, QLD (Robinson-Wolrath 2009), in (Queensland Department of Main Roads 2000).

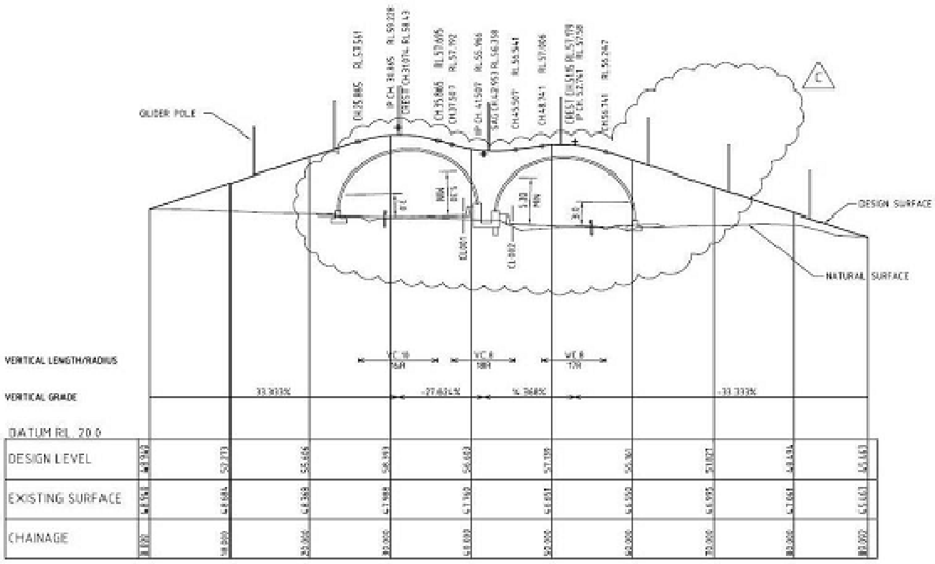


Figure 14. Plan for the Compton Road land bridge (see previous figure), from adapted drawing LB-02 in Queensland Department of Main Roads (2000) adapted from Chambers and Ingram (2005).

4.4.1.4 Maintenance and costs

Land bridges would need ongoing maintenance and monitoring to ensure that vegetation that is planted and/or regenerating is thriving, and that erosion (structural stability) is not an ongoing issue. Essentially, the time taken for vegetation to establish will need to be factored in the overall maintenance costs. As for any area of vegetation being maintained, weed control and, potentially, further planting will be required.

Due to the size and complexity of this structure, land bridges are likely to be more expensive than other crossing structures. A recent example (discussed below) on Compton Road, South Brisbane cost $1,385,000 for a 70 metre long and 20 metre wide crossing using two separate pre-cast concrete arches, 8 meters above the road. Soil and mulch was used to cover approximately 70% of the surface area and was planted with a mix on endemic species. Eight glider poles were also installed along the top to encourage arboreal mammals (Veage and Jones 2007). This example was part of a new road construction

4.4.1.5 Case study example

A successful example of a land bridge was established in 2005, on Compton Road, on the south-side of Brisbane, Queensland. This land bridge was installed alongside with a number of other fauna crossing structures, within a 1.3 km stretch of road bisecting habitat within Kurawatha Forest and Kuraby Bushlands. It was found that a high diversity of fauna were effectively using this structure to access habitat on either side of the road, and even residing on the land bridge itself. The species which were found to be resident in 2007, just two years since the finalisation of the connectivity upgrade in 2005, include Lace Monitor, Yellow-faced Whip Snake and Ornate Burrowing-frog (Veage and Jones 2007). A technical plan and photograph, as depicted on the previous page, are both of the land bridge discussed here.

4.4.2 Bridge Underpasses

4.4.2.1 Description

A bridge where a road maintains the same level, across a landform (i.e. small valley/creek line), or is elevated over the surrounding landscape, provides fauna connectivity by allowing animals to pass beneath the infrastructure (van der Ree et al. 2008). Bridge underpasses provide an excellent opportunity to provide high quality connectivity, particularly if intact, suitable habitat is continuous (i.e. there is sufficient available light and water throughout the underpass, with vegetation and other habitat features, such as waterways, rocks and logs.

Where an open infrastructure is present, along with continuous habitat and high clearance of the bridge itself, with minimal barriers caused by pylons or other bridge engineering features, bridge underpasses can provide connectivity for most, if not all, fauna species that may be present within the local landscape, particularly birds, bats, and ground-dwelling animals. Special consideration may be required to increase connectivity for arboreal or scansorial mammals, such as gliders, which may be less likely to travel along the ground in habitat that does not have a suitable canopy present (Abson and Lawrence 2003).

4.4.2.2 Context of use

Bridge underpasses could be implemented anywhere where a road travels above a landform, either at an elevated or level grade, with enough clearance to allow for a range of fauna and any waterways with adjacent riparian vegetation. This structure is particularly likely to be needed for wider, busy and/or high-speed roads where a largely level roadway is required to cross over waterways or uneven landscape.

4.4.2.3 Technical Specifications

There are several types of bridge underpasses, which include single span, multiple span, viaduct and grid bridges. Some considerations for all types should be taken on board when designing infrastructure include:

- Span the entire waterway with no in-stream supports, wherever possible
- Width of bridge underpass (measured between supporting banks) must be greater than the minimum width required to maintain normal (i.e. average) water flow AND ensure that enough bank and terrestrial habitat is available for animals to pass under the road
- Ensure that scour deterrents for erosion control, such as large rocks, are used sparingly and do not form a barrier to animal movement
- Consider all water flow conditions (i.e. flooding)
- Consider erosion management
- Provide light wells, such as gaps or grated decking on multilane bridges (to provide light and allow moisture to penetrate) – but also consider the risks of pollution
- Minimise disturbance to the local environment during construction

- Restore and/or maintain riparian habitat
- Installation of dead trees, arboreal runways or rope bridges (or trawler ropes), shrubs, dense groundcover vegetation, and nest-boxes can increase permeability under a land-bridge.

(Queensland Department of Transport and Main Roads 2010)

Figure 15. Slaty Creek Wildlife (bridge) Underpass, at Slaty Creek, near Maldon, Vic, with the Calder Freeway passing overhead (from Abson and Lawrence 2003)

Figure 16. Example of a bridge underpass, encompassing both wet and dry fauna passage, prior to revegetation, Steggall's Creek bridge, Yandina Bypass, Qld (Queensland Department of Main Roads 2000).

4.4.2.4 Maintenance and costs

Bridge underpasses would need ongoing monitoring to ensure that vegetation is present, planted and/or regenerating is thriving, and that pollution or erosion (structural stability), particularly where waterways are present, are not an issue. Essentially, the time taken for establishing suitable habitat and habitat features (rocks/logs/canopy connectivity) will need to be factored into the overall maintenance costs.

As for any area of native vegetation being maintained, weed control and, potentially, further planting will be required.

4.4.2.5 Case study example

The Slaty Creek Wildlife Underpass, a bridge designed to accommodate fauna movement between forest blocks within the Black Forest, near Macedon, Victoria, cost $3 million to construct (Abson and Lawrence 2003). To further encourage fauna usage of the underpass, fauna fencing 2 metres high, with chain-wire fencing, corrugated colorbond sheeting (on forest side only), and a 30 cm high chain-mesh skirting along the base (to deter animals burrowing underneath) was used. A standard bridge accommodating fauna movement is considered to be of lower cost than this project (van der Ree pers. comm.) and it should be noted that the actual cost to modify the design for fauna likely constitutes a fraction of the entire cost that would be required for bridge construction.

After establishment of the wildlife underpass was completed, 12 months of monitoring was undertaken to determine what species from the local area were utilising this passage. One hundred and sixteen species, including reptiles, amphibians, birds, and terrestrial and arboreal mammals were detected in the local area within the forest, however, not all these species were detected using the underpass. The species which were detected nearby, but not using the underpass, were mostly arboreal mammals (Abson and Lawrence 2003).

Additional structures and vegetation enhancement can improve connectivity for arboreal fauna. These include installation of fixed runways (above-ground rails to encourage arboreal fauna to use the structure), rope bridges suspended from the bridge, dead stag trees, and shrubs. Appropriate provision of essential habitat features directly adjacent to land-bridges (and any other fauna crossing structure) is essential to ensuring use and increased permeability. Dense cover and elevated vegetation is important for reducing the risk of predation at a crossing structure (see discussion below).

4.4.3 Box culverts

4.4.3.1 Description

Box culverts are rectangular or square in cross-section and depending on their dimensions and location within the wider landscape, can provide passage for a wide range of fauna, largely those that are terrestrial. Box culverts are generally constructed as pre-fabricated concrete cells, which are then assembled together as a long passage which passes underneath road infrastructure. They are similar in physical design to culverts often installed to provide drainage but carefully modified to be fauna-friendly and situated in suitable locations.

More than one culvert can be provided at a location, each designed to accommodate a different fauna group. A culvert designed for frogs would be a ‘wet’ passage with wetland habitats and aquatic vegetation on either side of the culvert entrances and some periodic water flow through the culvert to maintain a moist environment. Placing rocks and gavel along the culvert floor may assist in creating a more amenable microhabitat and encourage frog thoroughfare (Taylor and Goldingay 2003). A dry culvert furnished with logs, litter, and rocks would be more suitable for ground-dwelling terrestrial animals. The versatility of having a set of box culverts together means that one can be used as passage for terrestrial ground-dwelling animals, one for fish, and/or amphibians, while also providing dry passage for terrestrial animals in another. Culverts of larger width can also be designed to facilitate connectivity for multiple groups of fauna by the provision of different types of habitat both within the culvert and at either end of both entrances. For more detailed on how modified (wet) box culverts can also assist with fish passage, see Section 4.4.6.

4.4.3.2 Context of use

Culverts, as smaller fauna connectivity underpass structures should be focused for use with smaller roads (less than 30-35 metres wide), and it is ideal to install these along known fauna movement passages (for example frogs, turtles, and bandicoots), particularly between breeding and foraging areas.

A 3m x 3m box culvert underpass was used by macropods (including Black Wallabies), bandicoots, possums, rodents, and frogs, although overpasses are more frequently used by macropods (Hayes and Goldingay 2009). Culverts 2.4 m wide, 1.2m high, and 18m long were frequently used by bandicoots, wallabies (i.e. Black Wallaby), rats and other small mammals, and frogs with some use by possums, echidnas, koalas, and reptiles.

4.4.3.3 Technical Specifications

The below considerations are drawn from Queensland Department of Transport and Main Roads (2010). For further details, please refer to this document. In general, the below considerations apply to all fauna culverts:

- Small box culverts are generally those 0.4-1.2 metres in height (smaller ground-dwelling and semi-aquatic vertebrates i.e. frogs, reptiles, and rodents) and ≥ 1 metres width
- Large box culverts are generally those ≥ 1.2 metres in height and ≥ 2.4 metres in width (for macropods i.e. Black Wallaby)
- Culverts should be installed at regular intervals along a road where it intersects a corridor linkage or habitat patch
- Positioned at a height with respect to surrounding landform that ensures the passage floor remains dry
- Install sediment / natural substrate to cover the culvert flooring
- In large box culverts (where possible) of greater width (≥ 3m) install a channel in the middle of the culvert (or in the middle of a set of culvert cells), to encourage movement of amphibians, particularly when it becomes moist in wetter seasons.
- The other end of the culvert ideally should be visible for fauna entering at the other end, with suitable habitat present near both entrances. Avoid any bends in the culvert design.
- Dense ground-cover vegetation established up to the culvert entrance.
- Provide furnishing to allow connectivity for more arboreal species, such as a raised wooden rail or trawler ropes, as well as on-ground habitat features, such as earth/sand/small stones covering the base of the culvert, rocks and logs – to provide shelter for ground-dwelling fauna that may move along the culvert.
- Use fauna exclusion fencing along adjacent roadsides to encourage fauna to use the culvert
- Height has been found to be a more important dimension for greater use of such passages by fauna. Where possible, increase height over width.
- Intensive, targeted predator control within 500m of culverts
- Ensure fauna culverts are clearly signed to ensure they are not mistaken for drainage culverts and are appropriately managed as wildlife passages

Figure 17. Photos (a) and (b) both show an example of a dedicated box culvert fauna underpass, with a variety of fauna furnishing, to encourage diverse terrestrial and arboreal fauna to utilise the passage – Compton Road, near Brisbane, Qld (from Veage and Jones 2007), note the concrete apron at the entrance, which could be improved with further revegetation.

4.4.3.4 Maintenance and costs

Box culverts of all sizes would need ongoing maintenance and monitoring to ensure that vegetation that is planted and/or regenerating near openings is thriving, and that erosion from runoff, or flooding events, is not an ongoing issue.

Maintenance is needed to ensure that culverts do not become obstructed with rubbish or natural debris in such a way that it prevents passage for targeted fauna, such maintenance is likely to be needed after any flooding events. Check that water does not pool within the culverts, or form ponds near entrances, where macropod passage is desired, as they are found to be less likely to use wet passages and are discouraged by clearing or pond presence at culvert openings (Queensland Department of Transport and Main Roads 2010).

An example of costing: box culvert underpasses (3 metres wide x 3 metres high), for the Pacific Highway, NSW (in van der Ree 2003), cost an average of $225 000 to install. Compton Road project in South Brisbane custom made 2 box culverts, 48 metres in length (pictured above) and comprises of 4 levels (lower cement level for water flow; a raised cement surface furnished with rocks; one wooden shelf attached to the wall and one raised split-log railing just above the floor of the culvert). Each structure cost $118,500 to construct (Veage and Jones 2007).

4.4.3.5 Case study example

Compton Road, near Brisbane, Qld, made use of both wet (pipe) and dry (box) culverts as part of a larger fauna connectivity project, to link habitat present in the Kuraby Bushland and Karawatha Forest, which is divided by Compton Road – a major east-west arterial road (Veage and Jones 2007). The culverts were 2.4 metres high, 2.5 metres wide, and 48 metres long, and incorporated a lower cement level for water flow, and a raised cement level (1.6 metres wide, and 0.4 metres raised above the ground level), which had a covering of natural material (leaf litter, rocks, sand and gravel) as well as some embedded rocks and two wooden shelves (250 mm wide)/rails (constructed out of half-logs, raised 1 metre above ground level – see figures provided above) extending the whole length of the underpass, to provide habitat features and added safety from predators for smaller fauna (Veage and Jones 2007). Post-construction, monitoring studies, using sand plots, scat collection and infrared cameras with motion sensors detected that the fauna underpass was largely used by rodents, lizards, snakes and birds, but also the Northern Brown Bandicoot (Queensland Department of Transport and Main Roads 2010). An issue which may have reduced utilization was that the box culverts installed had large concrete aprons with limited vegetation growth; this may have had a negative effect on which fauna species utilised the underpass (Queensland Department of Transport and Main Roads 2010).

4.4.4 Pipe (concrete) culverts

4.4.4.1 Description

Constructed as pre-cast concrete piping, pipe culverts are often laid under roads to provide drainage, but can also act as fauna connectivity structures when placed in suitable locations. Due to the limitations for placing more natural habitat features throughout these (due to their smaller size), pipe culverts are not suited for a wide range of fauna, however, they have been proven to be used by small, medium and, even large mammals (larger diameter pipe culverts), along with reptiles and amphibians (Queensland Department of Main Roads 2000). Small round pipes (300 mm diameter and 15-20 m long) have been successfully used to provide safe passage for Southern Brown Bandicoots under sealed roads within the Royal Botanic Gardens Cranbourne and is the only structure as yet recorded that the south-eastern subspecies has been recorded using (Terry Coates pers. comm.).

4.4.4.2 Context of use

In general, pipe culverts, as an alternative to box culverts, are not deemed to be as successful as other fauna connectivity structures in providing connectivity for wide range of different fauna groups across major roads. It has been determined, however, that larger pipe culverts (> 0.5 m in diameter) do provide more connectivity than smaller ones (< 0.5 m in diameter)(Queensland Department of Transport and Main Roads 2010). On the other hand, as discussed above, smaller diameter pipe (300 mm diameter) culverts can provide connectivity for smaller vertebrates and potentially frogs (evidence from overseas studies Glista *et al* 2009), such as the Southern Brown Bandicoot, while simultaneously deterring the passage of larger predators, such as the Red Fox (Terry Coates pers. comm.). A greater number of pipe culverts can be installed for the same cost as one larger culvert structure, spreading the risk of predation over a larger area and intersecting the home ranges of many more animals. Modified (wet) pipe culverts can also assist with fish passage (Kapitzke 2010). Crossing structures can be designed to accommodate both aquatic (fish) and ground-dwelling fauna passage in an integrated way (Ross Kapitzke pers. comm.). Further details for these culvert designs are provided in Section 4.4.6.

Considering the above information, pipe culverts are recommended for situations where smaller vertebrates are the most common group at threat from road crossings, for crossing more narrow width roads, and as additional structures in more major road crossings. These smaller fauna connectivity underpass structures should be focused for use with smaller roads (less than 30-35 metres wide), and it is ideal to install these along known fauna movement passages (for example frogs, turtles, and bandicoots), particularly between breeding and foraging areas.

4.4.4.3 Technical Specifications

The following general specifications apply to all pipe type culverts:

- Large pipe culverts (> 0.5 metres in diameter)
- Small pipe culverts (0.3-0.5 metres in diameter)
- Culverts should be installed at regular intervals along a road
- Culvert passages longer than 20 metres are less likely to be utilised
- Allow sediment / natural substrate to cover the culvert flooring
- Where possible, install a channel in the middle of the culvert (or in the middle of a set of culvert cells), to encourage movement of amphibians, particularly when it becomes moist in wetter seasons.
- The other end of the culvert needs to be visible for fauna entering at the other end, with suitable habitat present near both entrances.
- Use fauna exclusion fencing along adjacent roadsides to encourage fauna to use the culvert
- Provide furnishing to allow connectivity for more arboreal species, such as a raised wooden rail, as well as on-ground habitat features, such as earth covering the base of the culvert, rocks and logs - to provide shelter for ground-dwelling fauna that may move along the culvert.

A B

Figure 18. Large pipe culvert in south-east Queensland (A) and northern New South Wales (B). Note limited provision of ground-cover at the installation stage in the pipe culvert on the left (A) which should be increased to a dense ground-cover through time (Queensland Department of Main Roads 2000).

4.4.4.4 Maintenance and costs

Pipe culverts of all sizes would need ongoing maintenance and monitoring to ensure that vegetation that is planted and/or regenerating near openings is thriving, and that erosion from runoff, or flooding events, is not an ongoing issue. Water velocity can be an issue with pipe culverts as their shape tends to cause fast-moving shallow water, and this can cause erosion issues, including 'shelving' at the exit, which may deter fauna movement into the passage (Kapitzke 2010).

Maintenance is needed to ensure that culverts do not become obstructed with rubbish or natural debris in such a way that it prevents passage for targeted fauna, such maintenance is likely to be needed after any flooding events. Check that water does not pool within the culverts, or form ponds near entrances, where macropod passage is desired, as they are found to be less likely to use wet passages and are discouraged by clearing or pond presence at culvert openings (Queensland Department of Transport and Main Roads 2010).

An example of costing: pipe culvert underpasses (1.8 metres in diameter), for the Pacific Highway, NSW (van der Ree et al. 2008), cost an average of $50 000 to install.

4.4.4.5 Case study example

As a cheaper option (in general), than box culverts, pipe culverts are installed regularly, but largely with the aim of water flow, and not with fauna movement as the aim of installation. However, the installation of pipe culverts under roads at the Royal Botanic Gardens – Cranbourne, are frequently used by the threatened Southern Brown Bandicoot and also have the desired benefit of excluding foxes (Terry Coates – RBGC, pers. comm.). Large box culverts, however, can cater to a larger range of fauna. This indicates that installation of both smaller (pipe culverts) and larger (box culverts) fauna underpasses could cater better for a wider range of fauna, while also minimising the risk of predation by foxes.

4.4.5 Rope Bridges

4.4.5.1 Description

Rope (or canopy) bridges, generally structured as a tube of netting, or a flat rope 'ladder', stretched across a road, suspended from tall timber poles, provide an 'overpass' style connection between canopy habitat on either side of a road. The most common design being used at present is the flat rope ladder (pers. comm. Rodney van der Ree). This type of structure is ideal for arboreal or scansorial (climbing) mammals such as possums and gliders (van der Ree et al. 2008). Rope bridges stretching across the entire roadway also have the advantage in that they as discourage fauna moving in to the median strip and potentially not using the crossing structure to cross back to either side of the carriageway (Bax 2006). While this is a rather specialised structure targeted at arboreal/scansorial mammals, it is quite effective in both costs and functionality.

4.4.5.2 Context of use

Rope bridges can be used for a wide range of situations, including small, but busy roads, or larger dual carriageway freeways/highways, where there is arboreal habitat present on either side of the roadway. This will ensure that the arboreal fauna likely to be present can make use of this type of fauna crossing structure, particularly possums and gliders. It is ideal to, where there is a median strip with or without trees present, to have the rope crossing structure extend across the entire width of the roadway.

4.4.5.3 Technical Specifications

The below specifications are from Bax (2006), which were used for the rope bridges used for the Karuah Bypass (see case study below, followed by technical drawings).

- 14mm diameter marine grade 'silver rope' (i.e. ultraviolet light stabilised) woven into a rectangular tube 300mm wide and 200mm high. The tube shape was adopted in lieu of a flat 'ladder' configuration to provide protection for crossing fauna from predators, however, it was later stated that fauna tended to cross on the top of the 'tube' hence, where predators are not an issue, rope 'ladders' may suffice. Hence, the flat ladder design is recommended over a 'rectangular tube' or 'box' rope ladder.

- Tube held in shape using a series of stainless steel frames and four 4mm diameter longitudinal stainless steel cables in the corners.

- Rope tube (done in sections were) held together by two main 10mm galvanized cables strung between the poles.

- Poles were braced back to concrete footings in the ground by 16mm diameter galvanized cables.

- Single-strand rope bridge should NOT be used due to a higher than acceptable risk of animals falling or absence of evidence for use by arboreal fauna (Rodney van der Ree pers comm.)

All rope bridges must have 'connecting' ropes from the poles into adjacent trees to encourage fauna movement directly from the canopy such as an example from the Compton Road crossings shown in Figure 20 below (Queensland Department of Transport and Main Roads 2010).

Figure 19. Common Brushtail possum within a 'tube-style' rope bridge, Karuah Bypass, NE NSW (sourced from Bax 2006).

Figure 20. Rope bridge with connecting rope connecting adjacent trees, Compton Road, near Brisbane, QLD (Robinson-Wolrath 2009).

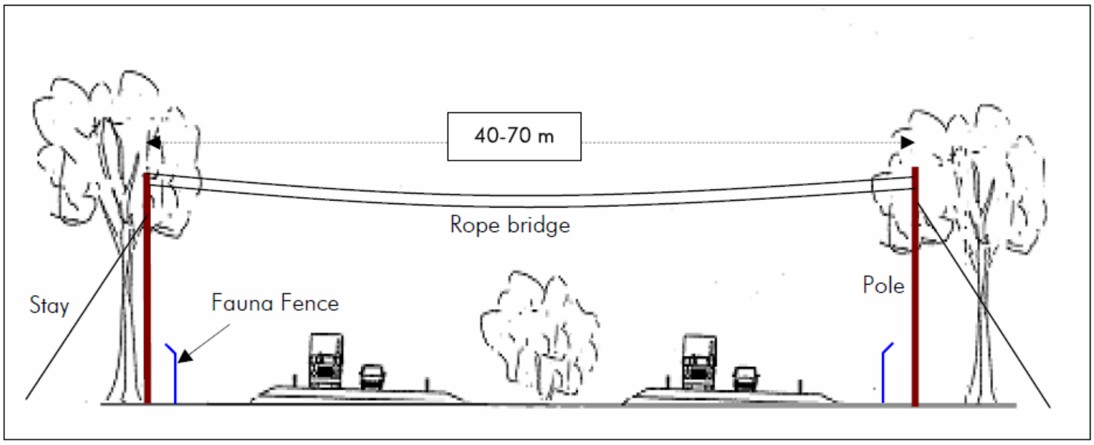


Figure 21. Schematic diagram of a typical rope bridge installation with fauna fencing – note that the rope bridge does not connect with median strip vegetation, and bridge terminals end within canopy habitat (from Bax 2006).

4.4.5.4 Maintenance and costs

Costings for installation of rope bridges are likely to vary between approximately $15,000 and $20,000, for base level rope or flat top bridges of approximately 30 metres wide, which provide connectivity for possums and gliders. For more solid constructions that will facilitate connectivity for larger arboreal species, such as the Koala, or longer bridges across multilane highways, the costs are likely to be approximately $100,000 or more. For more information regarding rope bridges and variations on designs refer to: http://www.faunacrossings.com.au. Companies specialising in their installation can also undertake training of Council employees to undertake further installations. Significant reductions in cost can be achieved by consulting with specialist companies early on in the engineering design and specification process.

The Department of Transport and Main Roads Queensland recently installed Koala overpass gantry structures for the Koala Task Force around Brisbane which cost approximately $500-600,000 for each structure (Baath 2012)

Rope bridges would need ongoing maintenance and monitoring to ensure that ropes are not rotting/fraying, and that the framework and rope netting is maintained to prevent sagging. Monitoring should also consider whether adjacent vegetation is still providing connectivity with the crossing structure, and that fauna fencing alongside the road is still functional.

4.4.5.5 Case study example

Karuah Bypass, which is situated three hours north of Sydney, has five rope bridges installed within a 9.8 km stretch of road, which is part of the Pacific Highway (Bax 2006). This was to provide connectivity between large areas of treed habitat on either side of this busy, dual carriage road. A study was undertaken by Thiess Pty Ltd (Bax 2006) to determine the use of these structures, and it was found that possums and gliders did make use of these, traversing the median-divided freeway along a 70 metre long rope bridge. Recommendations resulting from this study suggest that it is important that ends of the crossing are close to suitable vegetation, to encourage its use.

4.4.6 Fish passages

4.4.6.1 Description

Fish passages can be any of a broad range of 'crossing' structures. In many cases, fish passages are modified box or pipe culverts, through which water flow is continuous, or flows ephemerally. To aid fish movement, the modifications include the installation of baffles or ledges within a culvert, thus creating eddies. This allows a wider range of fish species to move through the passage; with less energetic species being able to traverse the passage upstream using burst-swim-rest manoeuvres between baffles (Kapitzke 2010). Culverts with 'offset' baffles seem to work well for most situations, but Kapitzke (2010) developed a new type of baffle, the 'quad', for pipe culverts where 'offset' baffles do not suit the hydrological conditions.

In conjunction with wet pipe or box culverts, modified to enhance fish passage, aquatic habitat and hydrological features adjacent to the passage should also be considered. Modifications to ensure that water velocity and surface drops do not hinder movement of fish should be included as part of the fish passage construction process. In the book, *Culvert Fishway Planning and Design Guidelines*, Kapitzke (2010) recommends the use of rock ramps and cascade fishways to ameliorate the effect of surface water drops and high velocity shallow water flow.

4.4.6.2 Context of use

Fish passages should be used at all locations where waterways, including drains, pass underneath a roadway. Such passages could be incorporated as part of a broader fauna crossing structure, such as a bridge underpass, or larger culverts which have some areas partially submerged within water, but also provide ground-dwelling fauna connectivity. Or, if culverts are installed for waterway connectivity, these could be targeted as fish passages.

4.4.6.3 Technical Specifications

Most culverts, as described earlier, are constructed of pre-cast concrete piping or cells. However, for fish passages, these culverts should be modified to incorporate a number of structural features, such as baffles. General technical details are given below, but for detailed specifications on various culvert designs, please refer to Kapitzke (2010).

For accessibility, it is best to have a minimum pipe/box culvert height of 1.2-1.5 metres, to allow for installation of effective baffles and for personnel access for installation and maintenance (Kapitzke 2010). For the below culvert modifications, it is recommended in Kapitzke (2010) that baffles be constructed with consideration to the following more robust materials of pre-cast concrete, steel, or high-strength plastics. In prototypes developed for an assessment of functionality in Kapitzke (2010), waterproof plywood and steel brackets were used and these are not recommended for permanent installations. Baffles should be spaced at no greater than 2.0 metres apart (Kapitzke 2010).

Box culvert

- corner 'EL' baffles
- 'offset' baffles

Pipe culvert

- 'offset' baffles
- 'quad' baffles

For rock ramps and cascade fishways, the following is likely to be required for suitable hydrological modification: weathered 'angular' rocks/boulders of various sizes, grouting, and loose gravel, in incorporation with mechanical and hydrological engineering of the waterway – for more detail, refer to Kapitzke (2010). It is also desirable that water flow be at a minimum of 0.2 – 0.3 metres, to allow passage for small to medium-sized fish (Kapitzke 2010).

Examples of modified box culverts – with prototype corner 'EL and 'offset' baffles are given below (Kapitzke 2010).

Figure 22. Box culvert with corner 'EL' baffles (Kapitzke 2010)

Figure 23. Box culvert with 'offset' baffles (Kapitzke 2010)

As for above, examples of modified concrete pipe culverts, with 'offset' and 'quad' baffles are given below (Kapitkze 2010)

Figure 24. Pipe culvert with 'offset' baffles (Kapitzke 2010)

Figure 25. Pipe culvert with 'quad' baffles (Kapitzke 2010)

Examples of associated rock ramp and cascade fishways, which could be implemented in conjunction with, or in place of, culvert modifications, as a holistic approach to fish passage functionality and effectiveness, are given below.

Figure 26. Ridge rock fishway with large boulders creating 'V' slots for fish passage (Kapitzke 2010)

Figure 27. Cardwell (QLD) ridge rock ramp fishway at weir (Kapitzke 2010)

4.4.6.4 Maintenance and costs

Wet culvert fauna passages of all types would require regular checking for sedimentation and debris build-up, particularly after flooding events. However, in the fish passage study undertaken at the Solander Road crossings of University Creek, Townsville, QLD (Kapitzke 2010), it was found that there was minimal accrual of loose gravel (pipe culverts with offset baffles, along oblong baffle side), and no sedimentation or debris build up, over a two or five year period, for any of the modified wet culverts with baffles.

The following are estimates of costs for the physical structures facilitating fish passage as applicable to different passage structures:

Box culverts / aprons / channels

- Offset Baffle fishway system – precast concrete (1200 wide channel) $200 – $300/linear metre of culvert

- Block Ramp fishway system – precast concrete (1200 wide channel) $600 – $800/linear metre of culvert

- EL Baffle fishway system – precast concrete (900mm high wall / 325mm high floor baffle); cost: $250 – $350/ linear metre of culvert

- Wall Baffle fishway system – HDPE plastic (900mm high wall baffle @ 1200crs) $300 – $400/linear metre of culvert

- Training Wall system – precast concrete (225mm / 325mm high) $150 – $200 per linear metre of training wall

Pipe culverts

- Quad Baffle fishway system – HDPE plastic on 316SS rails (1200mm diameter pipe culvert) $ 450 – $ 600 / linear m of culvert (Kapitzke 2010).

4.4.6.5 Case study example

As part of a broad study on the efficacy of fish barrier mitigation, through the use of baffles and rock ramp/cascade fishways, Kapitzke (2010) installed (mainly through retrofitting existing structures) and reviewed the success of, various fish passage structures in northern Queensland. Along University Creek, in Townsville, the use of baffles, both corner “EL” and “offset” baffles provided passage accessibility for fish swimming upstream through box culverts, as did both “offset” and “quad” baffles, within pipe culverts (Kapitzke 2010), with all types having good self-cleaning capability, preventing sedimentation. However, Kapitzke (2010) stated that in-stream fishways should reflect, as much as possible, the natural conditions of the adjacent stream conditions, and a pre-existing assessment of stream conditions, fish species (and their limitations), and variation in potential hydrological conditions is essential before a particular fish passage structure can be recommended.

4.4.7 Fauna exclusion barriers and guide fencing

4.4.7.1 Description

Fauna exclusion barriers and guide fencing are designed to both encourage fauna movement towards fauna connectivity structures and minimise road casualties though wildlife-vehicle collisions. In Australia, fauna exclusion fencing has most commonly been used for the conservation of Koalas (Gardyne 1995) and to exclude macropods from roads. Exclusion fencing has also been used for frog species such as the Growling Grass Frog *Litoria raniformis* on a number of new major road developments such as the Pakenham Bypass and Craigieburn Bypass in Melbourne. Structures typical consist of a fence of varying heights and cell gauge dependent on the target fauna for exclusion. Fences generally have an underground skirt and a solid above-ground skirt that inhibits passage by smaller animals and reduces visibility of the road as an additional deterrent.

4.4.7.2 Context of use

Fencing of areas where regular movement paths cross over roads may be of significant benefit to some fauna populations. Guide fencing is an essential component of underpasses and culverts in funnelling animals into crossing structures (Queensland Department of Transport and Main Roads 2010). Many animals are hit by cars where unfenced sections of road join a fenced culvert, particularly at high risk areas such as woodland/grassland interfaces or areas that support remnant corridor vegetation (Queensland Department of Main Roads 2000).

4.4.7.3 Technical Specifications

Guide fencing may be constructed to suit a range of animals or may be species-specific.

Figure 28. An example of fauna exclusion fencing, deterring animals from climbing over, or burrowing underneath (from Veage and Jones 2007)

4.4.7.4 Maintenance and costs

Fauna exclusion barriers/fencing, to be effective, would require regular monitoring to check for incursions or holes (i.e. vandalism, damage caused by car accidents, fauna digging below fences) within the fencing structure. Fencing that is installed near waterways or is installed within moist areas should be checked regularly to check for corrosion issues.

Fencing running parallel to areas with tall vegetation should be checked periodically, to minimise uncontrolled crossings by fauna climbing over fence from adjacent vegetation. Thus, vegetation clearing/management to maintain a three metre buffer zone should be incorporated as part of the overall maintenance plan.

Monitoring road kill will guide fencing has been successfully installed. If rates of wildlife casualties remain high, additional fencing, or changes to the barrier structure may be required.

The Compton Road project fencing costs were approximately $220,000 and ran the entire length (2.5 km) of the site.

4.4.7.5 Case study example

The Compton Road project involved installing wildlife exclusion fencing with the aims of:

- stopping animals from entering the roadway
- allowing animals entry to the forest from the roadway
- providing for small and large mammals
- preventing 4WD's and motorcycles entering the forest

- directing wildlife to the crossing; and being of low maintenance requirement.

4.4.8 Additional Infrastructure Costs

Apart from the larger structures discussed above, there are other components and options for providing fauna linkages. The Department of Transport and Main Roads Queensland recently retrofitted existing culverts along the Koala Coast for the Koala Task Force around Brisbane at sites that were considered ideal linkages. The project involved 21 sites and cost $300-$400 each to install fauna furniture in culverts which cost approximately $500-600,000 for each structure. The project is currently being monitored (Baath 2012).

4.5 Summary and Recommendations

Land bridges and bridge underpasses possibly accommodate the largest range of fauna, as these structures are more likely to be able to provide continuous, or near continuous, habitat throughout. In particular, they are the only structures which will improve connectivity for bird fauna across major multi-lane roads. However, where there are constraints present, box culverts provide the next best level of connectivity for ground-dwelling mammals and reptiles. More specialised fauna connectivity structures are needed when passage for other target fauna groups, such as fish, frogs, and arboreal mammals is required. Smaller pipe culverts are recommend for minor road crossings in lower threat environments (e.g. agricultural land) and also as additional structures where small ground-dwelling animals are the dominant fauna group. A summary of recommendations is provided in Table 3 below.

Road or infrastructure projects that could result in further fragmentation of existing habitat or threaten the establishment of proposed corridors should follow the three step approach of stopping animals from entering the roadway

- *Avoid*: alter road or infrastructure plans
- *Minimise*: reduce the impact e.g. avoid areas supporting existing habitat or use methods to reduce traffic volume and speed
- *Mitigate*: implement fauna crossing structures

As the last option, any new road planned to run through a habitat patch, or a recommended higher priority corridor, should be planned to accommodate fauna crossing structures. Any upgrades of roads (i.e. widening) that intersect proposed or existing corridor should also consider incorporating crossing structures.

Fauna crossings recommended in this report should be retrofitted in a staged manner as road-works or upgrades are undertaken. However, strategic retro-fitting of crossing structures at other locations should also be considered. The order of implementation may not strictly follow the priority recommended in this report; rather Frankston City Council should pursue the implementation of crossing structures when opportunities arise (e.g. large road upgrade projects).

Ideally, smaller fauna passage structures should incorporate as many features as possible to cater for a wide range of fauna, this can be easily done by incorporating fauna furniture within the infrastructure, such as logs/rocks, standing ‘escape’ trees/poles, wooden ledges or rails, and an earthen covering (for culverts).

While it is not possible to provide exact cost estimates for fauna connectivity structures, due to the variability in the engineering requirements; with due consideration to local geotechnical and/or hydrological conditions, traffic volume, and significant fauna habitat, some important factors to consider when obtaining cost estimates include the below (some are derived from van der Ree *et al.* 2008):

- Length and width of underpass/overpass
- Construction of infrastructure (e.g. prefabricated concrete cells, or unique structures)
- Design – is it straightforward or complex?
- Is the fauna passage being installed as a new structure, or as a retrofit of existing infrastructure?
- Costs of engineering/construction/vegetation management work before, during and after installation of the infrastructure

Table 3. Summary of fauna crossing structures, the level of connectivity they provide and the context in which they can be applied

Fauna crossing structure type		Brief description[1]	Context in which structure could be implemented	Fauna subgroups likely to benefit
Land bridges	Over road	A bridge extending over a road, typically 20-70 m wide. The bridge is covered in soil, planted with vegetation and enhanced with other habitat features (e.g. logs, rocks etc).	Crossings across large, busy roads with large, high quality areas of fauna habitat bisected by freeways and multi-lane highways	All species excluding aquatic
	Small (dual purpose) road overpass	A narrow bridge (not hour-glass shaped) above a major road, which allows human or vehicular access across the major road. The road on the overpass is typically a minor road, which may be unsealed or a single lane. Additional areas adjacent to the road may be used for fauna movement.		All species excluding aquatic
	Cut-and-cover road tunnel	The road passes below ground level through a tunnel with the area above available for revegetation and use by some fauna species.		Small to large terrestrial mammal, semi-arboreal & arboreal mammals, reptile, amphibian

Fauna crossing structure type		Brief description[1]	Context in which structure could be implemented	Fauna subgroups likely to benefit
Underpasses	Bridge underpass	A structure that maintains the grade of the road or elevates the traffic above the surrounding land, allowing animals to pass under the road. Facilitates water drainage or the movement of local human traffic and secondarily facilitates fauna passage. Vegetation clearing can also be minimised (clearing only required for bridge piers or pylons) and allow natural vegetation to grow under the structure.	For roads that are wide, busy and/or high-speed that crosses over waterways or uneven landscape and travels above a landform with enough clearance to maintain clearance for a range of fauna and any waterways with adjacent riparian vegetation	All fauna subgroups but potentially lower permeability for birds
	Box culverts	Square, rectangular, or half-circle in shape and may be purpose-built for fauna passage or water drainage, or a combination of both. They are typically pre-cast concrete cells, or arches made of steel.	For smaller roads (less than 30-35 metres wide) along known fauna movement passages, particularly between breeding and foraging areas	Small to large terrestrial mammal, semi-arboreal & arboreal mammals, reptile, amphibian
Pipe (concrete) culvert		Typically round pipes of relatively small diameter (e.g. >1.5 m).	For smaller roads (less than 30-35 metres wide) along known fauna movement passages, particularly between breeding and foraging areas	Small to medium terrestrial mammals, reptiles and amphibians
Rope (canopy) bridge		A rope or pole suspended above the traffic, either from vertical poles or from trees. Used by arboreal and climbing species.	For a wide range of situations, including small, but busy roads, or larger dual carriageway freeways/highways, where there is arboreal habitat present on either side of the roadway	Semi-arboreal & arboreal mammals

Fauna crossing structure type	Brief description[1]	Context in which structure could be implemented	Fauna subgroups likely to benefit
Fish passage (i.e. fish ladder) -> short section	Usually a short passage beneath a road, generally via a bridge underpass or box culvert. Structurally designed so that fish can travel through, unimpeded. Generally structured with concrete base and/or pre-cast concrete cells/arches.	All locations where waterways, including drains, pass underneath a roadway and can include a broader fauna crossing structure. Anywhere culverts are installed for waterway connectivity.	Frogs, aquatic mammals and fish

1. As described in Queensland Dept of Transport and Main Roads (2010) – to maintain continuity with terminology

4.5.1 Associated management recommendations

Exotic predators

Design considerations need to reduce the impact of exotic predators on native species

When designing the fauna linkage structure, consideration should be given to minimising the potential that a native animal's use of the structure will make it more vulnerable to exotic predators. For example, an investigation of fauna use of culverts by the western Australian subspecies of the Southern Brown Bandicoot (Harris, Mills and Bencini 2010) found that a dramatic decline in bandicoot use occurred once foxes were also observed using the underpasses. The authors suggested that funnelling of bandicoots by the underpasses attracted foxes and potentially resulted in predation of bandicoots. Nontheless, a review of wildlife crossing structure studies found that increased rates of predation with crossing structure installation was not a consistant occurrence and that most studies recorded no evidence of predation in or around passages. Consequently, the benefits of crossing structures far outweigh any risk of predation (Little, Harcourt and Clevenger 2002).

In many cases, it will not be possible to exclude predators (such as cats and foxes) from also using the structure, but there are methods that can be used to limit the potential for these predators to reduce the potential use of the structure by native animals or to cause harm to these animals. To ensure that predation does not inhibit connectivity for some species, on-going predator control (fox and cat) and monitoring at fauna crossing structures (e.g. fauna underpasses, culverts, and land bridges) must be part of installation and management of this technique to connect populations. Vegetation at the culvert entrance (Taylor and Goldingay 2003) or large logs linking the entrance to vegetation (Harris *et al.* 2010) may be important in facilitating use and providing some protection from predators. To achieve maximum use, the provision of logs and branches (Harris *et al.* 2010) within fauna culverts has been suggested, while the provision of dense vegetation within fauna crossings would be more desirable.

Management of exotic predators

In order to properly address the threat posed to native animals by exotic predators, a management program is required. Foxes and cats are the exotic species that are most likely to predate the native species using the linkages and for both species an integrated, region-wide management program will be most effective.

Methods for fox and cat control will need to be sensitive to the suburban environment in which many of the linkage sites will exist. Some suitable fox and cat management methods include cage trapping and the use of soft-jaw traps. Local residents must always be notified of the management activities well in advance. A community engagement program may complement the on-ground activities associated with the introduction of the linkages as well as assisting with community acceptance and understanding of these activities.

Should resources be constrained, initial focus should be on sites that are of very high priority for crossings and/or are part of a very high priority corridor or stepping stone area. As more funding becomes available, the monitoring program should move to areas focussing on high, then medium then lower priority sites.

Monitoring exotic predators

Monitoring of predator numbers and behaviour across the region should be an initial step to guide predator management activities. Should resources be constrained, initial focus should be on sites that are of very high priority for crossings and/or are part of a very high priority corridor or stepping stone area. Monitoring of predator numbers and activity should continue during and following the construction of the linkage structures along with similar monitoring for native animals. As more funding becomes available, the monitoring program should move to areas focussing on high, then medium then lower priority sites.

Additional measures to increase the permeability of roads and reduce wildlife casualties

Although fauna crossing structures are the most reliable way of improving the permeability of roads and lowering rates of mortality/injury, some other techniques could be applied as additional measures and as education devices for the broader community.

Additional **recommended measures** include:

- Consider lowering speed limits and/or installing speed humps (Hobday and Minstrell 2008) in high areas where high numbers of wildlife casualty have been recorded ('high density' hotspots in Figure 10).

- Designing future road networks and upgrades so high traffic volume roads do not intersect or run adjacent to major patches of habitat or identified existing or potential linkages.

- Modify existing fencing immediately adjacent to roads and bordering habitat to ensure animals have an escape route if confronted by an on-coming vehicle (Magnus et al. 2004). One-way gates and 'wildlife jump-outs' or 'escape ramps' can be used to allow animals to move off the road easement and back into the adjacent habitat. Wildlife jump-outs/escape ramps are sloping mounds of soil positioned up to the height of the existing fence on the right-of-way (i.e. road) side of the fence. For example, fencing on either side of McClelland Drive adjacent to the Pines FFR may be causing increased casualty rates of casualties in Black Wallabies as animals are trapped within the road reserve with on-coming traffic.

- Installing signs at all locations where fauna crossing structures are recommended (Figure 11) and areas experiencing a high number of wildlife casualities ('high density' hotspots in Figure 10), particularly where roads are bordered on both sides by native vegetation habitat. Signs should warn drivers to be conscious that fauna may attempt to cross a road.

4.5.2 Monitoring of crossing structures

Techniques

There are various forms of monitoring that are available to determine the effectiveness of fauna linkage structures. Some that we have looked at include the use of sand pads; capture-mark-recapture or radio/satellite tracking; camera trapping; and genetic methods. Simmons et al. (2010) have reviewed three of these methods, capture-mark-recapture; satellite/radio tracking; and genetic methods. Upon review of current literature they find that:

- The capture-mark-recapture (CMR) method can provide some good information on population density and some information on daily movements of smaller vertebrate, and how this is influenced by roads and landscape features. However the drawbacks for this method include the need for a lot of equipment, stress inflicted upon the animal, a level of danger involved in working beside roads, and the data are limited to the points of capture associated with a subset of behaviour, i.e. feeding on bait.

- The radio tracking technique is very long established and well used. Devices are becoming smaller, able to last longer (have improved battery life) and as GPS technology is now being incorporated, data collection is becoming more accessible. Animals still need to be trapped and usually recaptured and this method may be better for larger animals as there is a weight to longevity ratio associated with the devices. Although the costs of these devices are reducing as technology improves, they are still high. Capturing and recapturing enough suitable individuals for the study can be challenging. There is usually attrition of numbers due to mortality, dispersal or via the loss/failure of devices. These issues have generally combined to lead to narrow time-frames of observation relative to the potential dispersal period for the study species. Therefore this technique may fail to detect dispersal events such as those that are life-stage specific or rare.

- Genetic techniques (allele frequency and genome-based) analyses can be applied to any organism with obtainable genetic material and tailored to a range of temporal and spatial scales. With appropriate sampling they can provide important information about movement of individuals and their genetic material, including habitat use, dispersal and gene flow. The main considerations for using genetic techniques involve careful planning of the study. This involves identifying the target species and compiling appropriate population genetic input in the design of the study to determine the availability of suitable genetic markers for the time scale and study questions. Following the study design, tissue samples are collected. This may involve animal trapping or could even involve using hair tubes, depending on the study requirements. Costs of genetic techniques are generally comparable to CMR methods.

- Sand pads can be a cheap and easily accessible method of identifying some animals that are utilising a crossing. Its use is largely limited to identifying the potential presence or absence of species at the site of the sand pad. The best results will result from a sand pad constructed of firm and slightly damp sand (Harris, Mills and Bencini 2010; Wayne et al. 2005). It has been found by Taylor and Goldingay (2003) that it was adequate to check the sites every two days. The drawbacks with this technique are the difficulty of identification of unclear tracks and also limitations associated with accurate identification of tracks to species level in some cases.

- Camera trapping is the use of automatic cameras triggered by passing animals. It is recognised as a very useful technique for recording larger bodied ground-dwelling vertebrates in the field. Photographs provide objective records, or evidence, of an animal's presence and identity and it is a technique which has gained in popularity as technology has improved and costs have reduced in the past decade. Camera trapping can be useful for determining fauna presence and linkage usage patterns, also their relative abundance and habitat preference.

In regard to key species that could benefit from improved linkages in the Frankston region, the following monitoring methods have been found to have mixed results for the Southern Brown Bandicoot. Conventional cage trapping has a relatively low success rate for bandicoot species unless at high population densities. Use of camera traps are likely to increase the likelihood of detection where the species is at low density or range widely (e.g. in linear habitat).

Timing

To assess the eventual effectiveness of any crossing structure, monitoring of fauna must be begun well in advance (>1 year) of the actual construction phase to determine benchmarks for comparison. When designed appropriately, such crossing structures can greatly enhance the safe movement of fauna across barriers such as roads. Associated barrier fencing that funnel animals through fauna crossing structures can also reduce the incidence of mortality or injury to fauna. Fauna crossing structures combined with barrier fencing can also act to reduce costly collisions between fauna and vehicles and associated injuries to community members.

Recommendations

We recommend that:

> ***Fauna and habitat surveys are undertaken within the vicinity of the crossing structure locality at the detailed planning and design stage*** *to further refine the type and location of the structure.*
>
> ***Multiple survey methods should be used to monitor use of fauna crossing structures*** (van der Ree et al. 2007) and the success of other conservation management actions. The techniques that may be most useful include sand traps, camera traps, remote pit-tag scanners, radio-tracking, and genetic techniques. In the case of target indicator species, these should be used in combination with assessments of population sizes using cage trapping and assessed for effectiveness (e.g. >90% of individuals successfully cross over roads using fauna culverts) at the population level using PVA.
>
> ***Monitoring must occur before, during, and after the construction of crossing structures*** For example, the effectiveness of fauna road crossing structures in facilitating the movement of fauna across roads should measure fauna behaviour and demographics prior to, during, and after installation of a fauna culvert (Glista, DeVault and DeWoody 2009).
>
> ***Linkage structure design should include consideration of monitoring techniques.*** For example, consideration of potential locations for camera traps or sand pads should be part of the structure design. Consideration also should be made regarding future access and safety for the people undertaking the monitoring.

5. RECOMMENDATIONS FOR IMPLEMENTATION

From the larger number of higher priority corridors, two were selected to be the focus of on-ground efforts in the near future. Along with higher priority corridor identified in this report (Figure 7), these corridors are two specific very high priority examples seen as the most urgent for implementation.

These corridors were selected based on their overall provision of connectivity for target fauna species (see Table 4 below), the feasibility of implementing the corridor and a wider width, habitat values along the corridor route, significance of linking patches, and lower severity of barriers to implementation. Methods for selecting these corridors are detailed above in Section 2.1.3. Two important considerations were whether 1) the corridor was entirely or largely within the Frankston LGA (i.e. could be largely implemented by Frankston City Council) and 2) provided connectivity between larger and higher quality patches of fauna habitat.

5.1 Recommended fauna corridors for urgent implementation and specifications

Two primary fauna corridor linkages have been recommended (Figure 29: C1 and C2) for urgent implementation. Both corridors provide a fauna linkage between two core fauna habitat patches. Both corridors incorporate linkages assessed as being of High or Very High priority and obtained high scores in the individual criteria of 'conservation significance', 'feasibility', and 'opportunity' when compared to other linkages within Frankston LGA.

There are also two subsidiary linkages recommended that should also be pursued to further strengthen benefits to fauna connectivity within the study area by linking additional fragmented nodes of fauna habitat. Implementation of these corridors should provide improved connectivity for a substantial proportion of the target fauna species (Table 4).

The following points below are rationale for selection of the two recommended corridors and two subsidiary linkages:

C1: <u>Pines Flora and Fauna Reserve</u> to <u>Royal Botanic Gardens Cranbourne</u> Corridor

- Connects two large core patches of good quality fauna habitat i.e. Pines Flora and Fauna Reserve to Royal Botanic Gardens Cranbourne
- Provides linkages between several fauna habitat node patches
- Incorporates numerous areas of higher quality fauna habitat (both core and node patches) representing several EVCs
- A high proportion of the corridor length supports existing high quality native vegetation/fauna habitat
- A corridor with a continuous groundstorey habitat could feasibly be attained along the entire corridor length
- This corridor has a comparatively high likelihood of achieving a wide corridor width than most other assessed linkages within Frankston

- A high proportion of the corridor length incorporates public land or land which could be put aside in the future for conservation purposes

- There are comparatively few major existing infrastructure barriers (e.g. major roads) to corridor implementation

- A significant proportion of the corridor length is within Frankston LGA and consequently, Frankston City Council can play a large part in implementing this corridor and protecting nodes of habitat being connected.

C2: Pines Flora and Fauna Reserve to Langwarrin Flora and Fauna Reserve Corridor

- Provides a connection between two of the largest and highest quality core habitat patches within Frankston LGA

- Provides connectivity for fauna between a number of fauna habitat node patches

- Follows an existing corridor for fauna (i.e. Boggy Creek)

- Incorporates and protects an important existing aquatic corridor (i.e. Boggy Creek)

- A high proportion of the corridor footprint is already supporting fauna habitat (i.e. native vegetation) which can be enhanced through time

- A corridor with a continuous groundstorey habitat could feasibly be attained along a significant proportion of the entire corridor length

- A wide corridor width could be attained along some sections of this corridor

- Corridor is largely within public land or waterway easements

- There are comparatively few major barriers to implementation in the form of existing infrastructure such as major roads

- Opportunity for subsidiary linkage S1 to provide connectivity for Studio Park and adjoining nodes while subsidiary linkage S2 could provide connectivity to the important Langwarrin Woodlands

Subsidiary Linkages

S1: Pines Flora and Fauna Reserve to Boggy Creek via Studio Park node

- Facilitates movement of fauna to Studio Park node along non-riparian habitats.

- Incorporates a large area of good quality fauna habitat

- A continuous corridor of wide width and high quality fauna habitat can be feasibly attained

- Provides a secondary connection between Pines FFR and Boggy Creek node in the case of failure of the primary C2 corridor

- Currently few major barriers to implementation in the form of existing infrastructure such as major roads or private dwellings

S2: Langwarrin Woodlands to Corridor C2 (Langwarrin Equestrian Centre)

- In combination with Corridor C2, facilitates movement of fauna from the Langwarrin Woodlands node (ID# 424) to the Langwarrin FFR, Pines FFR, Boggy Creek node, and Studio Park

- Connects high quality fauna habitat in the Langwarrin Woodland nodes to Langwarrin FFR and the Greater Pines FFR including important woodland habitat for birds and arboreal mammals

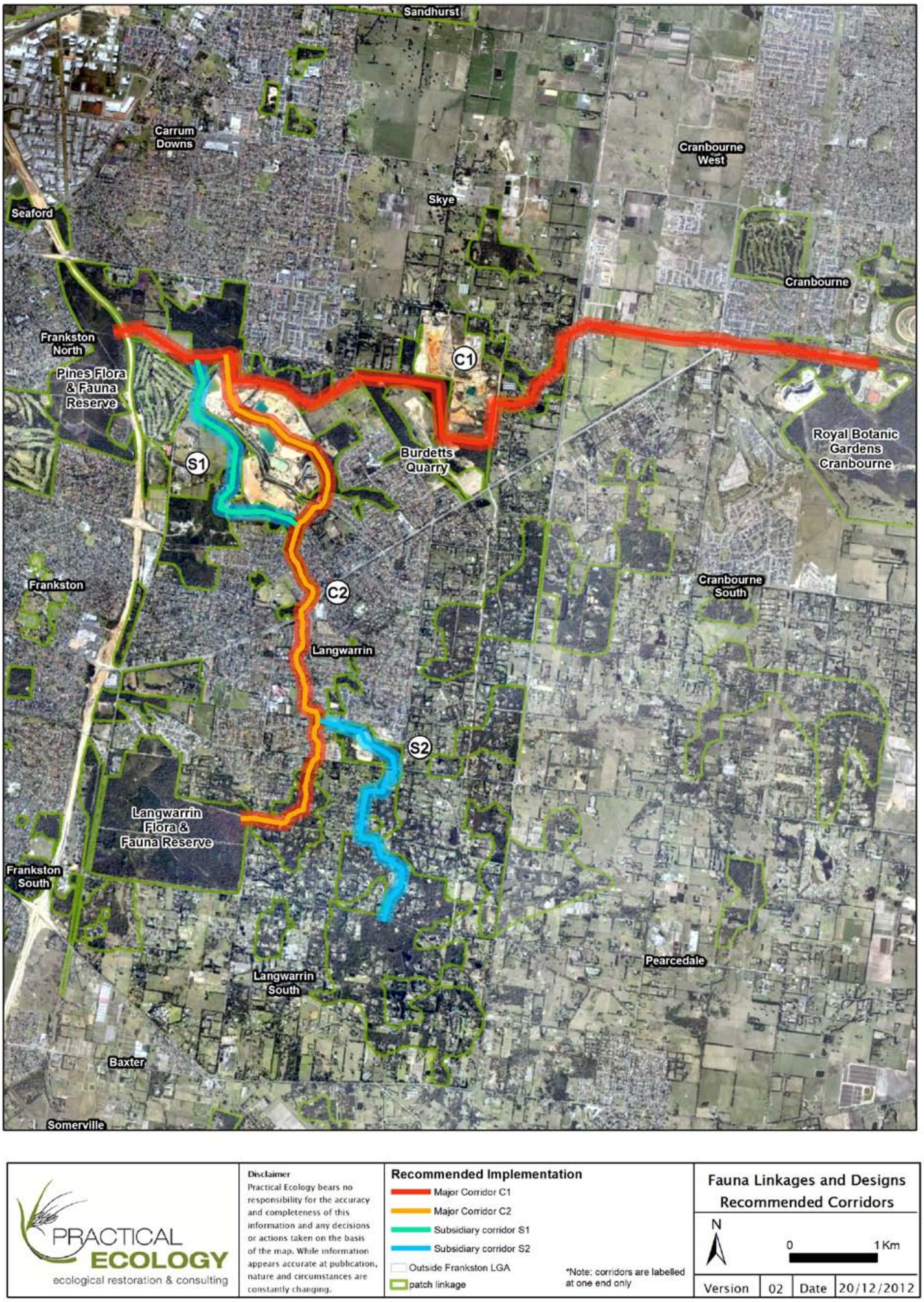
- Provides a potential secondary option for connecting fauna habitat to nodes of habitat south of Frankston in Pearcedale and beyond

- Provides connectivity among high quality habitat within the Langwarrin Woodlands node (ID# 424)

- Few major existing barriers to movement of fauna and potential to incorporate crossing structures in future planning opportunities

- Low existing private and public infrastructure and incorporates public reserves and private wildlife covenants

Figure 29. Two primary corridors (C) and two supplementary corridors (S) for urgent implementation.



5.2 Estimated connectivity provision of two urgent corridors for target fauna species

To provide support for implementation and guide management, the potential use of two urgent corridors, and two supplementary corridors was estimated. This was inferred from each species A) known distribution (i.e. inferred from species records), B) distribution of suitable habitat, movement behaviour, and C) likely barriers to movement. For each of the target species, the level of connectivity provided by implementation of the proposed corridor is given. A review of each target species ecology (habitat preferences, critical resources, and movement behaviour) was also used to inform potential use of corridors (APPENDIX 9)

KEY	
Code	**Description of Connectivity Provision Type**
P	Linking two or more populations
C	Connectivity among Core populations OR habitat
S	Providing connectivity between a population and significant areas of unoccupied suitable habitat
H	Protecting and enhancing habitat
[C]	Brackets denote two or more corridors must be implemented to achieve designated connectivity provision

Table 4. Estimated use of corridor linkages for urgent implementation by target fauna species (APPENDIX 8: Table 8)

	Primary Corridors						***Supplementary Corridors***					
	Corridor C1			***Corridor C2***			***Corridor S1***			***Corridor S2***		
Species	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**
Agile Antechinus	0	HCS	Providing a high level of connectivity among core and node habitats between the Pines FFR and the RBGC. The Agile Antechinus has previously been recorded within the RBGC and a wide corridor incorporating higher quality habitat restoration could provide connectivity to other suitable unoccupied habitat patches along the corridor route to the west. However, recent surveys (Practical Ecology 2007) failed to detect the species and further observations are required to confirm a population at the RBGC.	2	HCS	Providing a moderate level of connectivity among suitable habitats in core and node patches between the Pines FFR and Langwarrin FFR. Connectivity north and south of Cranbourne-Frankston Rd may be challenging due to a narrowing in potential corridor width at the juncture of Boggy Creek and Cranbourne-Frankston Rd, associated predation threats, and dependent on the species utilisation of fauna friendly culvert crossings over longer distance to pass under roads at the juncture.	0	H[S]	Protects and enhances moderate-high quality within Studio Park and nearby remnants along the western boundary with the Rocla Quarry. Could feasibly connect a Langwarrin FFR population to Studio Park habitat in combination with corridor C2 (but see C2 discussion of challenges to connectivity provision).	1	HC[S]	Dependent on the species presence in Langwarrin FFR, corridor S2 could provide a moderate-low level of connectivity for the Langwarrin FFR population to higher quality habitats in the Langwarrin Woodland node (ID#424) and associated Stringybark Bushland Reserve and North Road Reserve in combination with corridor C2.
Black Wallaby	22	PHC	Connectivity could be achieved among core populations and habitat in the northern half of the study area (the Pines FFR, former DARA Lands, Burdett's Quarry-Gumnut Reserve, Valley Rd node ID# 355, and Lyppards Rd node ID#315) between the Pines FFR and the RBGC.	32	PHCS	Provides connectivity among fragmented patches of suitable habitat along Boggy Creek north of Cranbourne-Frankston Rd. Connectivity between populations/habitat north and south of Cranbourne-Frankston Rd unlikely to be feasibly to due to existing land uses and infrastructure barriers. Alone, corridor C2 provides limited value connectivity for the Black Wallaby between Langwarrin FFR and adjacent Woodland node ID# 425. However, see S2 for further connectivity provision by C2.	21	PHS	Connects a route of safe passage for the Black Wallaby between the Greater Pines FFR and remnants in Studio Park and associated with Boggy Creek. Provides an alternate overland route to C2.	4	PHCS	In combination with corridor C2, this supplementary corridor could provide some dispersal opportunities for the Black Wallaby between Langwarrin FFR and the southern Langwarrin Woodland node ID#424. Alone this corridor would provide important habitat continuity within the latter node and also broader landscape connectivity along Watson's Creek to habitat south and south-east whilst incorporating swamp riparian scrubs favoured by the species.

	Primary Corridors						Supplementary Corridors					
	Corridor C1			Corridor C2			Corridor S1			Corridor S2		
Species	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**
Blotched Blue-tongue Lizard	3	HS	Dispersal from population in the Pines FFR could be facilitated into apparently unoccupied nodes supporting suitable habitat including Burdett's Quarry (ID# 375, 355, 319, and 315).	4	HS	May facilitate dispersal of individuals from the Pines FFR southward along Boggy Creek and with provision of crossing structure, south across Cranbourne-Frankston Rd to core habitat within Langwarrin FFR and Langwarrin Woodland nodes (ID#424-25).	4	PHCS	Connectivity provision between the Pines FFR and Studio Park populations and connecting the latter population to suitable habitat along Boggy Creek.	2	H[S]	Facilitating dispersal opportunities for the Studio Park population to recolonise suitable habitat within the Langwarrin Woodland nodes (ID#424-25) when combined with structural connectivity provided by corridor C2.
Common Froglet	120	PC	Provides dispersal opportunities between core populations in the RGBC to populations in Frankston including those associated with wet habitats in the Pines FFR.	31	PH[C]	Protects and enhances habitats for populations associated with Boggy Creek and in combination with corridor C1 connects core populations in the RBGC with those in Langwarrin FFR.	23	H	Assists in dispersal and habitat connectivity along Boggy Creek and to wet habitats in the Langwarrin Woodlands.	14	P	Studio Park population provided with dispersal opportunities along Boggy Creek.
Common Galaxias	0	H[S]	*No provision of improved connectivity.*	0	HS	Moderate potential for improving connectivity between suitable habitats along Boggy Creek. May assist dispersal between refuge pools during high flow events.	0	n/a	*No provision of improved connectivity.*	0	n/a	*No provision of improved connectivity.*
Common Ringtail Possum	27	PHS	Connectivity provision between the RBGC and Pines FFR along with habitat continuity amongst nodes between the Pines FFR and Western Port Hwy.	26	PHS	Could connect populations north and south of Cranbourne-Frankston Rd along with continuity of habitat along Boggy Creek, connecting the former DARA Reserve with Little Boggy Creek Reserve and the Pines FFR.	18	PH	Habitat connectivity between Studio Park and Pines FFR populations could be improved along with safeguarding connectivity to habitat along Boggy Creek (incl. the former DARA Reserve and Lloyd Park Reserve)	9	[P]HS	Provides connectivity between the occupied Stringybark Bushland Reserve and large areas of suitable habitat south of North Rd. In combination with corridor C2, connects Langwarrin Woodland (ID#: 424-25) habitat west to Langwarrin FFR populations and to Boggy Creek populations.
Crested Shrike-tit	12	HCS	Linking key areas of core woodland habitat between the RBGC and the Pines FFR.	13	[P]HCS	Provides habitat connectivity and dispersal opportunities between large areas of suitable wooded habitat north and south of Cranbourne-Frankston Rd.	4	HS	Provides a continuous link to suitable habitat in Studio Park.	2	HCS	In combination with corridor C2, could provide relatively continuous habitat between Langwarrin FFR and fragmented Langwarrin Woodland nodes (ID#424-25). Would provide improved connectivity among remnants with the Langwarrin Woodland node ID#424.
Dusky Woodswallow	75	PH[C]	Connects occupied woodland habitats in Langwarrin FFR to the Pines and when combined with the implementation of C1 provides connectivity with populations and habitat associated with the RBGC. Protects wooded habitats along Boggy Creek and Langwarrin nodes.	38	H	Provides dispersal opportunities between Langwarrin FFR and wooded habitats of Langwarrin Woodland nodes (ID#: 424-25) in combination with corridor C2.	12	[P]H	Connects utilised habitat at Studio Park with larger areas of habitat and populations in Langwarrin FFR and to a lesser degree, the Pines FFR.	6	H[S]	In combination with corridor C2, provides dispersal opportunities to suitable habitat in the Langwarrin Woodland node (Link ID: 424) from the population in Langwarrin FFR.
Dwarf Galaxias	1	n/a	*No provision of improved connectivity.*	7	PHCS	Key core habitat protected and enhanced within Boggy Creek. Considerable improvement of waterway health required within the Rocla Quarry (Quarry Rd) and south of Cranbourne-Frankston Rd to ensure connectivity among recorded populations and facilitate dispersal events and recolonisation of refuge sites.	0	n/a	*No provision of improved connectivity.*	0	n/a	*No provision of improved connectivity.*
Eastern Long-necked Turtle	1	HS	Protects small areas of suitable habitat and provides safe overland passage of animals between the Pines FFR and RBGC and intervening node habitats supporting	1	PHS	Boggy Creek is likely currently facilitating connectivity between habitat nodes in the north and southern of Frankston. Implementation of the corridor would	1	HC	Links wet habitats within Studio Park to core areas of suitable habitat along Boggy Creek.	0	HS	Of some limited value to the species in providing connectivity among a number of water-bodies with the Langwarrin Woodland

	Primary Corridors						Supplementary Corridors					
	Corridor C1			Corridor C2			Corridor S1			Corridor S2		
Species	#	Code	Connectivity Provision	#	Code	Connectivity Provision	#	Code	Connectivity Provision	#	Code	Connectivity Provision
			smaller areas of suitable habitat of moderate significance. Dependent on provision of some stepping stone water-body habitat along corridor route.			protect and enhance an existing corridor for the species.						node ID#424.
Eastern Yellow Robin	133	PHC	Provides connectivity between core population in RBGC and heathy woodland habitat in the Pines FFR. Combined with the C2 corridor connects core populations in RBGC and Langwarrin FFR. Also protects utilised habitat in Skye west of the Dandenong-Hastings Road and Burdett's Quarry.	84	PHC	Connects the Langwarrin FFR population and associated habitat with habitat in the Pines	14	PH	Connects utilised habitat at Studio Park with larger areas of habitat and populations in the Pines FFR and Langwarrin FFR.	31	PHC	Combined with corridor C2, provides connectivity between the Langwarrin Woodlands and Langwarrin FFR populations or assists movement of animals between these patches, as well as between areas of habitat in Studio Park and the Pines FFR.
Feathertail Glider	0	H[C][S]	Moderate improvement of connectivity for the species by linking several areas of large core habitat although a linkage to an extant population is required - possibly the Studio Park population through supplementary corridor S1.	0	H[S]	Could protect and enhance canopy habitat along Boggy Creek and provide a high level of connectivity between node and core habitat north of Cranbourne-Frankston Rd to those south, including Langwarrin FFR and Langwarrin Woodland nodes (ID#424-25).	1	HS[C]	Connecting a potential population in Studio Park to suitable habitat along Boggy Creek and north in the Greater Pines FFR (former DARA lands). In combination with corridors C1 and C2 could link the population to large areas of significant core habitat within the Greater Pines FFR, Burdett's Quarry, the RBGC, Langwarrin FFR, and the Langwarrin Woodlands where a tree canopy density is higher.	0	HS[C]	Protects and enhances habitat within the Langwarrin Woodland node ID#424. Combined with corridor C2 could provide a high level of connectivity for an extant population in Studio Park to moderate quality (unoccupied) habitat within the Langwarrin Woodlands (node ID#424).
Garden Skink	6	PHCS	Connects several large areas of suitable core habitat.	9	PHCS	Connects several large areas of suitable core habitat.	11	PHCS	Studio Park population likely to have a viable connection to Pines populations and nearby areas of suitable habitat along Boggy Creek.	5	[P]HS	Links Stringybark Bushland Reserve population to Langwarrin FFR and suitable areas of habitat within Langwarrin Woodland node (ID#424).
Glossy Grass Skink	0	H[S]	Protects and enhances smaller areas of wet habitats within large core and nodes habitats between the Pines FFR and the RBGC. In combination with corridor S1 could link the Studio Park	0	[P]H[S]	Links core areas of habitat for the species including fragmented damp or periodically flooded habitats along Boggy Creek from the Greater Pines FFR to Langwarrin FFR.	1	[P]H[S]	In combination with corridor C2 could facilitate improved connectivity between Studio Park population and optimal habitat along Boggy Creek.	1	[P]H[S]	Provides access and improved connectivity among several areas of suitable habitat. Combined with connectivity provided by corridors C2 and S1, may provide a moderate level of connectivity along Boggy Creek between the Studio Park and Stringybark Bushland Reserve populations. Likely to also provide improved connectivity to optimal habitat within the Langwarrin Woodland node #424 and wet habitats south of Robinsons Rd.
Koala	7	HS	Medium connectivity provision between several nodes supporting suitable habitat.	15	PHC	Connecting habitat along Boggy Creek to Greater Pines FFR habitats	9	HS	Potential value in linking suitable habitat in Studio Park to surrounding remnant habitat along with providing an alternate route to that along Boggy Creek.	9	S	Limited connectivity value based on current records of the species
Lowland Copperhead	2	HS	Protecting and enhancing some wet habitats suitable for the species and providing connectivity of moderate importance to wet habitats within the RBGC.	4	HCS	Could facilitate movement and expansion of habitat for the species along Boggy Creek along with connecting to possible populations south of north road within the Langwarrin Woodlands.	4	PHS	In combination with corridor C2 could facilitate improved connectivity between Studio Park and Langwarrin populations and between Studio Park and Boggy Creek habitats.	2	HS	Protects waterbody-wetland foraging habitat for the species and connectivity among these areas within the Langwarrin Woodland node ID#424.
Rufous Whistler	59	PH[C]	In combination with corridor C2, this corridor would provide connectivity between core populations/habitat in	48	PH[C]	In combination with C1, provides connectivity between core populations associated with the RBGC and Langwarrin	12	[P]HCS	Several records are associated with woodland habitats of Studio Park. The S1 corridor could provide connectivity to	17	PH	Several records are associated with the southern Langwarrin Woodland node and the S2 corridor could provide dispersal

	Primary Corridors						Supplementary Corridors					
	Corridor C1			Corridor C2			Corridor S1			Corridor S2		
Species	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**
			Langwarrin FFR with those in the RBGC. Alone this linkage would provide dispersal opportunities between the RBGC and the Pines FFR and intervening habitat nodes including Burdett's Quarry. Large areas of suitable woodland habitat would also be protected within the corridor footprint.			FFR.			larger populations and areas of suitable habitat in combination with corridors C1 and C2.			opportunities from Langwarrin FFR where the species has been frequently recorded.
Short-beaked Echidna	16	PHCS	Links core population sin the RBGC to those within the Greater Pines FFR along with providing connectivity among several nodes of suitable habitat.	21	PHCS	Links the Greater Pines FFR to Langwarrin FFR populations, and incorporates several areas of suitable habitat. Links southern and northern populations and expands the amount of suitable habitat accessible to the species.	17	PHS	Connects the Studio Park population to those in the Pines and protects large areas of suitable remnant habitat.	11	PHS	In combination with corridor C2, may provide connectivity between Langwarrin Woodland population and Langwarrin FFR along with potentially improving habitat continuity within the Langwarrin Woodlands node ID#424.
Southern Brown Bandicoot	33	HCS	Providing dispersal opportunities for individuals from the RBGC population to re-occupy areas of suitable habitat within the Greater Pines FFR and possibly Burdett's Quarry.	29	HS	Protects small areas of suitable habitat for the Southern Brown Bandicoot and provides opportunities for limited dispersal and re-occupation of habitat within and adjoining Boggy Creek in combination with corridor C1. Connectivity provision south of Cranbourne-Frankston Rd (to Langwarrin FFR) unlikely to be achieved due to predation threats, engineering constraints, and insufficient land for habitat creation to provide a viable crossing structure at the intersection between Boggy Creek and Cranbourne-Frankston Rd.	26	HS	Allows recolonisation of suitable habitat within the Studio Park node when combined with provision of corridor C1.	21	n/a	*No provision of improved connectivity.*
Southern Brown Tree Frog	54	PH[C]	Infrequent overland dispersal opportunities provided between RBGC population and ones associated with damp-wet habitat within nodes in Skye, Burdett's Quarry, Gumnut Reserve, Pines FFR, and Boggy Creek. In combination with provision of corridors between the Pines FFR and Seaford Wetland/Melbourne Water Eastern Treatment Plant, C1 would link larger areas of suitable core habitat to the east and west of Frankston.	16	PH[C]	Dispersal opportunities provided along Boggy Creek and in combination with corridor C1 between the RBGC and Langwarrin FFR populations.	12	[P]H	Provides connectivity for Studio Park population to larger areas of habitat along Boggy Creek, the Pines FFR, and in combination with C2 with Langwarrin FFR.	5	P	Provides opportunity for dispersal from Boggy Creek to smaller areas of suitable habitat within the Langwarrin Woodlands node and movement further south along Watsons Creek.
Southern Bullfrog	50	PH[C]	Facilitates overland dispersal between the RBGC population and those associated with Boggy Creek and the Pines FFR.	12	PH[C]	Facilitates dispersal between the RBGC and Langwarrin FFR while also protecting large areas of suitable habitat along Boggy Creek.	13	P	Connectivity provided by S2 between smaller areas of suitable occupied habitat and larger-scale connections to south to Watsons Creek and Western-Port coastline habitats.	6	[P]HS	Could provide dispersal opportunities for a population associated with wet habitats within Stringybark Bushland Reserve with those recorded along Boggy Creek and Langwarrin FFR in combination with corridor C2. Also provides a high level of connectivity among small areas of wet habitats within the south Langwarrin Woodland node (ID#: 424) and larger landscape connectivity with Watson's Creek.
Southern Pigmy Perch	2	n/a	*No provision of improved connectivity.*	0	HS	Potentially protecting habitat and facilitating recolonisation of aquatic habitats.	0	n/a	*No provision of improved connectivity.*	0	n/a	*No provision of improved connectivity.*

	Primary Corridors						***Supplementary Corridors***					
	Corridor C1			***Corridor C2***			***Corridor S1***			***Corridor S2***		
Species	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**
Southern Toadlet	6	PHCS	Could potentially link RBGC and Pines populations along with allowing dispersal into unoccupied habitats within Burdett's Quarry.	11	PHS	Some potential for linking population north of Cranbourne-Frankston Rd to core population in Langwarrin FFR. Currently the latter road is a significant barrier to movement and dispersal opportunities.	9	PS	Links Studio Park population to ones along Boggy Creek and the Pines FFR.	7	[P]HS	Combined with corridor C2, may provide connectivity between the Langwarrin FFR population and one south of Robinsons Rd along with protecting areas of suitable habitat within the Langwarrin Woodlands node ID#424.
Sugar Glider	5	PHS	Pines FFR and RBGC populations potentially connected.	5	PHS	Pines FFR and Lloyd Park populations connected. Provision of a crossing structure at Cranbourne-Frankston Rd and corridor implementation could connect northern populations to ones south in Langwarrin Woodland nodes (ID#424-25).	6	[P]HCS	Studio Park population connected to Pines FFR population/habitat and to Lloyd Park and habitat along Boggy Creek.	3	[P]HCS	Improved connectivity among fragmented areas of habitat within the Langwarrin Woodlands node (ID#424) along with opportunities for dispersal with northern populations and associated habitat.
Swamp Rat	35	PHC	Currently no habitat connectivity between a core population in the RBGC and ones in the Pines FFR (including the former DARA Lands node), Gumnut Reserve/Burdett's Quarry (ID#: 319) and Lyppards Rd node in Skye/Langwarrin (ID# 315). Corridor C1 would provide connectivity between several populations between the Pines FFR and the RBGC.	42	PHC	Provides dispersal opportunities between large areas of suitable habitat north and south of Cranbourne-Frankston Rd. Protects suitable habitat along Boggy Creek.	33	PHS	Connects the Studio Park population to ones in the Greater Pines FFR and suitable habitat along Boggy Creek.	21	HS	Corridor S2 in combination with C2 would provide connectivity between the North Reserve population and suitable habitat south of North Rd. May also provide connectivity between areas of suitable within the Langwarrin Woodlands node #424 with the provision of a relatively continuous and suitable groundstorey vegetation along with crossing structures for road crossings.
Swamp Skink	1	[P]H[C]S	Combined with corridor C2 could link Studio Park population to unoccupied suitable habitat along Boggy Creek, Burdett's Quarry and the Greater Pines FFR.	1	HS	Could facilitate connectivity between populations at Studio Park and Stringybark Bushland Reserve if implemented with corridor S1. May also facilitate recolonisation of unoccupied swampy and wetland habitats along Boggy Creek and	2	[P]HS	Links Studio Park population to suitable habitats along Boggy Creek to the east and within the Greater Pines FFR to the north. Protects some short sections of habitat along Tamarisk Creek at crossing of McCullocks Avenue.	1	[P]HS	Stringybark Bushland Reserve population could be connected to the Studio Park population through corridor C2 and westward to Langwarrin FFR. This linkage may also expand habitat available to the species by connecting smaller areas of Swamp Scrub and Swampy Woodland habitats within the Langwarrin Woodland node ID#424.
Tree Dragon	4	PS	Links several large areas of suitable habitat.	6	HS	Provides dispersal opportunities to suitable habitat nodes south of Cranbourne-Frankston Rd such as Langwarrin FFR and remnants within the southern Langwarrin Woodland nodes (ID#424-25).	5	PHCS	Connection between significant population in the Pines FFR and Studio Park.	1	HS	Provides dispersal opportunities to suitable higher quality habitat within the Langwarrin node ID#424
Tupong	0	n/a	*No provision of improved connectivity.*	0	H[S]	Moderate potential for facilitating movement upstream along Boggy Creek from Eel Race Drain and connecting drains within the Melbourne Water Eastern Treatment Plant during high flow events.	0	n/a	*No provision of improved connectivity.*	0	n/a	*No provision of improved connectivity.*
Varied Sittella	21	[P]HS	Connects the RBGC population to large areas of suitable habitat in the Greater Pines FFR and intervening habitat nodes.	26	[P]HS	In combination with corridor C1, links the RBGC and Langwarrin FFR populations.	7	HS	Could provide the species with access to suitable habitat in Studio Park	5	HS	In combination with C2, could provide the species with access to suitable habitat in southern Langwarrin Woodland nodes (ID#424-25)
White-lipped Snake	0	CH[S]	Likely to provide a high level of connectivity among large areas of suitable habitat including between the Greater Pines FFR and the RBGC.	0	H[S]	Protecting and enhancing habitat of high significance for the species along Boggy Creek along with connecting (in combination with S1 and S2 corridors) Studio Park population to smaller areas of	1	H[S]	Providing connectivity of higher importance to suitable habitat along Boggy Creek and north to the Greater Pines FFR.	0	H[S]	Provision of connectivity to smaller areas of suitable habitat within the southern Langwarrin node ID#424 in combination with corridors S1 and C2.

	Primary Corridors						*Supplementary Corridors*					
	Corridor C1			*Corridor C2*			*Corridor S1*			*Corridor S2*		
Species	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**	**#**	**Code**	**Connectivity Provision**
						suitable habitat southward within the Langwarrin Woodlands.						

5.3 Target Fauna Specific Habitat Requirements:

An extensive review of each target fauna species habitat preferences, critical resource requirements, and movement behaviour was undertaken to inform parameters of linkage design, creation, and management (APPENDIX 9: Table 12 and Table 13). Recommendations for habitat management and creation for corridors is summarised below for each fauna group based on both broad requirements of the group and specific requirements of target fauna species. This information is also applied to recommendations for two urgent corridors for implementation (Section 5).

Arboreal

Canopy cover and hollow-bearing trees are the most critical habitat requirements for arboreal fauna, including target species. Larger hollow-bearing trees with numerous hollows are more likely to be utilised while a higher abundance of hollows is important for Sugar Gliders and Feathertail Gliders, and to a lesser extent Common Ring-tail Possums. A mix hollows with different entrance sizes is required to accommodate all three species. However, natural hollow formation can take considerable time with five species of eucalypt species predicted to take between 186 and 230 years to begin to producing hollows (Wormington et al 2003). Consequently, identifying and protecting trees of larger size classes (without hollows) along with trees already supporting hollows, is an important objective for provision of hollows for arboreal fauna over the long term.

Gaps in continuous tree canopy >20m are likely to reduce connectivity for gliding arboreal target fauna species. Any gaps in tree canopy may restrict daily movements for possums, while gaps of >5m may reduce dispersal and gene flow unless dense indigenous groundcover is present facilitating safe ground movements between trees (i.e. from predation). Koala can make ground movements between trees but need unobstructed and safe passage ideally through areas supporting native vegetation.

Target Species

- Eucalypt tree canopy (all arboreal fauna species)
- Hollow-bearing trees and stags ideally >10 per 3ha (all arboreal fauna except the Koala; also Agile Antechinus)
- Higher density and diversity of medium to tall understorey shrubs/trees (such as acacias and tea-trees)(Common Ring-tail Possum, Sugar Glider, and Feathertail Glider)
- Stands of specific eucalypt species that are the preferred feed trees of the Koala in the local area (likely Manna Gum *E. viminalis* but also Swamp Gum *E. ovata* and Narrow-leaved Peppermint *E. radiata*; Hindell et al 1985)(Koalas)

Ground-dwelling

Ground-storey habitat features such as dense groundstorey vegetation, logs (particularly hollow logs), litter, and rocks are critical habitat features for ground-dwelling mammals and reptiles. A number of target fauna also require wetland or swamp habitats while the Agile Antechinus will utilise tree hollows for denning.

Target Species

Reptiles:

- Low dense groundstorey vegetation of sedges/grasses (Blotched Blue-tongue Lizard, Garden Skink, Glossy Grass Skink, Lowland Copperhead, Tree Dragon; also Swamp Skink in swampy habitats)
- Hollow-bearing logs (Blotched Blue-tongue Lizard, White-lipped Snake, Tree Dragon) and low shrubs (Tree Dragon)
- Ground structures such as logs, rock piles, artificial tiles or tin sheets (Blotched Blue-tongue Lizard, Garden Skink, Swamp Skink, White-lipped Snake)
- Open areas with sparse understorey and abundant leaf litter and woody debris (i.e. fallen timber)(Garden Skink)
- Habitat within or adjacent to wetlands or swamps (Lowland Copperhead, Swamp Skink, Glossy Grass Skink)

Mammals

- Dense understorey vegetation (at 0-1.0m height)(Black Wallaby, Short-beaked Echidna, Southern Brown Bandicoot)
- Low dense groundstorey vegetation of sedges/grasses or low heath in or adjacent to wetlands, swamps, damp heaths or waterways (creeks, rivers, drains)(Swamp Rat)
- Leaf litter, woody debris, and large and hollow-bearing logs (Agile Antechinus, Short-beaked Echidna)
- Tree hollows, shrubs, and high habitat structural complexity (Agile Antechinus)
- Diversity and abundance of shrubs with foliage at <1m height (Black Wallaby)

Woodland Birds

A eucalypt canopy, understorey trees and shrubs, dead trees, logs, and structural complexity of vegetation are critical habitat components for woodland birds. Higher levels of tree cover are important for increasing connectivity between patches. Gaps in continuous habitat (i.e. along corridor route) may be more important than width, particularly where gaps are >50m. Isolated or scattered paddock trees can serve as stepping stones between patches of continuous habitat increasing likelihood of dispersal movements by woodland birds over distances of up to 250m

Target Species

- Canopy of eucalypts trees including stringybarks and ribbon gums (Varied Sittella and Crested Shrike-tit)
- Higher density of large mature - large living and dead - trees (Varied Sittella)
- Tall shrubby understorey (medium and large shrubs) forming high vertical stem density (Eastern Yellow Robin, Crested Shrike-tit, Rufous Whistler)

- Open or sparse understorey with high structural complexity (Dusky Woodswallow and Eastern Yellow Robin)

Semi-Aquatic

Water-bodies, wetlands, waterways, aquatic vegetation, and ephemeral soaks are critical habitat components for all semi-aquatic fauna species.

Target Species

- Slow-flowing shallow water-bodies, wetlands or waterways (Common Froglet, Eastern Long-necked Turtle)
- High groundcover of grasses, rocks, logs, and litter fringing waterbody or waterway (Common Froglet)
- Fringing or emergent tall sedges, tussock-grasses, and reeds or trees (Southern Brown Tree Frog, Southern Bullfrog)
- Submergent or floating aquatic macrophytes (Common Froglet, Southern Bullfrog)
- Deep >60cm water (Southern Brown Tree Frog, Southern Bullfrog)
- Terrestrial native vegetation adjacent to aquatic habitats (Common Froglet, Eastern Long-necked Turtle, Southern Toadlet)
- Heaths or woodlands with (or nearby) ephemeral shallow soaks, swampy areas, low-lying depressions or periodically inundated areas (Southern Toadlet)

Aquatic

Water-ways, refuge pools, good water quality (including low sedimentation and lower temperatures), in-stream and fringing aquatic vegetation (macrophytes), and structurally complex substrates (i.e. submerged woody debris, litter, rocks, and macrophytes) are important habitat features for all aquatic target fauna.

Target Species

- Slow-flowing waters or water-bodies (Common Galaxias, Dwarf Galaxias)
- Brackish estuaries or slow-flowing creeks or streams (Tupong)
- Diverse and abundant macrophytes, submerged roots, rocks, and woody debris (snags) supporting higher insect and copepod prey abundance (Common Galaxias, Dwarf Galaxias, Southern Pigmy Perch, Tupong)
- Waterway substrate with submerged woody debris (snags), leaf litter, and macrophytes (Tupong)
- Cooler water temperatures resulting from shading from fringing/overarching tree canopy/tall trees or shrubs, or fringing Common Reed *Phragmites australis* in more narrow waterways (Dwarf Galaxias)

- Higher water-quality: lower stormwater run-off and few disturbance events (i.e. construction or mining works, agricultural activities, earthworks, erosion) in surrounding catchment resulting in high sediment loads (Southern Pigmy Perch, Tupong)
- Well-vegetated waterway/waterbody edge (Dwarf Galaxias)
- Stands of macrophytes (Dwarf Galaxias, Southern Pigmy Perch)
- Connectivity to estuaries (Common Galaxias, Tupong)
- Low abundance of introduced trout (Dwarf Galaxias, Common Galaxias)

5.4 Pines Flora and Fauna Reserve to Royal Botanic Gardens Cranbourne Corridor

Map Code: C1

Type: Dryland Corridor

Component Linkages: Link ID# 13 - *Very High* conservation significance; Conservation Score/Rank: 60/3, Feasibility Score:77/34, Opportunity Score: 35/34

Conservation Priority: *Very High* overall Rank Priority among corridor linkages and attained the third highest score for *Conservation Significance* of all corridor linkages assessed.

Local Government Areas: Frankston and Casey

Incorporated Public Reserves: Pines Flora and Fauna Reserve, former KTRI site, and the Dandenong-Hastings Rd Reserve (1005 Dandenong-Hastings Road, Skye)

Remnant EVCs (% of total remnant cover): Heathy Woodland (84%), Damp Heathy Woodland (9%), Damp Sands Herb-rich Woodland (2%), Swampy Woodland (2%), Riparian Scrub (1%), Swamp Scrub (1%), Swampy Riparian Woodland (1%), and Sand Heathland (<1%).

Description:

This corridor extends from the Pines Flora and Fauna Reserve (122 ha) to the Royal Botanic Gardens Cranbourne (356 ha) core area and is approximately 10.5 km in length. Six intervening habitat nodes are linked along the recommended route including the former DARA lands node (ID#375), Valley Rd node (ID#355), Burdett's Quarry node (ID#319), and the Lyppards Rd node (ID#315). Vegetation along corridor route is composed mostly of Heathy Woodland EVC with up to nine other EVCs incorporated within linkage.

Between the Pines FFR and McClelland Drive, the corridor crosses the Peninsula Link freeway at the location of proposed fauna crossing structures (fauna underpasses and box-culverts), connecting to a node (recent addition to the Pines Flora and Fauna Reserve) supporting a mixture of remnant vegetation, pasture, and revegetation (former Keith Turnbull Research Institute land node ID#390) and running further east within remnant vegetation within the former DARA lands addition to the Pines FFR (ID#375) and adjacent to the Centenary Park Public Golf Course. The corridor crosses McClelland Drive just north of the intersection with Boggy Creek, following areas supporting remnant Heathy Woodland habitat near the boundary of the Rocla Quarry site and private properties on McClelland Drive and Valley Rd (node ID#355). From the latter node, the corridor flows through a short section of agricultural land with scattered canopy tree habitat to the Burdett's Quarry node supporting mostly heathy woodland habitat but also swamp scrub and riparian woodland habitats. The corridor follows the northern boundary of the Burdett's Quarry site through continuous high quality remnant fauna habitat, then runs north through disturbed remnants within a quarry on Harold Rd (Skye Mineral Sands) to link with remnant habitat within the Lyppards Rd node (ID#315) supporting woodland and some higher quality (Ecology Australia 2006) riparian scrub remnants and canopy habitat (1005 Western Port Highway patch). From this node, the corridor crosses the Western Port Highway and runs along the property boundary of Ranfurlie Golf Course, crossing Cranbourne-Frankston Rd through to remnant habitat north of Ballarto Rd and through to the northern section of the core habitat within the Royal Botanic Gardens Cranbourne.

Habitat Values and Significant Sites

The Pines Flora and Fauna Reserve: A BIOSITE (#4916) of state significance supporting large areas (195 ha) of highly significant fauna habitat. The reserve is composed of two large areas of fauna habitat either side of the Peninsula Link freeway. East of the freeway reserve, sand heathlands form the dominant habitat type. A diversity of other habitat types are also supported within the reserve, including riparian, heathy, and grassy woodlands, swampy scrubs, water-bodies, extensive canopy habitat, and aquatic habitats along Tamarisk Creek. The former Department of Agriculture and Rural Affairs (DARA) block supports mainly heathy woodland habitat and smaller areas of heathland, but also riparian scrub and swampy woodland habitats along Boggy Creek. High quality groundstorey habitat is present within the reserve and structural complexity of fauna habitat high. Within the reserve, Boggy Creek also supports significant aquatic habitats, with the nationally significant Dwarf Galaxias found to be present in the northern reaches of the waterway.

Former Keith Turnbull Research Institute site: supports smaller areas (6 ha) of High significance woodland habitat with indigenous groundstorey habitat, and also regenerating woodland habitat, native canopy habitat (mostly in northern section), dams, and open pasture habitats. There are also considerable opportunities for re-establishing high quality fauna habitat within this crown land site.

Valley Road remnants: supports swamp and heathy woodland remnants (30 ha) of high regional significance but with significantly disturbed understorey habitat in some areas. Primary habitat in the northern half of this node (ID#355) is restricted to tree canopy with some shrub and ground-storey habitat present on some private parcels, mostly in the southern sections of lots. Some areas of remnant indigenous vegetation on private land are currently protected under Section 173 agreements or covenants. This node provides a significant linkage in habitat for fauna between the Pines FFR and the Burdett's Quarry habitat node. Considerable reductions in remnant fauna habitat has occurred within the Rocla quarry site over recent years and past clearing of remnant understorey within node ID#355 has resulted in severe weed infestations.

Burdett's Quarry and Gumnut Reserve remnant habitat: A large 81 ha patch of remnant fauna habitat, largely consisting of heathy woodland supporting relatively intact groundstorey habitat. A small area of swamp scrub would also be incorporated within the corridor footprint. Additional areas of swamp scrub habitat and riparian woodland are also present within the western half of this node (ID#319). The site has been previously designated as of Very High regional significance based on floristic values (Ecology Australia) and it should be considered to be of equal significance for fauna. The smaller (2.2 ha) adjoining Gumnut Reserve (separated from the larger Burdett's Quarry patch by Potts Rd) also supports heathy woodland habitat of High significance for fauna.

Good quality areas of fauna habitat are also present within the nearby Woodlands Primary School with groundstorey present in patches along Gum Nut Drive and Cotoneaster Way. Shrub and canopy habitat is present in the north end of the school along Peppermint Grove. The adjoining Illawong Reserve and Cotoneaster Reserve also support smaller areas of heathy woodland habitat although groundstorey habitat is fragmented by Cotoneaster Way and open space.

Lyppards Rd remnants: Within this node (ID#315), the Dandenong-Hastings Rd Reserve (1005 Dandenong-Hastings Road, Skye) is a 2 ha site of Very High significance (Ecology Australia) supporting good quality woodland and riparian scrub remnant habitat. The site supports vegetation of high structural complexity and high quality ground-storey habitat and is managed by Parks Victoria.

Ballarto Rd remnants: supports heathy woodland fauna habitat of Moderate quality and relatively contiguous with habitat within the Royal Botanic Gardens Cranbourne, particularly for arboreal and avian fauna. The southern section of this node (to the south of Ballarto Rd) is within a BIOSITE (#4813) of regional significance ('Cranbourne Woodland'). Extraction of mineral resources has reduced the extent of fauna habitat in the southern half of the site.

Royal Botanic Gardens Cranbourne: A large (350 ha) state significant BIOSITE (#5095) supporting a diversity of habitat types and overall Very High quality fauna habitat. The majority of the site supports heathy woodland habitat although riparian scrub and grassy woodlands also form significant areas of habitat within the site. The site supports a large population of the nationally threatened Southern Brown Bandicoot and is the only reserve south-east of Melbourne to have predator-proof fencing combined with an on-going predator-control program. The RBGC core areas has a High to Medium likelihood of supporting populations of three threatened species with a further two State (Swamp Skink and Southern Toadlet) and one nationally listed (Southern Brown Bandicoot) threatened species observed to have populations within the RBGC.

Fauna Use and Movement

Target Species: Twenty-five of the 30 target species have been recorded within the vicinity of the proposed corridor route C1 and linking node or core patches (Table X). Nineteen of these target species have been observed within the last 10 years, including 3 arboreal, 5 reptile, 3 woodland bird, 4 frog, and 3 ground-dwelling mammal species. The proposed corridor could provide connectivity between two or more populations for 14 species. A further two target species could be provided with improved connectivity among populations with the addition of the two supplementary corridors. For 11 species the corridor is considered to provide connectivity among core populations or habitat within Frankston. Five target species populations would be provided with connectivity to unoccupied core areas of habitat through which the species may possibly re-colonise, including the Southern Brown Bandicoot, Crested Shrike-thrush, and Southern Toadlet.

Arboreal

Present Habitat Connectivity

There is relatively continuous canopy habitat between node the former DARA lands node (ID#375) and Burdett's Quarry node (ID#319) suggesting movement of some arboreal species is occurring between these areas through the Valley Road remnants (ID#355). Significant breaks in canopy cover habitat occur where the corridor route is intersected by McClelland Drive and at the eastern end of the Valley Rd node - south of the intersection between Valley Rd and Potts Rd, - where relatively continuous canopy cover gives way to scattered clumps of eucalypt trees over grazed pasture. Connectivity is likely poor at these points and movement of arboreal fauna more infrequent. Scattered canopy cover occurs along the general corridor north-east of Burdett's Quarry to the Western Port Highway, suggesting some movements of more mobile, fragmentation-tolerant arboreal species (e.g. Common Brush-tail Possum) through the Lyppard Rd node (ID#315). Sparse canopy cover between the highway crossing and the Ballarto Road remnants (ID#316) suggests there are few movements of arboreal fauna between these nodes of habitat. Daily and dispersal movements of fauna likely currently occur between the Ballarto Road remnants and the RBGC considering the continuity of canopy habitat.

Target Species

Along the corridor route or linking patches, recent (since 2002) records have been made of the Common Ringtail Possum (Pines FFR, Burdett's Quarry node, Lyppards Rd node, Ballarto Rd remnants, and RBGC), Sugar Glider (Pines FFR-west of Peninsula Link), and the Koala (Pines FFR). All four target species of arboreal fauna are provided with improved connectivity by corridor C1 (Table X). Corridor C1 provides connectivity among populations of Common Ringtail Possum and Sugar Glider, while connecting areas of suitable habitat for the Koala from potential source populations within the Pines FFR and Boggy Creek patches. The reported population of Feathertail Glider within Studio Park could be provided with improved connectivity to suitable habitat further north in combination with the supplementary corridor S1, particularly between the Pines FFR (former DARA lands) and the Lyppards Rd node (ID#315), with eventual connectivity to woodland habitats within the RBGC core area.

Ground-dwelling (reptile and mammal)

Present Habitat Connectivity

Connectivity in habitat for ground-dwelling fauna between the western section of the Pines FFR (i.e. west of Peninsula Link) and the eastern section (i.e. former DARA lands and KTRI site) is relatively poor due to division of habitat represented by the Peninsula Freeway. However, mitigation in the form of fauna bridge underpasses (1) and culverts (4) should provide opportunities for fauna movement at the population level including dispersing individuals. Breaks (~300m) in ground-level habitat along the corridor alignment east of the freeway within the former KTRI (Keith Turnbull Research Institute) land (node ID# 390) and former DARA lands addition to the Pines FFR (node ID#375) may reduce movement events in smaller, less mobile ground-dwelling fauna such as some reptile and small mammal species but not for more mobile species such as the Black Wallaby which has been shown to disperse across modified landscapes (Paplinska 2009). Even so, overall habitat connectivity is high east of the freeway to McClelland Drive. The continuity of ground-level habitat is broken by McClelland Drive but is in good condition either side of this road. Cyclone-fencing bounding this road likely reduces connectivity for the Black Wallaby although high casualties at this location suggest movement is being attempted.

East of McClelland Drive within the Valley Rd node (ID#355), ground-storey habitat is patchy and variable in quality among private blocks with weed cover previously reported (Ecology Australia 2006) to be high. A significant break in ground-storey habitat is also present between the Valley Rd node and the Burdett's Quarry node (ID#319) although dispersal movements are likely for many ground-dwelling fauna over this shorter distance (≈350m) considering it supports a pastoral landscape with scattered clumps of eucalypts. Daily or home-range movements of more mobile ground-dwelling species such as the Black Wallaby, Blotched Blue-tongue Lizard, and Eastern Long-necked Turtle are also possible. High connectivity is provided by good quality ground-storey habitat within the Burdett's Quarry node. Beyond this node, connectivity for ground-dwelling fauna declines with large distances between areas supporting suitable habitat within the Lyppards Rd node, and little to no groundstorey habitat along the corridor alignment until the Ballarto Rd remnants are reached. Ground-storey quality within the latter node is patchy but may facilitate some movement of less sensitive ground-dwelling fauna, particularly lizards and larger, more mobile mammals (i.e. Short-beaked Echidna and Swamp Wallaby).

Target Species

This corridor provides connectivity among core populations of Black Wallaby, Short-beaked Echidna, Swamp Rat, Tree Dragon, and Garden Skink. Connectivity between populations or habitat could also be achieved for the Blotched Blue-tongue Lizard, Lowland Copperhead, Glossy Grass Skink. In combination with supplementary corridor S1, this corridor provides connectivity for the Swamp Skink, Glossy Grass Skink, and White-lipped Snake to disperse from recorded populations in Studio Park to suitable (possibly unoccupied) habitats in the Pines FFR. The Southern Brown Bandicoot population within the RBGC core area is also provided with connectivity to suitable unoccupied habitat, particularly within the Pines FFR where the species is likely to be locally extinct.

This corridor links several very large core and node habitat patches and is one of the few in which a wide corridor width and continuous ground-cover could feasibly be attained over the long-term, linkage traits which are highly important for ground-dwelling fauna. Between the Pines FFR and Burdett's Quarry – a distance of approximately 3 kilometers –gaps in groundcover habitat occur over relatively short distances with over 80% of the proposed corridor alignment already supporting remnant vegetation. Only two minor road crossings and one freeway crossing (for which structures are already in place) are also required to achieve connectivity within this section of the corridor. This corridor represents an ideal opportunity to provide connectivity for ground-dwelling fauna among several large areas of high quality habitat.

Birds (woodland birds)

Present Habitat Connectivity

Within the western section of the Pines FFR (ID#304), habitat connectivity for woodland birds is high. Connectivity eastward to habitat within the former KTRI and DARA land nodes is broken by the Peninsula Link freeway. It is unknown how effectively fauna underpasses will provide connectivity for woodland birds, although very rare dispersal events may possibly occur over the freeway for some species. As for arboreal and ground-dwelling species, habitat connectivity is moderate (approximately a 300m break in canopy) along the corridor route between the former KTRI land node (ID#390) and the Pines FFR-eastern section (i.e. former DARA lands; ID#375). Similarly, breaks in habitat at McClelland Drive may be an obstacle for more edge-sensitive woodland bird species, although movement across the road to a patch of woodland in the far eastern end of the Valley Rd node (ID#355) is likely to occur for many species. The Valley Rd is likely to facilitate connectivity for woodland birds between the Pines FFR-eastern section node and Burdett's Quarry node, although breaks in tree canopy and shrub cover may reduce movement of some species with lower dispersal capabilities and higher sensitivity to fragmentation. The Burdett's Quarry likely facilitates a high level of connectivity for woodland birds within the surrounding landscape, and may be a significant stepping stone between the Pines FFR and the RBGC core areas. North-east from this site along the corridor route, the Lyppards Rd node largely supports canopy habitat but also some smaller patches with more structurally complex habitats including intact indigenous understorey habitat or a shrub layer. Beyond this node, there is very little suitable habitat along the corridor route until it intersects the Ballarto Rd remnants. Nonetheless scattered trees along the Ballarto Rd easement and along property/lot boundaries likely facilitates movement of some woodland bird species and a range of other avifauna. Connectivity between the Ballarto Rd remnants and the RBGC is relatively continuous with frequent movement and utilisation expected of less edge sensitive species.

Target Species

Populations of woodland bird species directly connected by this corridor, based on recent records, are likely to include the Dusky Woodswallow and Eastern Yellow Robin, both of which are recorded within linking node or core patches: the Pines FFR-western section, Burdett's Quarry, and RBGC. In combination with other recommended corridors, this corridor provides a critical linkage for core populations of the Rufous Whistler, Varied Sittella, and Dusky Woodswallow between the RBGC and Langwarrin FFR while also providing connectivity between core areas of habitat for the Crested Shrike-tit. Extensive areas of suitable eucalypt woodland habitat are connected by this corridor.

Semi-aquatic

Present Habitat Connectivity

Overall habitat connectivity for frogs is patchy along this dryland corridor due to the restricted occurrence of wet habitats for breeding such as waterways, dams, and wetlands. However, the best connectivity exists between the Pines FFR and the Lyppards Rd node (ID#315). Patches of damp habitats (e.g. swampy or riparian woodlands and scrubs) form stepping stones for dispersal movements during wet periods. Waterbodies within the adjacent Centenary Golf Course, artificial wetlands within the former KTRI site, and aquatic environments within Boggy Creek also improve connectivity for frogs and the Eastern Long-necked Turtle between the Peninsula Link freeway and McClelland Drive. One important uncertainty, however, is whether planned fauna crossing structures under Peninsula link will provide effective connectivity between frog or turtle populations on either side of the freeway. Achieving connectivity across the freeway will be important for the conservation of frog populations, including the threatened Southern Toadlet, within the local area. East of McClelland Drive frogs could also be making some use of storage dams within the adjacent Rocla Quarry site although overall connectivity through the Valley Rd node is relatively poor. Between the Burdett's Quarry site and the Western Port Hwy connectivity may be relatively good due to a high density of water-bodies (mostly dams) which may function as important stepping stones within the Lyppards Rd node. Connectivity further east along the corridor to the Ballarto Rd remnants and RBGC core area is very poor with little remnant vegetation, no flowing waterways, and few waterbodies or wetlands to assist dispersal movements. Ephemeral drains running south adjacent to the Western Port Hwy and artificial wetlands/waterbodies within the Ranfurlie Golf Course may assist some movements of frogs along this proposed corridor route.

Target Species

All four of the target frog species (Common Froglet, Southern Brown Tree Frog, Southern Bullfrog, and Southern Toadlet) are recorded within node or core areas linked by this corridor. Records of the Eastern Long-necked Turtle across Frankston are sparse although casualty records would suggest the species is present along the corridor route within suitable habitats. The first three of the aforementioned frog species have been recorded within a few hundred metres of the corridor centreline while the Southern Toadlet has been recorded within the former KTRI land (ID#390; Faithfull 2008) and both the eastern (former DARA lands) and western section of the Pines FFR. Some areas of suitable habitat for the threatened Southern Toadlet are present within linking nodes, particularly within the Pines FFR. Continuous woodland habitat with ephemeral pools, swamps, soaks or inundated grassy areas may assist dispersal and serve as important breeding sites for the Southern Toadlet. Dependent on effective connectivity provided by crossing structures under the Peninsula Link freeway and provision of suitable continuous habitat (i.e. few gaps), and other roads, this corridor provides connectivity among core areas of habitat for the Southern Toadlet. If series of vegetated water-bodies (ponds), swamps or wetlands are distributed along the proposed route, this corridor could provide a high level of connectivity for all three target species.

Aquatic

This corridor provides no effective connectivity for aquatic fauna although it may afford protection and habitat enhancement for aquatic habitat within Boggy Creek immediately upstream and downstream of McClelland Drive.

Target Species

Only the threatened Dwarf Galaxias has been recorded along this corridor: a record located along Boggy Creek near the intersection with McClelland Drive. Provision of this corridor and associated improvement of riparian habitat may be of some indirect benefit to the species.

Key Threats to Connectivity and Recommended Actions:

The following sections details key threats to connectivity for fauna along the corridor route and recommended on-ground actions to mitigate them.

Road Barriers: Although there are few road barriers along the corridor route they are significant in severity by being major barriers to movement. The Peninsula Link freeway, McClelland Drive, and the Western Port Highway are likely the most significant roads limiting movement of fauna, particularly ground-dwelling fauna. Potts Road (unsealed section) may also constitute a lower level of resistance to movement of ground-dwelling fauna.

High traffic flow can deter movement of fauna across roads, essentially fragmenting an area of habitat. Higher vehicle speeds and traffic volume are also implicated in higher rates of fauna casualties (i.e. death or injuries) resulting in reduced successful movement of fauna between areas of suitable habitat (i.e. animals do not survive an attempt to cross a road). Potts Rd potentially carries a relatively high traffic load (FCC data) travelling at high speed (average=71 km/hr) which may deter movement of some fauna and result in unsuccessful crossing attempts for others (i.e. animal mortality). Currently, the road is unsealed north of Candwindara Rd and this likely reduces traffic volumes and speed although the lack of posted speed limits is undesirable for fauna connectivity. Although the highest traffic volume and speed are arguably along the Peninsula Link freeway, the Western Port Hwy, and Cranbourne-Frankston Rd, Frankston City Council traffic data suggest McClelland Drive is one of the busier local roads in Frankston, carrying a very high traffic volume travelling on average well over 70 km/hr.

Cyclone fencing currently exists along the perimeter of the Pines FFR adjoining McClelland Drive and the Rocla Quarry site (although this only extends north-east to Boggy Creek) and also along the boundary of Burdett's Quarry adjoining Potts Rd. Currently, this fencing likely reduces connectivity for larger fauna species, such as the Black Wallaby. When combined with crossing structures, fencing can facilitate improved connectivity across major roads where successful crossings by fauna are less likely due to traffic volume and/or speed, by ensuring animals cross at safe locations. However, these require regular maintenance once crossing structures are installed. For example, where larger animals such as the Black Wallaby breach a fence at an unsafe crossing location they can be essentially trapped by the fencing and are even more likely to be injured by vehicles.

A series of fauna crossing structures have been implemented under the Peninsula Link freeway that may provide successful connectivity for ground-dwelling fauna and possibly some arboreal and bird fauna between the western and eastern sections of the Pines FFR. A fish passage is also provided for Tamarisk Creek along the Peninsula Link freeway just south (300m) of Ballarto Rd. Future extension of Valley Rd into the Burdett's Quarry node would fragment habitat and reduce habitat connectivity while further road construction within the Ballarto Rd easement between the Western Port Hwy and Cranbourne-Frankston Rd could threaten the implementation of this corridor. East of Cranbourne-Frankston Road, ground connectivity is reduced by Ballarto Rd within node ID#316 and strong edge effects exerted by heavy vehicle traffic from a quarry to the south.

Solutions:

- *Implement fauna crossing structures at recommended strategic locations to facilitate connectivity across road barriers along the corridor route.*
- *Pursue the implementation of fauna crossing structures at corridor C1 intersections with McClelland Drive, Potts Rd, Western Port Hwy, and Cranbourne-Frankston Rd*
- *Combine the crossing structures with fencing on either side of crossing locality to ensure animals are funnelled through at these points and ensure they are regularly maintained*
- *Avoid or mitigate further road construction or upgrades (including from unsealed to sealed and widening to multiple lanes) within node or score areas linked by corridor C1 (e.g. Valley Rd). Of priority is avoiding further upgrades of Potts Rd, Valley Rd, or McClelland Drive*
- *Discourage further road development along the Ballarto Road reserve between the Western Port Hwy and Cranbourne-Frankston Rd and Valley Rd easement intersecting the Burdett's Quarry node*
- *Where major roads (new or upgrades) intersecting the corridor route or linking core/core patches are proposed, require or encourage the provision of fauna crossing structures*
- *Consider lowering speed limits (to 60 km/hr or lower) on McClelland Drive (particularly between Darnley Drive and Quarry Rd) and Potts Rd (unsealed section) and install wildlife crossing signs*
- *Consider installing devices such as speed humps or rumble bars on McClelland Drive and Potts Rd within 200m of proposed corridor C1 crossing location*
- *Attempt to provide continuous canopy cover surrounding recommended arboreal crossing structures (rope bridge) with gaps of <5m for arboreal fauna (Common Ringtail Possum, Koala) and <20m for gliders (Sugar Glider), OR continuous canopy cover overarching roads (i.e. McClelland Drive and Potts Rd)*
- *Ensure gaps in continuous tree canopy AND dense tall to medium shrub cover along corridor route are less than 25m for woodland birds at intersections with McClelland Drive, Potts Rd, and Cranbourne-Frankston Rd*
- *Implement land-bridge or a bridge underpass at the intersection of corridor C1 with the Western Port Hwy for Woodland Birds OR ensure gap in continuous tree canopy and tall to medium shrubs along corridor route are less than 50m with canopy trees and medium-tall shrubs (>10m height) planted in medium strip. Note that a land-bridge is likely to provide a much higher level of connectivity for woodland birds*

Infrastructure Barriers: Fencing can reduce movement of fauna, particularly larger ground-dwelling fauna and arboreal fauna where there are gaps in canopy cover. Solid fencing provides the highest resistance to fauna movement followed by barbed wire fencing which may also cause injury of animals. Along the corridor route, private property fencing is likely to occur within the Valley Rd and Lyppards Rd nodes and be of higher resistance to movement within the former node due to the smaller block size. As discussed above, fencing along the perimeter of bushland adjoining busy roads can improve connectivity where combined with crossing structures but should be possibly avoided.

Solutions:

- *Encourage landholders and developers to remove, replace or modify existing fences for the safe and easy movement of fauna. Removal of fencing is the best option followed by replacement of hard fences (e.g. brick, concrete, or solid timber fencing) with soft fences such as three-tined plain wire (not barbed) fences.*

- *Focus incentives for removal or replacement of fencing within the Valley Rd node (potentially at the back of lots)*

- *Consider only using fencing along roads where combined with crossing structures at strategic locations*

- *Liaise widely with infrastructure managers (water, electricity, roads) and government department to promote the implementation of the corridor and avoid conflicts with future infrastructure upgrades or maintenance.*

Habitat Fragmentation and Loss: Habitat loss and fragmentation is the major cause of reduced connectivity for all fauna groups. Habitat is fragmented along most of the corridor route for most of the target species. Habitat loss and fragmentation is most severe along the corridor route between the Western Port Hwy and the Ballarto Rd node and to a lesser extent within the Lyppards Rd and Valley Rd nodes.

Subdivision of land largely leads to the loss and fragmentation of habitat for fauna. Although only a lower level of subdivision has occurred along the corridor route it is only of moderate severity at the current point in time, being most severe within the Valley Rd node and a lesser extent within the Lyppards Rd node. However, subdivision of land will be am increasing threat to the implementation of corridor C1 into the future.

Mining operations have also been the major cause of losses in high quality remnant vegetation and canopy cover within Frankston, particularly between the Pines FFR and the RBGC. Even where some habitat is retained on lots proposed for development or mining operations, connectivity and resulting ecological function may be lost or decline due to poor provision of connectivity. Along this corridor route, habitat loss is most severe between.

Hollow-bearing trees are a critical habitat component for numerous bird species and most microbats and arboreal fauna. Losses in hollows across the landscape have been implicated in decline of many once common species and the continued decline of several species threatened by extinction. The extent of hollow-bearing trees along the corridor route is unknown and may be crucial for managing connectivity for some target fauna species over the long-term.

Solutions:

General

- *Council should pursue retaining land entitlements that abut the corridor alignment. Opportunities for reserving (i.e. setting aside for conservation purposes) existing habitat along alternate routes should also be considered where the same ecological and connectivity service is provided.*

- *Consider the acquisition of key parcels on private land along the corridor alignment and linking node patches.*

- *Commit to managing new land acquisitions along the corridor route, or adjoining to linked patches, for conservation purposes including the re-establishment of indigenous vegetation.*

- *Support revegetation of land where significant gaps in habitat occur along the corridor route and adjoining land according to target fauna habitat requirements and appropriate EVCs. The following areas are priority locations for restoration and revegetation works:*

  - *the former KTRI land node (ID#390) and western extending leg of the Pines FFR-eastern section (ID#375).*

  - *the Rocla Quarry site (post-mining operations) adjacent to southern boundary of the Valley Rd node (ID#355).*

  - *within the Valley Rd node, prioritised firstly according to lots where canopy cover needs to be re-established and secondly on restoration works (i.e. weed control and understorey plantings)*

  - *on private rural blocks between the Valley Rd and Burdett's Quarry nodes including re-establishing canopy trees and understorey vegetation.*

  - *along the corridor route between Burdett's Quarry and the Lyppards Rd node including the eastern boundary of the Skye Mineral Sands quarry.*

  - *between the Lyppards Rd node and the Ballarto Rd remnants node (ID#316). This section of the corridor requires the greatest areas of revegetation and also collaboration with the adjacent Casey City Council beyond the Western Port Hwy.*

- *Encourage landholders to retain remnant vegetation and hollow-bearing trees.*

- *Encourage the plantings understorey shrubs (such as acacias) along fence lines or property boundaries or in clumps, focusing on properties within 200m of corridor centreline.*

- *Avoid the building of new dwellings within 200m of the corridor centreline to avoid potential losses in remnant habitat or restrictions on habitat creation due to fire protection measures (i.e. fuel modified zones).*

- *Support the winding down of mining operations along the corridor route, the re-instatement of self-sustaining indigenous vegetation communities within 200m of the corridor centreline within former mine sites, and advocate for no further losses in remnant vegetation.*

- *Discourage the subdivision of larger lots supporting remnant vegetation along the corridor route.*

- *Encourage the control of weed infestations, particularly in properties adjacent to higher quality remnants and in areas where weed infestations are more severe such as the Valley Rd node.*

- *Allocate resources to the control of weed infestations on Council land within the corridor footprint including any future additions (e.g. Burdett's Quarry)*

- *Consider larger habitat connectivity in all planning permit applications and attempt to align any required offsets so they improve connectivity for fauna and have long-term viability. For example, offsets at the back of blocks are less likely to be threatened by the development of future roads, driveways or installation and maintenance of other infrastructure.*

Arboreal

- *Undertake surveys for significant habitat trees (e.g. LOTS and hollow-bearing) along the corridor route and develop a register of significant trees for fauna. Consider installing nest-boxes where large gaps exist along the corridor route and foster the involvement of community groups in their maintenance.*
- *Plant indigenous tree canopy species including a mixture of both smooth- and rough-species along the corridor route forming a continuous canopy with gaps no greater than 5m (no dense native groundstorey habitat) or 20m (dense groundstorey present) and 30 m in width. Aim to create a mixed-aged stand of canopy trees over the long-term.*
- *Plant a diversity tree and tall shrub species including eucalypts and acacias*

Ground-dwelling

- *Plant appropriate indigenous species to form dense groundstorey vegetation with gaps supporting more open vegetation/leaf litter measuring no more than 25m between these refuge areas.*
- *Retain all fallen timber and logs and consider re-introduction of large logs (particularly hollow-bearing ones) where this can be undertaken without damaging remnant vegetation.*
- *Retain all large rocks and logs for reptiles and consider introduction of artificial substitutes (e.g. tin sheets or tiles) where depleted*

Woodland Birds

- *Protect all remaining areas of remnant woodland habitat*
- *Protect scattered trees in paddocks which assist dispersal between patches of continuous habitat.*
- *Pursue the planting of canopy trees (eucalyptus spp.), understorey trees, and shrubs (small, medium, and tall) on public and private land to increase the overall landscape cover of woodland habitats to >10% and ideally to at 20%]*
- *Plant indigenous tree canopy species including a mixture of both smooth- and rough-species along the corridor route forming a continuous canopy with gaps no greater than 50m*

Semi-aquatic

- *Conserve existing vegetated water-bodies (including farm dams) within 500m of corridor centreline and encourage their retention and enhancement as habitat refuges for frogs and turtles.*

- *Undertake surveys for wet refuge habitats for frogs along the corridor route and support the establishment of indigenous aquatic vegetation within existing identified refuges.*

- *Encourage and provide in-kind support for landholders to plant existing dams with fringing and semi-emergent aquatic vegetation.*

- *Encourage and provide in-kind logistical support for landholders to construct small wetlands or frog ponds in cleared areas on their property near to remnant bushland and within 500m of the corridor centreline.*

- *Establish small (500m2) intermittent ponds/wetlands along the corridor route including both deep, shallow and marsh sections to act as stepping stones for semi-aquatic fauna.*

Land Use, Management and Interactions: Certain land uses and activities can reduce the quality of habitat for fauna and in more severe cases remove critical habitat. Although the impact of land uses and their severity of fauna connectivity has not be studied along the corridor alignment, variation among blocks in remnant vegetation, bare ground, or tree cover (such as the Valley Rd node) illustrate how different land uses and management may influence the quality of habitat for fauna and resulting degree of connectivity.

- *Encourage landholders to practice ecologically sensitive land uses, particularly where an indigenous canopy cover or understorey vegetation is present.*

- *Encourage landholders to remove or exclude (i.e. fencing) domestic stock from within 75-100m of the corridor centreline to ensure revegetation/restoration of land can be implemented.*

- *Encourage landholders to fence-off mature canopy trees to encourage regeneration of canopy trees and understorey and make revegetation/restoration of land with suitable fauna habitat feasible.*

- *Discourage the collection or removal of rocks or fallen timber and reductions in course woody debris (i.e. fallen timber and leaves) within the corridor and adjacent land (200m of corridor centreline).*

- *Pursue ecological appropriate fire regimes (e.g. small scale mosaic burns) are practised in remnant bushland both within the corridor footprint and linking node/core patches.*

- *Discourage heavy use of fertilizers (phosphates) on private and public land and ensure any stockpiles are appropriately contained*

- *Pursue the control of listed noxious and environmental weeds on private and public land. Ensure that commitments to remove environmental weeds on private properties under planning permits are followed through by landowners*

Exotic predators: High predation rates by exotic predators at certain locations inhibiting effective connectivity between otherwise isolated populations of native fauna (particularly ground-dwelling fauna). Cats (domestic and feral) are a well-established threat to ground-dwelling mammals, reptiles, frogs, and woodland birds. The severity of this threat (exotic predators) is likely to be high - 75 million native animals are predicted to be killed by cats every day in Australia. Heavy predation can lead to loss of connectivity between fauna populations even where suitable habitat is present.

- *Encourage the control of pest animal species (foxes, cats, and rabbits) on private land and ensure crown land (including Council managed land) is appropriately managed for pest animal issues.*

- *Require cat-free residential areas in all new residential development applications within at least 500m of the corridor centreline and preferably within 1km.*

- *Encourage owners to keep cats indoors at night and ensure cat control is undertaken within sections of the corridor which are designated conservation reserves.*

5.4.1 Specific Linkage Details and Parameters:

Dependent Habitat Patches (ID#): 304, 390, 375, 355, 319, 315, 316, and 302.

Core Width: >50m; recommended 100m width

Buffer Zones: >50m (either side)

Bushfire Protection Zones

Bushfire Prone Areas: 10-12 m ('woodland') *or* 30-35 m ('forest')

Bushfire Management Overlay: 27-33 m ('woodland') *or* 40-50 m ('forest')

Details:

The corridor runs entirely through a designated Bushfire Prone Area. Heathy Woodland is the dominant remnant vegetation along this corridor. Under a Bushfire Attack Level (BAL) assessment, existing Heathy Woodland EVC remnants and established revegetated areas (buffer and core zones) are likely to be classified as 'Forest' vegetation due to the density of shrubs planned. Some areas of remnant vegetation and revegetated areas where shrub establishment is more sparse could be classified as 'Woodland'. Along the corridor route, slope varies between 0 degrees (i.e. flat land) and <5 degrees based on a 10m contour map. A Bushfire Management Overlay (BMO) also covers the Pines FFR, four properties south of McClelland Drive, several properties off Valley Rd (south) eastward from 50 Valley Rd, Burdett's Quarry node and some surrounding land, and the Ballarto Rd remnants (south of Ballarto Rd only) and the Royal Botanic Gardens Cranbourne node.

An assessment of the BAL required is highly site specific and requires detailed examination in the field. Very broadly, under a BAL29 scenario and 'Forest' vegetation classification, open space/fire management zones would need to be between 25-35 metres wide (~30m) on flat land (or where vegetation is on an 'upslope' respective to the closest dwellings) and 32-43 metres (~35m) on slopes >0 to 5 degrees (where vegetation near dwellings is on a down slope - respective to the dwelling). Where a BMO exists, this would increase to 40m on flat land to 50m (>0 to 5 degrees down slope).

Under a BAL29 and 'Woodland' classification, an open space/fire management zone would need to be between 10m (flat or upslope) and 12m (>0 to 5 degrees down slope) in Bushfire Prone Areas, and between 27m to 33m where a BMO exists. A BMO also covers most of supplementary corridor S1 and Studio Park node with the exception of a 600m stretch running south-east from McClelland Drive.

Note that fire protection offsets from remnant bushland or revegetated areas can also include adjacent backyards of properties supporting 'low threat' maintained vegetation (e.g. cultivated gardens and lawns). Also, narrow strips of vegetation <20m wide AND not within 20m of other areas of vegetation or dwellings are also considered low threat vegetation.

Target Fauna Ecological Requirements:

- Slow-flowing shallow water-bodies or wetlands with some deeper sections (>60cm), submergent or floating aquatic macrophytes, fringing and emergent vegetation (tall sedges, tussock-grasses, and reeds or trees) and adjacent terrestrial habitat with high groundcover of grasses, rocks, logs and litter (Semi-Aquatic)

- Heaths or woodlands with (or adjacent to) ephemeral shallow soaks, swampy areas, low-lying depressions or periodically inundated areas (Southern Toadlet)

- Dense (>50% foliage density) groundstorey (<1.0m) vegetation (grasses, sedges, ferns, low heaths and shrubs), 50m width, relatively continuous with gaps <25m of more open areas (Ground-dwelling, Woodland Birds)

- Open areas with sparse groundstorey cover and higher litter/fallen timber (>50% cover), abundant logs and rocks, and high stem density of taller shrubs (Woodland Birds, some Ground-Dwelling)

- High density shrub layer composed of a diversity of shrub species (including *Acacia* and *Leptospermum* spp.) and forming high structural complexity (i.e. small, medium and tall shrub layer at mature height)(Arboreal, Woodland Birds, Ground-Dwelling)

- Hollow-bearing trees (including stags) and logs with a diversity of small to large entrances (between 2-30cm)(Arboreal, Ground-Dwelling)

- Eucalypt canopy including stands of ribbon gum (e.g. Coast Manna Gum *E. viminalis* ssp. *pryoriana*), stringybark (e.g. Silver-leaf Stringybark *E. cephalocarpa*), and rough-barked (e.g. Swamp Gum *E. ovata*, Narrow-leaved Peppermint *E. radiata*) eucalypt species. Gaps in canopy <5m (no dense native groundstorey) or <20m (dense native groundstorey present)(Arboreal, Woodland Birds)

Establishment Costings for On-Ground Actions

Area estimates are based on plantings in areas not predicted to currently support tree cover or native vegetation (DSE modelled data and Ecology Australia 2006 mapping). It is expected that plantings will act as islands from which further recruitment can occur within the corridor and also some recruitment from remnant patches. Site preparation is based on large-scale application using a boom sprayer for weed control, some woody-weed control, and soil preparation (scraping/scalping or deep ripping).

Estimates are based on tube-stock (seedling plants) at a rate of $1.00 per plant assuming large-scale plantings can occur, some labour costs are reduced through volunteer work, and a 10% plant failure (i.e. plant death) rate in the first establishment year. The above rate per plant and estimates below do not cover further costs of maintenance and follow-up site treatment of tube stock plants to ensure a high survival rate (e.g. watering, replacement of plants, plant guards etc.) which may vary greatly depending on specific site conditions (well watered riparian site versus exposed pastures in poor soils). Some of the corridor could be direct-seeded, particular land supporting pasture between the

Lyppards Rd node and the Royal Botanic Gardens. Up-scaling planting work with direct seeding could result in different costs estimates to those provided below.

The dense groundstorey plantings within core habitat (50m width) was calculated at 2.5 plants/1m^2 and assumes that grass/sedge species forming large tussocks will dominate plantings. Some estimates, such as pest control and weed control are also on-going yearly costs although (yearly) costs may decline over time. Monitoring should be considered as part of more detailed implementation proposals and will be important for justifying on-ground works, connectivity functionality, and an adaptive management approach.

Table 5. Establishment costings for on-ground actions within corridor C1

	Action	Area (ha) or Perimeter (km)	Unit	Cost$/ha	Costings
Plantings	Site preparation	86	-	$673	$57,878
	Tree canopy overstorey	86	-	$105	$9,030
	High density shrub understorey	86	-	$2,750	$236,500
	Dense groundstorey (core)	26	-	$27,500	$715,000
	Open groundstorey (buffer)	60	-	$5,500	$330,000
	Follow-up weed control (spot)	86	-	$3,712	$319,232
Other	Fencing	21	-	$3,240	$69,367
	Pest animal control	159	-	$500	$79,500
	Constructed wetland*	0.25 ha each	1	$500,000	$125,000
	Constructed vegetated pond**	0.05 ha each	8	$100,000	$40,000
	Farm dam plantings	0.02 ha each	10	$52,000	$10,400
	Total				$1,991,907

1	based on a corridor width of 150m (buffer and core zones), planting density of 1 plant/10m^2, and assuming no further losses in tree canopy cover and recruitment (i.e. natural replacement) of existing trees occurring over time (i.e. exclusion of stock)
2	based on a corridor width of 150m (buffer and core zones), planting density of 1 plant/4m^2
3	based on a core corridor width of 50m, at a planting density of 2.5 plants/1m^2 to establish a dense groundstorey
4	based on a buffer zone width of 50m either side of corridor (100m width in total) at a planting density of 1 plant/2m^2 to establish a sparse groundstorey
5	4-line plain wire fencing with rabbit-proof skirting and fencing around the perimeter of the 150m wide corridor
*	based on greenfield wetlands in Melbourne reported by Taylor 2005 although estimates for water quality treatment wetlands (entirely vegetated) can range from $500 000 to $700 000 per wetland hectare.
**	based on minimum cost estimate given by Walsh 2001 (cited in Taylor 2005 and Taylor and Wong 2002). For a small 25m x 25 m (or 500m^2) waterbody with 2m fringing strip of fringing and also some emergent, submergent, and floating vegetation (i.e. macrophytes)

Land Ownership/Responsible Authorities within Corridor

Mostly private land along corridor C1 although larger node and core patches of habitat are managed by public authorities. Larger blocks of private land along the corridor alignment include land managed/owned by Rocla Quarry, Skye Mineral Sands, the Natural Resources Conservation League of Victoria (NRCL; property east of the Western Port Hwy), and Ranfurlie Golf Course.

Public land ownership/responsible authorities along the corridor route include:

Frankston City Council: Gumnut Reserve (within the linking Burdett's Quarry node)

Parks Victoria: Pines Flora and Fauna Reserve (patch ID#304 and 375), the former KTRI land node (patch ID#390), and Dandenong-Hastings Rd Reserve (Western Port Hwy; within the Lyppards Rd node ID#315)

Royal Botanic Gardens Board Victoria: Royal Botanic Gardens Cranbourne (patch ID#302)

Melbourne Water: short section of Boggy Creek and small lots within the Burdett's Quarry node

VicRoads/Linking Melbourne Authority/Southern Way: Peninsula Link freeway

VicRoads: Western Port Highway

Landholder and Community Interest in Corridor

The Natural Resources Conservation League of Victoria has a strong interest in establishing a linkage through its property off the Western Port Hwy linking planned restoration works on the property with remnant patches in Casey (i.e. RBGC) and Frankston. The Royal Botanic Gardens Cranbourne has also expressed interest in linking the gardens with other large patches of remnant vegetation/fauna habitat within Frankston (i.e. the Pines FFR) and Casey. A number of private landholders within the corridor alignment have also committed to restoration/conservation works on their properties, particularly within the Valley Rd node.

5.5 Pines Flora and Fauna Reserve to Langwarrin Flora and Fauna Reserve

Map Code: C2

Type: Riparian Corridor

Component Linkages:

Link ID# 1 – *High* conservation significance; Conservation Score/Rank: 33/44, Feasibility Score: 65/56, Opportunity Score: 44/24; Type: Riparian

Link ID# 40 – *High* conservation significance; Conservation Score/Rank: 33/41, Feasibility Score: 65/43, Opportunity Score: 44/66; Type: Terrestrial

Conservation Priority: *High* overall Rank Priority among corridor linkages and a significant riparian and aquatic linkage within Frankston connecting two of the largest core habitat patches.

Local Government Areas: Frankston

Remnant EVCs (% of total remnant cover): Swampy Riparian Woodland (40%), Heathy Woodland (30%), Swamp Scrub (14%), Riparian Scrub (11%), Damp Heathy Woodland (6%), and Swampy Woodland (<1%).

Incorporated Council Reserves: Little Boggy Creek Reserve, Pindara Reserve, Lexton Reserve, Lloyd Park, and Langwarrin Equestrian Centre.

Description: This corridor extends from the Pines Flora and Fauna Reserve-eastern section (71 ha) to Langwarrin Flora and Fauna Reserve (213 ha) core area and is approximately 6.9 km in length. It largely follows riparian habitat along Littel Boggy Creek and Boggy Creek between these two core areas. Four intervening habitat nodes are linked along the recommended route including the Little Boggy Creek node (ID#:374; 70 ha), Lloyd Park node (ID#372; 3.6 ha), the Langwarrin Equestrian Centre node (ID#405; 2.8 ha), and the Langwarrin Woodland-Sunnybank Rd node (ID#425; 54 ha). Vegetation along corridor route is composed mostly of Swampy Riparian Woodland and Heathy Woodland EVC with at least four other EVCs incorporated within linkage. The northern section of the corridor within the Rocla Quarry site is designated as a potential future project site for the Port Phillip and Westernport CMA through its 'Living Links' initiative.

Along Little Boggy Creek, the corridor runs through alluvium soils deposited within the creeks floodplain, followed by pale sands south of Lloyd Park and sandstone/mudstone derived soils approximately south of the Langwarrin Equestrian Centre node. The former swamps of Little Boggy Creek were historically drained with a large expanse of land south of McClelland Drive quarried for sand deposits. The first section of this corridor runs through this area following the alignment of Little Boggy Creek. Habitat along the creek between McClelland Drive and the Little Boggy Creek node has been severely reduced in extent and quality, now forming a narrow strip of fragmented habitat bounded by quarry pits. Within the Little Boggy Creek node, the quality and extent of remnant vegetation is greater, forming a significant habitat corridor between 50m to 200m in width to Cranbourne-Frankston Rd. From this point the corridor crosses Pindara Boulevard and connects to the Lloyd Park node, then running south along Boggy Creek under Cranbourne-Frankston Rd and to mown areas with sparse tree cover to 400m south of the road. The corridor continues to run south along a narrow (~50m wide) strip of land bordering Boggy Creek, through a modified remnant (Langwarrin Equestrian Centre node) and south of North Rd into the Langwarrin Woodland-Sunnybank Rd node where landscape tree cover is greater. The corridor diverges from Boggy Creek at Bergman Rd to run westward along a transmission line easement to Langwarrin Flora and Fauna Reserve.

Habitat Values and Significant Sites

The Pines Flora and Fauna Reserve: A BIOSITE (#4916) of state significance supporting large areas (195 ha) of highly significant fauna habitat. *See detailed description under Corridor C1.*

Little Boggy Creek node (ID#374): a large area (71 ha) of remnant fauna habitat associated with Little Boggy Creek and Boggy Creek waterways and adjoining riparian and terrestrial remnant vegetation. The site supports at least 24 ha of remnant native vegetation and has recently been considered of Very High significance for floristic values (Ecology Australia 2006). Significant aquatic and terrestrial habitats are present within the site. The site incorporates several Council reserves: Little Boggy Creek Reserve, Pindara Reserve, Boggy Creek Link, Lexton Reserve, and Stevens Road Reserve. Also incorporates the Melbourne Water Little Boggy Creek Retarding Basin and Boggy Creek Waterway Reserve which supports good quality in-stream habitat, high quality remnant vegetation, and four threatened EVCs: Swamp Riparian Woodland, Damp Heathy Woodland, Riparian Scrub, and Swamp Scrub. Threatened fauna species recorded within the site include the nationally threatened Dwarf Galaxias, state vulnerable Southern Toadlet, and the locally threatened Swordgrass Brown Butterfly. Eight of the target fauna species have been recorded within the site.

Lloyd Park – south (ID#373): a site of Very High significance based on floristic values and quality of remnant vegetation (Ecology Australia 2006) comprised of Riparian Scrub and Heathy Woodland EVCs. The locally declining Swamp Rat is recorded from the reserve along with target fauna species the Common Froglet, Sugar Glider, and Common Ringtail Possum in a remnant immediately north. A potential record for the state threatened Southern Toadlet has also been made in a remnant immediately north within Lloyd Park in 2011 (SMEC 2011) suggesting this southern site could serve an important role in connectivity for the species. However, the site requires connectivity to this remnant habitat in the north of Lexton Reserve which supports potential habitat for the Sugar Glider (SMEC 2011)

Langwarrin Equestrian Centre (ID#405): a small site (2.6 ha) supporting remnant heathy woodland and swampy woodland habitats. Considered of High significance for floristic values and supporting remnants of an endangered EVC (Swamp Riparian Woodland). The site supports a relatively degraded understorey with high weed invasion and dissected by horse trails but has an intact tree canopy. This habitat node constitutes an important stepping stone for fauna along the Boggy Creek corridor. A recent (since 2002) record has been made of the Common Froglet and older records (i.e. 1996) of several target fauna species including the Southern Brown Tree Frog, Southern Bullfrog, Eastern Yellow Robin, Ringtail Possum, Short-beaked Echidna, Swamp Rat, Koala, Blotched Blue-tongued Lizard, Garden Skink, and Lowland Copperhead Snake.

Langwarrin Woodland-Sunnybank Rd node (ID#425): a site supporting scattered (fragmented) remnants of heathy and swampy woodland and high canopy tree cover. Encompassing land mostly in private tenure, this node supports two BIOSITES of regional significance, the 'Robinsons Road Forests' (#5151) and the 'Baxter/Pearcedale Bushland' (#5210). Both areas support vegetation types of High regional significance. Overall significance of floristic values is Very High (Ecology

Australia 2006). Recent records (2011) of the Sugar Glider have been made within this node along with 28 bird species.

Langwarrin Flora and Fauna Reserve (ID#303): a large reserve intact area of remnant fauna habitat (~213 ha) supporting a wide variety of vegetation communities (~7) and fauna habitats. A state significant BIOSITE (#5094) and considered previously as a site of regional zoological significance (Brereton et al. 2004). Based on the latter studies criteria and numerous recent records for the threatened Southern Toadlet within the reserve, Langwarrin FFR should be considered of state significance. The Langwarrin Railway Reserve (29 ha) immediately west of Langwarrin FFR is also considered a BIOSITE of State significance for important flora, fauna, and vegetation community values. The Langwarrin FFR is also recently considered to be a site of Very High significance for floristic values (Ecology Australia 2006). Several other threatened fauna species have been recorded within the reserve including the New Holland Mouse, Swamp Skink, Latham's Snipe, Nankeen Night Heron, Pied Cormorant, Satin Flycatcher, and Haswell's Froglet. The reserve also supported a population of Southern Brown Bandicoot up until the late 1980s.

Fauna Use and Movement

Target Species: Ten of the 30 target species have been recently (last 10 years) recorded directly along the corridor route and intervening node patches. Another fourteen target fauna species have been recorded in linking core areas (Pines FFR and Langwarrin FFR) or within 100m of the corridor centreline over a longer period of time (Table X). These include all woodland bird, ground-dwelling mammal, and frog target fauna species, and 5 ground-dwelling reptile, 3 arboreal, and 2 fish target species.

The proposed corridor could provide a direct linkage between two or more populations for 14 species (Table X). In combination with the implementation of supplementary corridors S1 and S2, the number may increase to 16. For 10 species, the corridor may provide connectivity among core populations or habitat within Frankston. Populations of seven target species could potentially be provided with connectivity to unoccupied core areas of habitat which could be re-colonised, including the Southern Toadlet, Eastern Yellow Robin, Common Ringtail Possum, and Sugar Glider.

Arboreal

Present Habitat Connectivity

Present connectivity for arboreal fauna varies considerably along the corridor route. Severe gaps in canopy and understorey habitat occur within the Rocla Quarry site between McClelland Drive and the Little Boggy Creek node suggesting little movement of fauna along the corridor in this section. Movement and dispersal events between the Pines FFR and Little Boggy Creek node are more likely to occur through canopy and remnant understorey along the route of supplementary corridor S1. Canopy habitat within the latter node is somewhat fragmented but a relatively intact remnant understorey provides improved connectivity and daily movements of arboreal fauna are likely. The physical barrier of Quarry Road, associated gaps in habitat and adjacent low canopy cover and height (i.e. for gliders) likely reduces movements of arboreal fauna within this node however. The physical barrier of Lexton Drive, associated gaps in canopy cover and lack of bordering tree cover (i.e. only young juvenile trees border the road) results in poor connectivity for arboreal fauna to Little Boggy Creek Reserve. Similarly, Pindara Boulevard and the absence of any terrestrial underpass and significant canopy gaps likely reduces movement of arboreal fauna between the Little Boggy Creek node and suitable habitat within Lloyd Park. Movement south is likely to be highly restricted due to the barrier of Cranbourne-Frankston Rd and poor habitat connectivity (only a single row of trees and no understorey) for a 400m stretch south of the road. Further south, connectivity is moderately good due to a relatively consistent canopy and further improves south of North Road to Langwarrin FFR where the cover of remnant eucalypt overstorey canopy is high and forms a relatively wide corridor. However, few large trees are reported to occur within the Langwarrin Woodlands-Sunnybank Rd node (Ecology Australia 2006), suggesting limited current potential for resident arboreal populations.

Target Species

Recent records (last 10 years) of target fauna species along the corridor route include the Koala (Little Boggy Creek Reserve, Boggy Creek-Pindara Reserve, Lloyd Park), Ringtail Possum (Little Boggy Creek Reserve), and Sugar Glider (Lloyd Park). All three of these arboreal species are likely to utilise this corridor and be provided with much improved connectivity among populations (Table X). In particular, corridor C2 would provide a significant linkage between core areas of habitat for the Koala. Combined with the Studio Park supplementary corridor (S1), improved connectivity for the Feathertail Glider could also be achieved, connecting the Studio Park population to large areas of habitat within the Langwarrin Woodland nodes and Langwarrin FFR. Connectivity between populations of Sugar Glider recorded in Stringybark Bushland Reserve and Studio Park could also be achieved with the additional implementation of supplementary corridor S2.

Ground-dwelling (reptile and mammal)

Present Habitat Connectivity

Movements of ground-dwelling fauna along the corridor route between the Pines FFR and Langwarrin FFR are likely to be exceedingly rare due to several significant gaps in habitat and a number of major barriers (i.e. roads). Within the linking nodes, groundstorey habitat is also often fragmented and discontinuous. As for arboreal fauna, movements of ground-dwelling fauna between the Pines FFR and Little Boggy Creek is more occurring along the supplementary corridor S1 (i.e. Studio Park linkage) due to less fragmented and higher cover of groundstorey habitat. However, movements of ground-dwelling fauna are likely occurring along the C2 corridor within the Little Boggy Creek and Langwarrin Woodlands-Sunnybank Rd nodes, although Quarry Rd (and associated gaps in habitat) likely impedes movement for a number of target fauna species within the former. Fencing along the southern boundary of Quarry may also impede movements of Black Wallabies within the Little Boggy Creek node. Movement to and from Little Boggy Creek Reserve is possibly impeded by gaps in groundcover and unsafe passage where Lexton Drive intersects the node. Good quality indigenous plantings either side of Lexton Drive are likely to form a dense groundcover over time – i.e. facilitating movement – although crossing structures would improve connectivity.

Cranbourne-Frankston Rd (and associated Pindara Boulevard) is a more severe barrier due to the lack of any terrestrial underpass and a severe bottleneck in corridor (groundstorey) width at this juncture. Connectivity for ground-dwelling fauna generally improves south of the Langwarrin Equestrian Centre although the fragmented and patchy distribution of suitable groundstorey habitat, residential infrastructure (fencing, driveways etc), and roads likely reduces connectivity for a number of target fauna species. The Garden Skink, Blotched Blue-tongue Lizard, Lowland Copperhead, and Short-beaked Echidna could be moving along short sections of the corridor between the Langwarrin Equestrian Centre, the Langwarrin Woodlands-Sunnybank Rd node, and Langwarrin FFR. However, the latter species is considered to have declined in recent decades within Frankston, possibly due to poor connectivity between suitable areas of habitat (the species has a reportedly very large home range of 48-107 ha) and poor quality/patchiness in groundstorey habitat. Swamp Rats could also potentially move along the Boggy Creek drainage line considering the high density of groundcover, particularly within the Langwarrin Woodlands node. Movements of Black Wallabies north and south of North Rd are likely based on casualty records, suggesting some attempts by the species to utilise this corridor.

Target Species

Ground-dwelling target fauna recently recorded along the C2 corridor include the Short-beaked Echidna (Little Boggy Creek Reserve), Swamp Rat (Little Boggy Creek Reserve, Lloyd Park), and Swamp Wallaby (Langwarrin Woodlands-Sunnybank Rd node, Little Boggy Creek Reserve). Another 7 ground-dwelling target species have been recorded within linking core areas (Pines FFR and Langwarrin FFR) or within 200m of the corridor centreline.

This corridor provides connectivity among core populations of Short-beaked Echidna, Garden Skink, and Swamp Rat. Improved connectivity between populations could also be achieved for the Blotched Blue-tongue Lizard and potential for recolonization of unoccupied habitat by the Swamp Skink, Short-beaked Echidna, and Lowland Copperhead. In combination with corridor C1 and supplementary corridors S1 and S2, this corridor could also provide improved connectivity for populations of Glossy Grass Skink (Studio Park and Stringybark Bushland Reserve), Swamp Skink, Tree Dragon, and Black Wallaby.

Birds (woodland birds)

Present Habitat Connectivity

Connectivity for woodland birds between the Pines FFR and Little Boggy Creek node is very poor due to large gaps in canopy cover and only very narrow strips (5-15m) of mostly shrubby habitat, likely well beyond the threshold tolerance of most woodland bird species, including the target fauna species. Where it occurs, movement of woodland birds from the Pines FFR southward to the Little Boggy Creek node likely occurs along the route of supplementary corridor S1 and associated woodland habitat. Habitat connectivity along the corridor route within the Little Boggy Creek node is much higher with the intersecting Quarry Rd unlikely to be a significant barrier. However, patchiness in tree canopy cover (sparse in areas) and low abundance of larger trees may reduce movement or utilisation in a number of the target fauna species (e.g. Varied Sittella and Crested Shrike-tit). Sections of Little Boggy Creek node also support few older trees (although this is likely to improve over time where restoration work has been undertaken) which is likely to impede movement in some woodland bird species. A large gap (~400m) in tree canopy cover and understorey trees and shrubs south of Cranbourne-Frankston Rd is a major barrier to movement and only rare dispersal events are likely by woodland birds, such as the Eastern Yellow Robin. Only a narrow strip of patchy tree and shrub cover occurs along Boggy Creek to the Langwarrin Equestrian Centre, with higher density residential housing bordering the creek and overall low landscape tree cover. South of North Rd connectivity improves markedly within the Langwarrin Woodlands-Sunnybank Rd node, although the sparseness of larger trees and larger shrubs likely inhibits movement and utilisation by some species (i.e. Varied Sittella and Rufous Whistler) recorded within the nearby Langwarrin FFR.

Target Species

Woodland Birds recently (last 10 years) recorded along the corridor route and intervening nodes include the Crested Shrike-tit (Little Boggy Creek Reserve) and Eastern Yellow Robin (Little Boggy Creek Reserve). Older records (i.e. 1996) include the Crested Shrike-tit (Lexton and Lloyd Reserves), Rufous Whistler (Little Boggy Creek Reserve), and Dusky Woodswallow (Lloyd Reserve). The Varied Sittella has also been frequently recorded within Langwarrin FFR in recent times. The latter core area is also a stronghold for the Eastern Yellow Robin based on recent records. The distribution of records for the species provides some support for limited movement southward of Cranbourne-Frankston Rd.

Eastern Yellow Robin populations (Langwarrin FFR, Little Boggy Creek, and Pines FFR) are directly connected by this corridor while populations of Crested Shrike-tit, Rufous Whistler, and Varied Sittella may be connected in combination with implementation of additional corridor (C1, S1, and S2). Important connectivity between larger areas of woodland within Langwarrin FFR, the Langwarrin Woodland-Sunnybank Rd node, Little Boggy Creek, Studio Park, the Pines FFR, and the RBGC is provided by the combination of these corridors. In particular, the greatest number of records of woodland birds are associated with Langwarrin FFR and the RBGC suggesting landscape connectivity between these larger core areas should be priority goal.

Semi-aquatic

Present Habitat Connectivity

As for all other fauna groups, connectivity is poor for semi-aquatic fauna between the Pines FFR (i.e. McClelland Drive) and Little Boggy Creek node and little movement is expected except during dispersal events. The health of Little Boggy Creek and riparian habitat along this section of the corridor is very poor. Southward along the corridor route, connectivity improves markedly within the Little Boggy Creek node due to good quality in-stream aquatic, riparian, and wetland habitats. The continuity and wide width of habitat, combined with the mixture of aquatic and terrestrial habitats likely favours movement of the Eastern Long-necked Turtle. Some movement likely occurs between the Little Boggy Creek node and Lloyd Park although movement of the Southern Toadlet is less likely due to the terrestrial habits of adults and poor ground connectivity across Pindara Boulevard. Movement further south past Cranbourne-Frankston Rd is only possible directly over the road or through several large semi-submerged pipe culverts. Connectivity further south along Boggy Creek to approximately Dunmore Close is moderate although exotic weeds dominate the waterway while few wetlands or waterbodies occur until the corridor reaches the Langwarrin Woodlands-Sunnybank Rd node. A number of small and larger dams just north of the transmission line easement may serve as important stepping stones for some semi-aquatic fauna, particularly those species requiring open water, deeper water-bodies, or overhanging trees or shrubs. Connectivity along the corridor route following the transmission line easement is relatively poor due to the absence of aquatic or swampy habitats although a high density of dams/ponds occur within the area towards Langwarrin FFR, resulting in a landscape of relatively low resistance for frog movement and dispersal. The low intensity of residential activity and large areas of open space bordering Boggy Creek south of North Rd also assist in substantially increasing landscape connectivity for semi-aquatic fauna within the area.

Target Species

Along this corridor recent records have been made of the Southern Bullfrog (North Rd), Southern Toadlet (Little Boggy Creek Reserve, Lloyd Park), Common Froglet (North Rd, Little Boggy Creek Reserve), and Southern Brown Tree Frog (Little Boggy Creek Reserve, Lloyd Park). The Eastern Long-neck Turtle has been recorded within the Pines FFR in recent times and casualty records suggest frequent movement throughout Frankston. All four frog species have been recorded within the core areas connected by the linkage, the Pines FFR and Langwarrin FFR. Records may greatly underestimate the distributions of these species in more rural areas due to relatively low survey efforts on private land in semi-rural areas (e.g. Langwarrin Woodland nodes).

The corridor is likely to provide connectivity among two or more populations for all five semi-aquatic fauna species. Core populations of Common Froglet, Southern Brown Tree Frog, and Southern Bullfrog are provided with connectivity provided the additional implementation of corridor C1. Additional connectivity to Stringybark Bushland Reserve populations are provided by the supplementary corridor S2. The Southern Toadlet and Eastern Long-necked Turtle could be also provided with dispersal opportunities into suitable unoccupied habitat. Boggy and Little Boggy Creeks are highly significant corridors for frog and turtle movement and habitat provision within Frankston. These waterways and associated habitats provide refuges for the species and provide connectivity among a network of suitable habitat patches.

Target Species

Specific target fauna recorded are the Crested Shrike-tit (1-10 yrs; Little Boggy Creek Reserve), Dwarf Galaxias (1-10 yrs; Boggy Creek-Pindara Reserve, North Rd, McClelland Drive, Pines FFR-eastern section), Eastern Yellow Robin (Little Boggy Creek Reserve), Short-beaked Echidna (Little Boggy Creek Reserve), Koala (Little Boggy Creek Reserve, Boggy Creek-Pindara Reserve, Lloyd Park), Ringtail Possum (Little Boggy Creek Reserve), Southern Bullfrog (North Rd), Southern Toadlet (Little Boggy Creek Reserve, Lloyd Park), Sugar Glider (Lloyd Park), Swamp Rat (Little Boggy Creek Reserve, Lloyd Park).

Aquatic

Connectivity for target fish species is currently very poor between the Pines FFR and the Little Boggy Creek node. Within the Rocla Quarry site, Little Boggy Creek has been substantially degraded through substantial removal of remnant vegetation, earthworks, and the impacts of adjacent mining activities. Within the Little Boggy Creek node connectivity improves due to ongoing restoration works within the associated Council reserves and Melbourne Water retarding Basin. Connectivity further south along Boggy Creek is poor to moderate due to the modified nature of the watercourse including low water flows, high sedimentation, weed invasion, earthen grassed banks, and very narrow setbacks from residential areas. Areas of suitable habitat likely exist along the creek for some of target fauna species due to stands of in-stream macrophytes and retention of water after high flow events. Dispersal events would be very rare between the Pines FFR section of Little Boggy Creek, although they could occur within the latter node and southward, most likely for the Dwarf Galaxias which uses small pools of still waters as refugia.

Target Species

Recent records of target fish species within the corridor footprint is limited to the Dwarf Galaxias (1-10 yrs; Boggy Creek-Pindara Reserve, North Rd, McClelland Drive, Pines FFR-eastern section). Suitable habitat is present for other target fish species although connectivity to extant population is poor and dispersal challenging. It is unknown at this stage whether modifications to Little Boggy Creek further downstream and infrastructure development (i.e. Peninsula Link) will cause a decline or improvement in connectivity for the target fish species, although connectivity north of the Pines FFR has been poor in most recent times. Based on records of the target fish species, only the Dwarf Galaxias and Southern Pigmy Perch are likely to be provided with connectivity by corridor C2. Connectivity for the remaining two species is dependent on improvements in aquatic habitat connectivity further downstream and also substantial restoration of Little Boggy Creek within the Rocla Quarry site.

Key Threats to Connectivity and Recommended Actions:

The following sections details key threats to connectivity for fauna along the corridor route and recommended on-ground actions to mitigate them.

Road Barriers: Road barriers are relatively few along the corridor with the most severe being Cranbourne-Frankston Road/Pindara Boulevard intersection with the corridor. Other road barriers intersecting the corridor route include McClelland Drive, Quarry Road, Union Road, Morecroft Way, North Road, Bevnol Road, and Warrandyte Road. Lexton Road also fragments habitat within the Little Boggy Creek node and Archibald Place and Sunnybank Road within the Langwarrin Woodlands-Sunnybank Rd node. When considered along with gaps in habitat (bordering the roads) and traffic, Warrandyte Road, McClelland Drive, North Road and Quarry Road likely represent to most severe road barriers to faunal movement and threat to achieving connectivity for all six target fauna groups. Based on fauna casualty records, traffic along Warrandyte Road, McClelland Drive, Cranbourne-Frankston Road/Pindara Boulevard, and to a lesser extent, North Road, pose the greatest barrier to movement of fauna. There was some differences among fauna groups in spatial patterns of observed casualties. Lower densities of arboreal mammal and bird casualties were observed at the North Road intersection – although a hotspot occurs east with the intersection with corridor S2 – compared to Warrandyte Road, which was the opposite trend for ground-dwelling fauna.

At the present moment in time, solutions for overcoming the barrier effect of most of these roads are available, largely due to sufficient land for habitat creation and crossing structure installation at intersections with these roads. However, the Cranbourne-Frankston Road/Paratea Boulevard intersection with the corridor poses an on-going challenge to providing connectivity for some target fauna species and fauna groups. The corridor passes through a severe bottleneck at the intersection with these two roads – specifically, immediately east and west of Pindara Boulevard – and it is unlikely that good connectivity can be provided for the Black Wallaby at this point without major road modifications and earthworks. Only very narrow (15m) strip of groundstorey habitat (for 25m west and 35m north-east of Pindara Blvd) can be provided for ground-dwelling fauna at this point. Currently all other roads intersecting the corridor are single lane roads and considering the estimated gap crossing thresholds for woodland birds, movement across these roads is likely to occur given suitable habitat creation up to the road easement (i.e. without the creation of vegetated land bridges). Multi-lane roads such as the Cranbourne-Frankston Road are a significantly greater challenge for gap-sensitive woodland birds although some dispersal movements may occur if high quality habitat is provided on either side.

Solutions:

- *Implement fauna crossing structures at recommended strategic locations to facilitate connectivity across road barriers along the corridor route.*
- *Pursue the implementation of fauna crossing structures at corridor C2 intersections with McClelland Drive, Quarry Road, Cranbourne-Frankston Road/Pindara Boulevard, North Road, and Warrandyte Road as a high priority.*
- *Combine fauna crossing structures with fencing on either side of crossing locality to ensure animals are funnelled through at these points and ensure they are regularly maintained*

- *Avoid or mitigate further road construction or upgrades (including from unsealed to sealed and widening to multiple lanes) of roads intersecting corridor C2 and linking node patches along the corridor (e.g. Little Boggy Creek and Langwarrin Woodland-Sunnybank Rd nodes). Of highest priority is avoiding further upgrades of McClelland Drive, Quarry Rd, Warrandyte Road, and North Rd.*

- *Where new roads or upgrades are proposed which intersect corridor C2 (or linking habitat patches), require or encourage the provision of fauna crossing structures*

- *Consider lowering speed limits (to 60 km/hr or lower) on McClelland Drive (particularly between Darnley Drive and Quarry Rd), Quarry Rd (currently 80 km/hr), North Rd (currently posted 70 km/hr at the intersection with C2 travelling east) and Warrandyte Rd (posted 80 km/hr south of Bevnol Rd).*

- *Consider installing devices such as speed humps or rumble bars on McClelland Drive Quarry Rd and Warrandyte Rd within 200m of proposed corridor C2 crossing location*

- *Attempt to provide continuous canopy cover surrounding recommended arboreal crossing structures (rope bridge) with gaps of <5m for arboreal fauna (Common Ringtail Possum, Sugar Glider, Koala) and continuous canopy cover overarching roads (McClelland Drive, and possibly North Rd and Warrandyte Rd considered feasible)*

- *Ensure gaps in continuous tree canopy AND dense tall to medium shrub cover along corridor route are less than 25m for woodland birds at all corridor intersections with roads. At Cranbourne-Frankston Rd (minimum gap is 45m i.e. road width), plant eucalypts in medium strip east and west of Union Rd.*

- *Investigate the likelihood of further upgrades (i.e. single to multi-lane) of roads intersecting corridor C2 and undertake a feasibility assessment of implementing larger crossing structures (bridge underpasses or land-bridges) to provide connectivity for woodland birds and other fauna*

Infrastructure Barriers: Fencing barriers are relatively low along the corridor route between the Pines FFR and North Rd due to the route following a creekline and travelling through large areas of crown land. However, chain-link or mesh fencing is present at McClelland Drive and Quarry Road along with steel pedestrian fencing at North Reserve. Infrastructure barriers increase south of Cranbourne-Frankston Road where the route is largely within private residential blocks. In particular, numerous properties and associated infrastructure (e.g. fences and driveways) are intersected by the corridor within the Urban Floodway Zone between approximately Fawn Court and the Langwarrin Equestrian Centre. Property fencing and driveways also intersect the corridor within the Langwarrin Woodlands-Sunnybank Rd node including Bevnol Rd.

Solutions:

- *Encourage landholders and developers to remove, replace or modify existing fences for the safe and easy movement of fauna. Removal of fencing is the best option followed by replacement of hard fences (e.g. brick, concrete, or solid timber fencing) with soft fences such as three-tined plain wire (not barbed) fences.*

- *Focus incentives for removal or replacement of fencing within the Urban Floodway Zone south of Cranbourne Frankston Road and the Langwarrin Woodlands-Sunnybank Rd node, and also bounding properties/public land bordering McClelland Drive and Quarry Road.*

- *Consider only using fencing along roads where combined with crossing structures at strategic locations.*

- *Liaise widely with infrastructure managers (water, electricity, roads) and government department to promote the implementation of the corridor and avoid conflicts with future infrastructure upgrades or maintenance.*

Habitat Fragmentation and Loss: Substantial tracts of remnant habitat along the corridor route have been lost as a result of mining activities and residential development. Recent habitat loss and fragmentation has been most severe between McClelland Drive and the Little Boggy Creek node. Incremental losses have also occurred south of Cranbourne-Frankston Rd as a result of residential development and poor historical planning and management of the Boggy Creek waterway. Large areas of habitat are still at threat of complete loss due to continuing mining activities. There is the threat of losses of *all* remnant vegetation, including terrestrial, riparian and aquatic fauna habitats along Little Boggy Creek within the Rocla Quarry site. This would lead to severe degradation of natural values along the waterway including connectivity for fauna, particularly the nationally significant Dwarf Galaxias. Further subdivisions are a significant threat to connectivity for fauna, particularly two larger private lots between the Langwarrin Equestrian Centre and North road which are currently zoned Residential 1 and if subdivided could threatened the establishment of corridor C2. Also of threat are further subdivisions within the Langwarrin Woodlands-Sunnybank Rd node (Low Density Residential Zone) and also building or infrastructure development resulting in habitat loss or fragmentation.

Solutions:

General

- *Council should pursue retaining land entitlements that abut the corridor alignment. Opportunities for reserving (i.e. setting aside for conservation purposes) existing habitat along alternate routes should also be considered where the same ecological and connectivity service is provided.*

- *Consider the acquisition of key parcels on private land along the corridor alignment and linking node patches.*

- *Carefully consider any planning application within proximity (~500m) of the proposed corridor alignment to ensure connectivity for fauna is not threatened*

- *Commit to managing new land acquisitions along the corridor route, or adjoining to linked patches, for conservation purposes including the re-establishment of indigenous vegetation.*

- *Support revegetation of land where significant gaps in habitat occur along the corridor route and adjoining land according to target fauna habitat requirements and appropriate EVCs. The following areas are priority locations for restoration and revegetation works:*

    - *Sections of corridor C2 through the Rocla Quarry site (post mining operations) and gaps in habitat along supplementary corridor S1.*

    - *Establishment of canopy and shrub habitat south of Cranbourne-Frankston Rd to Langwarrin Equestrian Centre node*

- *Establishment of canopy and understorey habitat between the Langwarrin Equestrian Centre node and North Rd*

- *On crown land between the Langwarrin Equestrian Centre and North Road (i.e. Stringybark Bushland Reserve) along the route of supplementary corridor S2*

- *within the Langwarrin Woodlands-Sunnybank Rd node, prioritised firstly according to lots where canopy cover needs to be re-established and secondly on restoration works for the understorey (i.e. weed control and understorey plantings)*

- *Encourage landholders to retain remnant vegetation and hollow-bearing trees.*

- *Encourage the plantings understorey shrubs (such as acacias) along fence lines or property boundaries or in clumps, focusing on properties within 200m of corridor centreline.*

- *Avoid the building of new dwellings within 150m of the corridor centreline to avoid potential losses in remnant habitat or restrictions on habitat creation due to fire protection measures (i.e. fuel modified zones).*

- *Strongly pursue the cessation of mining operations along the corridor route, the re-instatement of self-sustaining indigenous vegetation communities within 200m of the corridor centreline within former mine sites, and advocate for no further losses in remnant vegetation.*

- *Discourage the subdivision of larger lots supporting remnant vegetation along the corridor route.*

- *Encourage the control of weed infestations, particularly in properties adjacent to higher quality remnants and in areas where weed infestations are more severe. Priority areas include the Boggy Creek waterway south of North Rd.*

- *Allocate resources to the control of weed infestations on Council land within the corridor footprint including any future additions. Liaise with other relevant management authorities (e.g. Melbourne Water) to implement weed control works. High priority areas include the Boggy Creek easement south of Cranbourne-Frankston Rd to the Langwarrin Equestrian Centre, and within the Little Boggy Creek node.*

- *Ensure that weed control is a requirement for approval of any future subdivision applications within the corridor or linking nodes and allocate resources for follow-up inspections.*

- *Consider larger habitat connectivity in all planning permit applications and attempt to align any required offsets so they improve connectivity for fauna and have long-term viability. For example, offsets at the back of blocks are less likely to be threatened by the development of future roads, driveways or installation and maintenance of other infrastructure.*

Arboreal

- *Undertake surveys for significant habitat trees (e.g. LOTS and hollow-bearing) along the corridor route and develop a register of significant trees for fauna. Consider installing nest-boxes where large gaps exist along the corridor route and foster the involvement of community groups in their maintenance.*

- *Reduce gaps in canopy or tall understorey trees (<5m height) to <5m for arboreal fauna (Common Ringtail Possum, Koala) and <20m for gliders (Sugar Glider)*
- *Plant a diversity tree and tall shrub species including eucalypts and acacias forming a continuous canopy with gaps no greater than 5m (no dense native groundstorey habitat) or 20m (dense groundstorey present) and 30 m in width. Aim to create a mixed-aged stand of canopy trees over the long-term.*

Ground-dwelling

- *Plant appropriate indigenous species to form dense groundstorey vegetation with gaps supporting more open vegetation/leaf litter measuring no more than 25m between these refuge areas.*
- *Retain all fallen timber and logs and consider re-introduction of large logs (particularly hollow-bearing ones) where this can be undertaken without damaging remnant vegetation.*
- *Retain all large rocks and logs for reptiles and consider introduction of artificial substitutes (e.g. tin sheets or tiles) where depleted*

Woodland Birds

- *Protect all remaining areas of remnant woodland habitat*
- *Protect both scattered and isolated trees which assist woodland birds and arboreal mammals in moving through the landscape and between patches of continuous habitat.*
- *Pursue the planting of canopy trees (eucalyptus spp.), understorey trees, and shrubs (small, medium, and tall) on public and private land to increase the overall landscape cover of woodland habitats to >20%*
- *Plant indigenous tree canopy species including a mixture of both smooth- and rough-species along the corridor route forming a continuous canopy with gaps no greater than 5m (no dense native groundstorey habitat) or 20m (dense groundstorey present) and 30 m in width. Aim to create a mixed-aged stand of canopy trees over the long-term.*
- *Plant indigenous tree canopy species including a mixture of both smooth- and rough-species along the corridor route forming a continuous canopy with gaps no greater than 50m*

Semi-aquatic

- *Continue to undertake environmental works within the Little Boggy Creek and Boggy Creek waterways and catchments to improve water quality, habitat quality, and the overall condition of riparian and aquatic habitats*
- *Pursue the retention and enhancement of all existing water-bodies, drainage lines, wetlands, or swampy habitat (permanent or ephemeral) within 500m of the corridor centreline.*
- *Encourage and provide in-kind support for landholders to plant existing dams with fringing and semi-emergent aquatic vegetation.*

- *Encourage and provide in-kind logistical support for landholders to construct small wetlands or frog ponds in cleared areas on their property near to remnant bushland and within 500m of the corridor centreline.*

- *Establish small (500m2) pond stepping stones along the corridor route including both deep, shallow and marsh sections.*

- *Undertake surveys for wet refuge habitats for frogs along the corridor route and support the establishment of indigenous aquatic vegetation within existing identified refuges. Ensure that wet habitats are distributed at a minimum 500m interval along the corridor route to assist dispersal of frog species and Eastern Long-necked Turtle.*

- *Encourage residents to install frog ponds on properties*

Aquatic

- *Pursue the protection and restoration of Little Boggy Creek and associated habitat within the Rocla Quarry site*

- *Re-establish connectivity for the Dwarf Galaxias and other fauna within Little Boggy Creek both upstream and downstream of McClelland Drive and also along Boggy Creek south of Pindara Boulevard*

- *Undertake restoration of Boggy Creek south of Cranbourne-Frankston Rd including weed control works, and the re-establishment of riparian and aquatic habitats*

- *Support and encourage environmental works and initiatives by other management authorities such as Melbourne Water within the Boggy Creek Retarding Basin*

Land Use, Management and Interactions: Land uses and interactions of particular threat to connectivity along the corridor route include mining operations being undertaken within the Rocla Quarry site, excessive nutrient flows into Boggy Creek from residential lawns and septic systems, overgrazing by domestic stock or severe reductions in ground cover through mowing and removal of fallen tree debris, the planting of environmental weeds (particularly in areas supporting remnant vegetation) or inaction by landholders/land managers to control noxious or environmental weeds.

Solutions:

- *Encourage landholders to practice ecologically sensitive land uses, particularly where an indigenous canopy cover or understorey vegetation is present.*

- *Encourage landholders to remove or exclude (i.e. fencing) domestic stock from within 75-100m of the corridor centreline to ensure revegetation/restoration of land can be implemented.*

- *Encourage landholders to fence-off mature canopy trees to encourage regeneration of canopy trees and understorey and make revegetation/restoration of land with suitable fauna habitat feasible.*

- *Discourage the collection or removal of rocks or fallen timber and reductions in course woody debris (i.e. fallen timber and leaves) within the corridor and adjacent land (200m of corridor centreline).*
- *Pursue ecological appropriate fire regimes (e.g. small scale mosaic burns) are practised in remnant bushland both within the corridor footprint and linking node/core patches.*
- *Discourage heavy use of fertilizers (phosphates) on private and public land and ensure any stockpiles are appropriately contained*
- *Pursue the control of listed noxious and environmental weeds on private and public land. Ensure that commitments to remove environmental weeds on private properties under planning permits are followed through by landowners*
- *Educate private landholders near or adjacent to Little Boggy Creek and Boggy Creek (particularly at the headwaters of Boggy Creek south of Cranbourne-Frankston Rd) of the effects of nutrient enrichment and sediment flows into the waterways with a specific focus on Aquatic and Semi-Aquatic fauna.*
- *Encourage private landholders adjacent to, or within, the Urban Floodway Zone of Boggy Creek to reduce or mitigate nutrient and sediment flows into the waterway*
- *Continue to work with Melbourne Water to improve the quality of water entering waterways along the corridor, particularly stormwater runoff, including the implementation of water treatment wetlands/ponds wherever practicable (Aquatic and Semi-Aquatic fauna).*

Exotic predators: The severity of exotic predators along corridor C2 is unknown although large gaps in habitat or poor protective cover from hunting predators along a good proportion of the route suggest it will be a serious threat to connectivity for fauna.

- *Encourage the control of pest animal species (foxes, cats, and rabbits) on private land and ensure crown land (including Council managed land) is appropriately managed for pest animal issues.*
- *Require cat-free residential areas in all new residential development applications within at least 500m of the corridor centreline and preferably within 1km.*
- *Encourage owners to keep cats indoors at night and ensure cat control is undertaken within sections of the corridor which are designated conservation reserves.*

5.5.1 Specific Linkage Parameters:

Dependent Habitat Patches (ID#): 375 (Pines FFR core area), 374 (Little Boggy Creek node), 373 (Lloyd Park node), 405 (Langwarrin Equestrian Centre), 425 (Langwarrin Woodland-Sunnybank Rd), 303 (Langwarrin FFR)

Core Width: >50m; likely narrowing to 25m in some sections due to constraints by existing residential developments

Pines FFR to Cranbourne-Frankston Rd: >50m

Cranbourne-Frankston Rd to North Rd: >25m

North Rd to Langwarrin FFR: >50m

Buffer Zones: >50m (either side); likely narrowing of total buffer zone between 0 and 25m south of Cranbourne-Frankston Rd due to residential dwellings, amenities, and infrastructure.

Pines FFR to Cranbourne-Frankston Rd: >50m either side

Cranbourne-Frankston Rd to North Rd: >15m either side

North Rd to Langwarrin FFR: >50m (although no buffer in understorey habitat may be available on one or more sides of core habitat along short section of the route)

Bushfire Protection Zones:

Bushfire Prone Areas: 10-12 m ('woodland') *or* 30-35 m ('forest')

Bushfire Management Overlay: 27-33 m ('woodland') *or* 40-50 m ('forest')

Details

The corridor runs entirely through a designated Bushfire Prone Area. A BMO covers the Pines FFR, four properties south of McClelland Drive, most of the Little Boggy Creek node, Langwarrin FFR and land approximately 400m east of the reserve and covering the corridor footprint. A BMO also covers most of supplementary corridor S2. Swampy Riparian Woodland and Heathy Woodland are the dominant remnant vegetation types along the corridor route. Under a Bushfire Attack Level (BAL) assessment the minimum vegetation classification would be 'woodland' although through time planted/rehabilitated vegetation within the corridor may be classified as 'forest' largely due to the shrub layer proposed. Some areas of remnant vegetation and revegetated areas where shrub establishment is more sparse could be classified as 'Woodland'. Along the corridor route, slope varies between 0 degrees (i.e. flat land) and <5 degrees based on a 10m contour map.

As mentioned above, an assessment of the BAL required is highly site specific and requires detailed examination in the field. Very broadly, under a BAL29 scenario and 'Forest' vegetation classification, open space/fire management zones would need to be between 25-35 metres wide (~30m) on flat land (or where vegetation is on an 'upslope' respective to the closest dwellings) and 32-43 metres (~35m) on slopes >0 to 5 degrees (where vegetation near dwellings is on a down slope - respective to the dwelling). Where a BMO (Bushfire Management Overlay) exists, this would increase to 40m on flat land to 50m (>0 to 5 degrees down slope).

Under a BAL29 and 'Woodland' classification, an open space/fire management zone would need to be between 10m (flat or upslope) and 12m (>0 to 5 degrees down slope) in Bushfire Prone Areas and between 27m to 33m where a BMO exists. Note that these offset areas from remnant bushland or revegetated areas can also include adjacent backyards of properties supporting 'low threat' maintained vegetation (e.g. cultivated gardens and lawns). Also, narrow strips of vegetation <20m wide AND not within 20m of other areas of vegetation or dwellings are also considered low threat vegetation.

Target Fauna Ecological Requirements:

- Slow-flowing shallow water-bodies and wetlands with some deeper sections (>60cm), submergent or floating aquatic macrophytes, fringing and emergent vegetation (tall sedges, tussock-grasses, and reeds or trees) and adjacent terrestrial habitat (Common Froglet) with high groundcover of grasses, rocks, logs and litter (Semi-Aquatic)

- Heaths or woodlands with (or adjacent to) ephemeral shallow soaks, swampy areas, low-lying depressions or periodically inundated areas (Southern Toadlet)
- Dense (>50% foliage density) groundstorey (<1.0m) vegetation (grasses, sedges, ferns, low heaths and shrubs), 50m width, relatively continuous with gaps <25m of more open areas (Ground-dwelling, Woodland Birds)
- Open areas with sparse groundstorey cover and higher litter/fallen timber (>50% cover), abundant logs and rocks, and high stem density of taller shrubs (Woodland Birds, some Ground-Dwelling)
- High density shrub layer composed of a diversity of shrub species (including *Acacia* and *Leptospermum* spp.) and forming high structural complexity (i.e. small, medium and tall shrub layer at mature height)(Arboreal, Woodland Birds, Ground-Dwelling)
- Eucalypt canopy including stands of ribbon gum (e.g. Coast Manna Gum *E. viminalis* ssp. *pryoriana*), stringybark (e.g. Silver-leaf Stringybark *E. cephalocarpa*), and rough-barked (e.g. Swamp Gum *E. ovata*, Narrow-leaved Peppermint *E. radiata*) eucalypt species. Gaps in canopy <5m (no dense native groundstorey) or <20m (dense native groundstorey present)(Arboreal, Woodland Birds)
- Hollow-bearing trees (including stags) and logs with a diversity of small to large entrances (between 2-30cm)(Arboreal, Ground-Dwelling)
- Slow-flowing waterways (or water-bodies: Dwarf Galaxias) with diverse and abundant macrophytes, submerged roots, rocks, and woody debris (snags), fringing stands of emergent macrophytes (e.g. Common Reed *Phragmites australis*), shading trees or shrubs (overhanging), high water quality including low nutrient and sediment loads, low abundance of exotic trout, and good waterway connectivity (Aquatic: Dwarf Galaxias and Tupong)

Establishment Costings for On-Ground Actions

Area estimates are based on plantings in areas not predicted to currently support tree cover or native vegetation (DSE modelled data and Ecology Australia 2006 mapping). It is expected that plantings will act as islands from which further recruitment can occur within the corridor and also some recruitment from remnant patches. Site preparation is based on large-scale application using a boom sprayer for weed control, some woody-weed control, and soil preparation (scraping/scalping or deep ripping). Costings do not incorporate management of patches and are restricted to revegetation activities in areas where habitat (tree canopy and/or understorey) requires re-establishment (i.e. 45 hectares of land).

Estimates are based on tube-stock (seedling plants) at a rate of $1.00 per plant assuming large-scale plantings can occur, some labour costs are reduced through volunteer work, and a 10% plant failure (i.e. plant death) rate in the first establishment year. The above rate per plant and estimates below do not cover further costs of maintenance and follow-up site treatment of tube stock plants to ensure a high survival rate (e.g. watering, replacement of plants, plant guards etc) which may vary greatly depending on specific site conditions (well watered riparian site versus exposed pastures in poor soils). Some of the corridor could be direct-seeded, particular land supporting pasture between the

Lyppards Rd node and the Royal Botanic Gardens. Up-scaling planting work with direct seeding could result in different costs estimates to those provided below.

The dense groundstorey plantings within core habitat (50m width) was calculated at 2.5 plants/1m^2 and assumes that grass/sedge species forming large tussocks will dominate plantings. Some estimates, such as pest control and weed control are also on-going yearly costs although (yearly) costs may decline over time. Monitoring should be considered as part of more detailed implementation proposals and will be important for justifying on-ground works, connectivity functionality, and an adaptive management approach.

Table 6. Establishment costings for on-ground actions within corridor C2

	Action	Area (ha) or Perimeter (km)	Unit	Cost$/ha	Costings
Plantings	Site preparation	45	-	$673	$30,285
	Tree canopy overstorey [1]	40	-	$105	$4,200
	High density shrub understorey [2]	45	-	$2,750	$123,750
	Dense groundstorey (core) [3]	14	-	$27,500	$393,250
	Open groundstorey (buffer) [4]	31	-	$5,500	$172,150
	Follow-up weed control (spot)	45	-	$3,712	$167,040
Other	Fencing [5]	14	-	$3,240	$45,360
	Pest animal control	85	-	$500	$42,500
	Constructed wetland*	0.25 ha each	1	$500,000	$125,000
	Constructed vegetated pond**	0.05 ha each	9	$100,000	$45,000
	Farm dam plantings	0.02 ha each	8	$52,000	$8,320
	Total				$1,156,855

1	based on a corridor width of 150m (buffer and core zones), planting density of 1 plant/10m^2, and assuming no further losses in tree canopy cover and recruitment (i.e. natural replacement) of existing trees occurring over time (i.e. exclusion of stock)
2	based on a corridor width of 150m (buffer and core zones), planting density of 1 plant/4m^2
3	based on a core corridor width of 50m, at a planting density of 2.5 plants/1m^2 to establish a dense groundstorey. Also an approximate cost of establishing moderate quality aquatic vegetation.
4	based on a buffer zone width of 50m either side of corridor (100m width in total) at a planting density of 1 plant/2m^2 to establish a sparse groundstorey
5	4-line plain wire fencing with rabbit-proof skirting and fencing around the perimeter of the 150m wide corridor
*	based on greenfield wetlands in Melbourne reported by Taylor 2005 although estimates for water quality treatment wetlands (entirely vegetated) can range from $500 000 to $700 000 per wetland hectare.
**	based on minimum cost estimate given by Walsh 2001 (cited in Taylor 2005 and Taylor and Wong 2002). For a small 25m x 25 m (or 500m^2) waterbody with 2m fringing strip of fringing and also some emergent, submergent, and floating vegetation (i.e. macrophytes)

Land Ownership/Responsible Authorities within Corridor

From the Pines FFR (Parks Victoria managed) to approximately 400m north of Quarry Rd, corridor C2 runs through largely private land. A very narrow (10m) easement of crown land exists approximately along the alignment of Little Boggy Creek running south at Lexton Drive to Quarry Rd. Some of the corridor intersects Lexton Reserve (managed by Frankston City Council) followed by Melbourne Water retarding basins/reserves (Little Boggy Creek Retarding Basin) and a narrow Frankston City Council reserve on the eastern edge of the corridor to Cranbourne-Frankston Rd. Beyond Pindara Boulevard, the corridor intersects a small parcel of land managed by Melbourne Water (part of the Boggy Creek Waterway Reserve) followed by a large reserve managed by Frankston City Council (i.e. Lloyd Park). South of Cranbourne-Frankston Rd several parcels of land area managed by Melbourne Water although most are owned by private landowners. From Union Rd the corridor intersects the Langwarrin Equestrian Centre Reserve managed by Frankston City Council and five smaller parcels managed by Melbourne Water. South of North Road to Langwarrin FFR (Parks Victoria managed), land is managed largely by private landowners with the exception of road reserves and the transmission line easement. A Trust for Nature property (70c North Road; approximately 4.5 hectares in size) also forms the northern-most section of the Langwarrin Flora and Fauna Reserve node.

Public land ownership/responsible authorities along the corridor route include:

Frankston City Council: Lexton Reserve, Little Boggy Creek Link, Boggy Creek Link, Lloyd Park, and road reserves

Parks Victoria: Pines Flora and Fauna Reserve and Langwarrin Flora and Fauna Reserve

Melbourne Water: Boggy Creek and Little Boggy Creek reserves and retarding basins including the ‘Little Boggy Creek Link’, ‘Boggy Creek Link-Langwarrin’, ‘Little Boggy Creek Retarding Basin’, and ‘Boggy Creek Waterway Reserve’ (6 separate parcels south of Cranbourne-Frankston Rd).

VicRoads: Cranbourne-Frankston Rd

Landholder and Community Groups

Friends groups including those for Langwarrin Flora and Fauna Reserve, the Pines Flora and Fauna Reserve, and Boggy Creek are likely to have a keen interest in the implementation of corridor C2 linking the Pines FFR and Langwarrin via Boggy Creek. The Royal Botanic Gardens Cranbourne has also expressed interest in linking the gardens with other large areas of habitat, such as Langwarrin FFR. A number of private landholders within the corridor alignment have also committed to restoration/conservation works on their properties, within the linking Langwarrin Woodland nodes, particular along the route of supplementary corridor S2.

6. CONCLUSION

Fragmentation of fauna habitats is often considered a major factor contributing to species and population declines across landscapes and has the potential to reduce ecosystem resilience to numerous stochastic events such as wildfire, droughts, climate change, and disease. Fragmentation and the invariably associated process of habitat isolation and decreasing patch size lead to smaller populations more vulnerable to local-extinction. Isolation of habitats does not allow the stabilising processes of metapopulation dynamics to function that may sustain several small populations of a species across a landscape. Immigration of surplus individuals from larger populations cannot occur to increase the size of smaller populations, effectively carrying them through times of resource shortages. Neither can re-colonization (immigration) of unoccupied habitats occur after threatening stochastic events such as wildfire or processes resulting in reduced habitat quality to the extent it is incapable of supporting a resident population for a period of time (e.g. droughts). As many species within the study area may function as a single metapopulation, the importance of managing all habitat, whether it is presently occupied by a species or not, is of vital importance. Maintaining and re-establishing connectivity among these remaining patches of habitat is also critical.

The restriction of dispersal and movement of animals across the landscape through poor habitat connectivity may also lead to poor outcomes for other groups of organisms and ecosystem function in general. Without animal-mediated dispersal, many plant species may suffer from seed dispersal limitation and reduced gene flow among populations. Recolonisation of new habitats by plants may also be severely impacted where animal seed disperser movement is restricted. Similarly, reduced movement of animal pollinators (insects, mammals, and birds) may lead to inbreeding within plant populations and/or lower fecundity (reproductive output). Insectivorous birds are important for maintaining insect populations and where excluded, forests and woodlands can suffer severe dieback of canopy tree species. A diverse assemblage of invertebrate predators is also important in regulating herbivorous insects implicated in severe pastoral dieback of eucalypts (Reid 1999). Vertebrate ground-dwelling animals and insects are also important for dispersing the fungal symbionts of plants (i.e. arbuscular mycorrhizal and ectomycorrhizal fungal species) which increase plant resistance to environmental stress. These are a few examples of the importance of maintaining landscape connectivity for fauna, and how reduced faunal movement can result in flow-on effects that reduce the resilience of the ecosystem.

Several studies within the study region have identified the need for improved connectivity of faunal populations and habitat (Cardinia Environment Coalition 2008; McCaffrey and Henry 2010; PPWCMA 2009). Additional studies have also identified threatened species that require improved habitat connectivity within the study area, principally the Southern Brown Bandicoot (DSE 2011, O'Malley 2010). Increasing urbanisation has previously been identified as a key threat within the study area.

To ameliorate poor existing connectivity and plan for future improvement, linkages have been proposed in previous studies and in the present study. A large number of linkages were assessed in the present study and prioritised according to conservation significance, as well as feasibility and opportunities for implementation. A large number of criteria were used to realistically represent the complex task of discriminating different options for providing connectivity to fauna populations. Several key corridor linkages were considered of higher priority for implementation, along with numerous patches of habitat for which recommended corridors provide connectivity for. The results were generally consistent with previous assessment of linkages within the study area (McCaffrey and Henry 2010). Parameters for linkages were provided and the steps required implementing them over the long-term. Additional recommendations identified actions that can be implemented to increase the overall permeability of land within Frankston to faunal movement, both inside and outside recommended faunal linkages.

Fauna crossing structures are an integral part of any plan for provisioning fauna with habitat connectivity, particularly in more urban environments such as that of the study area. Crossing structures not only facilitate improved connectivity among populations but also facilitate the functioning of ecosystem services (seed dispersal, pollination etc), reduce wildlife injury or mortality due to vehicle collisions, and similarly decrease the risk of human injury or death in such collisions. Fauna crossing structures were recommended for a large number of locations. Largely this reflects the peri-urban nature of the study area where numerous existing roads intersect important areas of faunal habitat. Also, it reflects a debt in the provision of wildlife crossing structures over a long period of time and the lack of consideration or knowledge when making planning decisions. The high densities of indigenous wildlife mortality within the study area likely reflect the combined effects of high traffic volume close to major areas of wildlife habitat and that many major roads intersect or run parallel to them. The implementation of fauna crossing structures was prioritised according to broad estimates of likely animal movement at locations combined with the likely threat to animals crossing identified barriers (i.e. roads). The timing of each crossing structure implementation should be guided by their recommended priority but also as opportunities arise to implement them through internal and external (public or private) projects. Different fauna crossing structure designs were identified that provide connectivity for different groups of fauna. For each, standard specifications, general maintenance requirements, and approximate costs were provided to guide implementation within asset renewal projects. Overall implementation of crossing structures is likely to be over a long-term period and be incremental and opportunistic in nature, largely due to the costs involved with servicing a large debt in the provision of such structures.

This study provides a long-term framework for the provision of faunal connectivity within the study area. A key task is the strategic implementation of linkages and associated on-ground actions in coordination with adjacent municipalities, government departments, other land manager organisations, and the broader community. A large proportion of the highest priority linkages are ones which provide landscape scale connectivity with large areas of fauna habitat outside the municipality. Consequently, Council should strongly pursue coordinated actions at the landscape scale, not just those largely within Frankston. Faunal populations and species do not recognize socio-political boundaries and their future persistence is reliant on actions undertaken at a scale at which they, and the ecosystem services they provide, function at.

7. GLOSSARY

Habitat link, biolink, link, linkage	The spatial arrangement of habitat, not necessarily linear or continuous, that enhances the movement of plants and animals or the continuity of ecological processes through the landscape (Beier, Majka and Spencer 2008; Bennett 2003; Crooks and Sanjayan 2006). This also includes other life forms such as fungi.
Habitat corridor, wildlife corridor	A linear strip of vegetation that provides a continuous (or near continuous) pathway between two habitats (Beier, Majka and Spencer 2008; Bennett 2003).The strip of vegetation is generally dissimilar to the surrounding landscape or matrix (Beier and Noss 1998).
Linkage	Areas of connectivity between habitat patches that encompass movement of processes and target or umbrella species (Beier *et al.* 2008).
Stepping stones	One or more separate patches of habitat in the intervening space between ecological isolates, that provide resources and refuge that may assist animals to move through the landscape (Bennett 2003).
Core area	This term has two applications. Firstly, the term is used in landscape ecology and environmental planning to define a large, mostly intact area of remnant native vegetation > 50 ha (DNRE 2000). Secondly, it is used to define habitats that functionally control population spatial structure (Martin et al. 2004).
Structural connectivity	Habitat features in a fragmented or heterogeneous landscape that physically link other features, especially when they link discrete areas of habitat occupied by a particular species or community (e.g. patches) (Bennett 1990; Doerr, Doerr and Davies 2010).
Functional connectivity	The degree to which organisms actually move through the landscape, especially between discrete areas of occupied habitat (e.g. patches) and especially for dispersal & gene flow (Doerr, Doerr and Davies 2010). This also encompasses ecological processes occurring through the landscape. The interaction between structural elements in a landscape and processes occurring within those elements (Tischendorf and Fahrig 2000)
Ecological connectivity	The degree to which or the ability of organisms and processes move through a landscape. This includes both terrestrial, aquatic and riparian elements and also things such as wind, water, fire and soil, plants and animals, ecosystems processes and interactions (Crooks and Sanjayan 2006; Lindenmayer 2007).
Habitat mosaic	Areas of habitat that are arranged patchily throughout a landscape (Bennett 2003).
Matrix	This term refers to the dominant landscape in which habitat patches are embedded (Forman 1995, Lindenmayer and Fischer 2006)
Landscape linkage	This is generally a large area of native vegetation which can be linear or non-linear and can span kilometres which contributes to connectivity at a landscape scale (Bennett 2003). Connectivity at a landscape scale has also been described as the amount by which a landscape facilitates or impedes movement between resource elements (Taylor et al. 1993).
Scale	The spatial or temporal facet in which the species or process occurs, described by both resolution and scope (Chetkiewicz, St. Clair and Boyce 2006).
Resistance to movement	The level to which a landscape facilitates movement of fauna i.e. an area of land with low resistance is one in which animals can move freely while a landscape

	with high resistance is one where animals are very unlikely to move through or be able to utilise.
Edge effects	Biotic and abiotic changes that are associated with an abrupt habitat boundary such as that created by habitat fragmentation. The portion of an ecosystem near its perimeter, where influences of the surroundings prevent development of interior environmental conditions (Forman 1995).
Urban sensitive/tolerant Species	relates to how tolerant or sensitive a species is to urbanisation.
Dispersal	Movement without immediate return from an area repeatedly traversed by an animal. In specific, used to refer to movement away from place of birth (natal dispersal) or breeding site (breeding dispersal).
Gap-crossing	Distance a species will attempt to cross a non-habitat matrix to reach another habitat patch. Research studies often involve experimental translocation of individuals and observations of behaviour post-release although radio-tracking has also been used.
Metapopulation	A metapopulation is a group of spatially separated populations which interact. Generally, a metapopulation encompasses several distinct populations in combination with patches of unoccupied suitable habitat. When considered alone each population could go extinct due to demographic or environmental (e.g. catastrophic fire, floods, drought etc) stochasticity. A metapopulation is stabilized by the effect of immigrants from other populations re-colonizing suitable habitat left open by population extinction or decline, the latter termed the 'rescue effect'. In combination with source-sink dynamics, metapopulation theory emphasizes the importance of connectivity between separated populations particularly in modified fragmented landscapes
Home range	An area repeatedly traversed by an animal in which it forages, reproduces, and nests.
Stability (population)	Absence of fluctuations in populations; the ability to withstand perturbations without large changes in composition or size.

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APPENDIX 1. Linkage Scale

Figure 30. Identified local and landscape scale corridor linkages. Shows all linkages used in the analysis and assessed against the criteria as detailed in APPENDIX 8.

APPENDIX 2. Linkage Priority, Values, and Recommended Parameters

Descriptions for recommended linkages ('Very High' and 'High' priority rank) and their recommended linkage parameters. For corridor linkages, recommended (i.e. desirable) corridor parameters are provided along with the average width attainable along the corridor route considering landscape context and permanent infrastructure. The column 'Form' denotes whether the linkage is a patch (=P) or corridor (=C) type linkage. See Section 8.2.3 for column 'Connectivity Type' definitions.

Linkage Identification			Location and type of linkage						Description of Biological Values and Threats			Corridor Parameters			Tenure
Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
'Very High' priority															
Linkages within Frankston															
12	012ECT	Frankston-Seaford Foreshore	Frankston	existing	C	Terrestrial corridor	Very High		Linear coastal linkage supporting varied habitat for fauna. A diverse range of habitats within the linkage with at least 8 EVCs present. Remnant vegetation within the linkage consists mostly of Coast Banksia Woodland/Coastal Dune Scrub Mosaic EVC as identified in Practical Ecology (2010). The foreshore is listed as a regionally significant biosite (DSE 2005).	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation, minor roads, major roads, and ecological inappropriate burning regimes.	>25m	>25m	>50m	Mostly Frankston City Council
28	028PCT	Langwarrin FFR to Frankston North Linkage	Frankston	potential	C	Terrestrial corridor	Very High		Southern extent supporting fragmented linear habitat adjacent to a freeway easement. Centre and northern sections running through larger habitat patches within a semi-rural landscape bordered by densely urban areas. A diverse range of habitats within the linkage with at least 8 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Habitat and structural connectivity provision for most terrestrial fauna guilds including semi-aquatic fauna along the northern section of linkage and for the southern section more non-ground-dwelling species such as birds, insects, and microbats.	Barriers to faunal movement and occupation include Peninsula Link (freeway), residential/commercial infrastructure, habitat fragmentation, and major roads, and minor roads.	>50m	>100m	southern section: >50m; northern section: >150m	VicRoads and also VLine
53	053PCT	Burdett's Quarry to Studio Park Link	Frankston	potential	C	Terrestrial corridor	Very High		Relatively high quality remnant vegetation fauna habitat with high structural complexity. Linkage also incorporates agricultural land and borders sand quarries. A diverse range of habitats within the linkage with at least 5 EVCs present. Indigenous vegetation principally composed of EVCs Heathy Woodland and Swampy Riparian Woodland.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals. High potential for habitat restoration and large corridor width.	Barriers to faunal movement and occupation include peri-urban residential infrastructure, habitat fragmentation, and minor roads.	>50m	>100m	>200m	Mostly private
59	059PCT	Seaford Wetlands to Melbourne Water Eastern Treatment Plant	Frankston	potential	C	Terrestrial corridor	Very High		Supporting varied aquatic and terrestrial habitats. Supports at least 4 EVCs. Remnant vegetation consisting mostly of EVCs Grassy Woodland and Brackish Wetland.	Habitat and providing structural connectivity for a large range of fauna groups. Landscape connectivity dependent on provision of freeway crossing structures for fauna.	Barriers to faunal movement and occupation include Peninsula Link (freeway), habitat fragmentation, and minor roads.	n/a	n/a	>200m	Mostly Frankston City Council but also Melbourne Water and crown land
303	303EPC	Langwarrin Flora & Fauna Reserve	Frankston	existing	P	Core areas (more fragmented)		Very High	Largely representing Langwarrin Flora and Fauna Reserve but also a Trust for Nature property (70c North Road). A large core area supporting high quality fauna habitat and a range of major habitats and microhabitats including hollow-bearing trees. There are a number of significant flora and fauna species listed recorded within the reserve and is listed as a State significant biosite (DSE 2005). Large high quality habitat with intact and relatively undisturbed ground-storey, mid-storey, and canopy habitat. A diverse range of habitats are supported within this linkage with at least 6 EVCs present. Remnant vegetation within the linkage consists mostly of Damp Heathy Woodland EVC.	Supporting habitat and providing structural connectivity for most fauna guilds.	Barriers to faunal movement and occupation include major freeway/highway barrier(s), major roads, ecological inappropriate burning regimes, excess fire trails, and increasing isolation due to urbanisation of surrounding land.				Mostly Parks Victoria
304	304EPC	Pines Flora & Fauna Reserve	Frankston	existing	P	Core areas (more fragmented)		Very High	Reserve with a number of significant flora and fauna species listed as a State significant biosite (DSE 2005). Recent records of Southern Brown Bandicoots in Venosta et al. (2008). The Frankston Bypass will dissect the habitats of the reserve. Large high quality habitat with intact and relatively undisturbed ground-storey, mid-storey, and canopy habitat. Supports a range of major habitats and microhabitats including hollow-bearing trees. A diverse range of habitats within the linkage with at least 8 EVCs present. Remnant vegetation within the linkage consists mostly of Sand Heathland EVC.	Supporting habitat and providing structural connectivity for most fauna guilds.	Barriers to faunal movement and occupation include major freeway/highway barrier(s), minor roads, ecological inappropriate burning regimes, excess fire trails, and increasing isolation due to urbanisation of surrounding land.				Mostly Parks Victoria but also VicRoads and crown land
375	375EPC	Pines Flora & Fauna Reserve Area – former Department of Agriculture and Rural Affairs (DARA) land	Frankston	existing	P	Core areas (more fragmented)		Very High	Large high quality habitat with intact and relatively undisturbed ground-storey, mid-storey, and canopy habitat. Supports a range of major habitats and microhabitats including hollow-bearing trees. A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Supporting habitat and providing structural connectivity for most fauna guilds. High potential for habitat restoration.	Barriers to faunal movement and occupation include major freeway/highway barrier(s), major roads, ecological inappropriate burning regimes, and increasing isolation due to urbanisation of surrounding land.				Mostly Parks Victoria
Linkages with adjoining municipalities															
2	002ECR	Balcombe Creek Landscape Linkage	Mornington	existing	C	Riparian corridor	Very High		A drainage line linkage that runs mostly through agricultural land with some scattered occurrences of remnant vegetation and terrestrial and aquatic fauna habitat Supports at least 4 EVCs.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects,	Barriers to faunal movement and occupation include agricultural land use activities, habitat fragmentation,	>50m	>100m	>200m	Mostly private but also Melbourne

Linkage Identification			Location and type of linkage						Description of Biological Values and Threats			Corridor Parameters			Tenure
Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
									Remnant vegetation within the linkage consists mostly of Swamp Scrub EVC.	arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	major roads, and minor roads.				Water
13	013PCT	Pines FFR to RBGC linkage	Frankston-Casey	potential	C	Terrestrial corridor	Very High		Existing remnants of Grassy Woodland and Swamp Scrub either side of road. Connections to Regional and State Biosites. Mostly direct ground-level linkages for ground-dwelling mammals, woodland birds, reptiles, amphibians etc. This part of Ballarto Rd was avoided for upgrade in due to the ecological values. Relatively high quality remnant vegetation fauna habitat with high structural complexity. Linkage also incorporates agricultural land and borders sand quarries. Several EVCs present, potentially up to nine present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals. Highly significant potential linkage providing connectivity among the two largest remaining patches of fauna habitat within the study area. High potential for habitat restoration, and large corridor width.	Barriers to faunal movement and occupation include the Peninsula Link (freeway), Dandenong-Hastings Rd/Western Port Hwy, peri-urban residential infrastructure, and habitat fragmentation, major roads, and minor roads.	>50m	>100m	>200m	Mostly private but also public road
14	014ECT	Mornington/Mount Eliza Foreshore Linkage	Mornington	existing	C	Terrestrial corridor	Very High		Linear coastal linkage supporting varied habitat for fauna. A diverse range of habitats within the linkage with at least 6 EVCs present. Remnant vegetation within the linkage consists mostly of Coastal Headland Scrub EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include residential/commercial infrastructure, habitat fragmentation, and minor roads.	>25m	>25m	>50m	Crown land
26	026PCT	North Frankston to northern ranges Linkage	Frankston-G Dandenong-Casey	potential	C	Terrestrial corridor	Very High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Indigenous vegetation principally composed of EVCs Heathy Woodland and Plains Grassland/Plains Grassy Woodland Mosaic.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Barriers to faunal movement and occupation include in-stream artificial barriers (e.g. weirs, dams), agricultural land use activities, habitat fragmentation, and major roads, and minor roads.	>50m	>100m	>200m	Mostly private but also crown land and Melbourne Water
34	034PCT	Westernport Bay Linkage	Casey-Mornington	potential	C	Terrestrial corridor	Very High		Important coastal habitats including intertidal and coastal saltmarsh habitats. Intersecting areas of very high quality fauna habitat of regional importance. Supports at least 4 EVCs. Remnant vegetation within the linkage consists primarily of Coastal Saltmarsh EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals. Highly significant regional linkage.	Barriers to faunal movement and occupation include habitat fragmentation, ecological inappropriate burning regimes, and ecological inappropriate burning regimes.	>25m	>100m	>200m	Mostly Parks Victoria
54	054PCT	South-west Foreshore Linkage	Mornington	potential	C	Terrestrial corridor	Very High		A linkage running through a predominantly agricultural landscape following a drainage line and intersecting a large node linkage in the east. Mostly riparian type habitats for aquatic and semi-aquatic fauna. A diverse range of habitats within the linkage with at least 6 EVCs present. Remnant vegetation consisting mostly of EVCs Grassy Woodland and Swamp Scrub.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Faunal movement and occupation restricted by agricultural land use activities, habitat fragmentation, and minor roads.	>50m	>100m	>200m	Mostly private but also Melbourne Water
79	079PCT	Baxter Park southward Linkage	Frankston-Mornington	potential	C	Terrestrial corridor	Very High		A linkage running through a predominantly agricultural landscape following a drainage line. Mostly riparian type habitats for aquatic and semi-aquatic fauna. Supports at least 4 EVCs. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Barriers to faunal movement and occupation include agricultural land use activities, habitat fragmentation, major roads, and minor roads.	>50m	>100m	>200m	Mostly private but also public road
81	081PCT	Southern Brown Bandicoot southward linkage	Casey	potential	C	Terrestrial corridor	Very High		Highly significant southward connection from the RGBC to large remnant patches along Western Port including Quail Island. Highly important for connecting populations of Southern Brown Bandicoot. Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Supports at least 4 EVCs. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include agricultural land use activities and habitat fragmentation.	>25m	>100m	>200m	Mostly private
82	082PCA	Southern Brown Bandicoot Sweetwattle Drive linkage	Casey	potential	C	Aquatic corridor	Very High		Additional linkage to highly suitable habitat for the Southern Brown Bandicoot along with other fauna. Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Potential habitat and connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include agricultural land use activities and habitat fragmentation.	>25m	>100m	>200m	Mostly private
83	083PCT	Yaringa to Quail Island and Warneet Node Linkage	Cardinia-Casey	potential	C	Terrestrial corridor	Very High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation and minor roads.	>50m	>100m	>200m	Mostly private but also Melbourne Water
88	088PCT	Southern Brown Bandicoot eastern linkage	Casey	potential	C	Terrestrial corridor	Very High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals. Highly significant linkage for connecting the RGBC population to those within the Koo Wee Rup region.	Barriers to faunal movement and occupation include agricultural land use activities, habitat fragmentation, and increasing isolation due to urbanisation of surrounding land.	>50m	>100m	>200m	Mostly private

Linkage Identification			Location and type of linkage						Description of Biological Values and Threats			Corridor Parameters			Tenure
Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
105	105PCA	Mount Eliza to Warneet Linkage	Casey-Mornington	potential	C	Aquatic corridor	Very High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Several EVCs present, potentially up to seven present, and representing a diverse range of fauna habitats Remnant vegetation present predominantly belonging to the EVCs Grassy Woodland and Swamp Scrub.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include Dandenong-Hastings Rd/Western Port Hwy, agricultural land use activities, and habitat fragmentation.	>25m	>100m	>200m	Mostly private but also crown land and Melbourne Water
106	106PCT	Mount Eliza south-east Linkage	Mornington	potential	C	Terrestrial corridor	Very High		A drainage line linkage that runs mostly through agricultural land with some scattered occurrences of remnant vegetation and terrestrial and aquatic fauna habitat Remnant vegetation consisting mostly of EVCs Grassy Woodland and Swamp Scrub.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Faunal movement and occupation restricted by agricultural land use activities and habitat fragmentation.	>50m	>100m	>200m	Crown land and also Melbourne Water
114	114PCT	Seaford Wetlands Linkage to Braeside Park Linkage	Frankston-G Dandenong-Kingston	potential	C	Terrestrial corridor	Very High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Remnant vegetation within the linkage consists mostly of Plains Grassy Wetland EVC.	Habitat and providing structural connectivity for a large range of fauna groups. Landscape connectivity dependent on provision of freeway crossing structures for fauna.	Barriers to faunal movement and occupation include Peninsula Link (freeway), agricultural land use activities, habitat fragmentation, major roads, and minor roads.	>50m	>100m	>200m	Crown land and also Melbourne Water
301	301EPC	Quail Island-Warneet	Casey	existing	P	Core areas (more fragmented)		Very High	Internationally-significant Ramsar-listed wetlands; highly intact vegetation types including Estuarine Scrub, Coastal Saltmarsh, Mangrove Shrubland, Heathy Woodland and Damp-sands Herb-rich Woodland. Large continuous high quality fauna habitat with intact ground-storey, mid-storey, and canopy habitat. Highly significant coastal habitat. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Coastal Saltmarsh EVC.	Supporting habitat and providing structural connectivity for most fauna guilds. Highly important habitat for the Southern Brown Bandicoot and overall very high quality habitat.	Barriers to faunal movement and occupation include habitat fragmentation, adjacent land use activities, and ecological inappropriate burning regimes.				Mostly Parks Victoria along foreshore, with private land incursions mostly near townships
302	302EPC	Royal Botanic Gardens Cranbourne	Casey	existing	P	Core areas (more fragmented)		Very High	State significant native vegetation and habitat with numerous EVCs including Sand Heathland, Heathy Woodland, Swamp Scrub, Sedge Wetland, Riparian Scrub and Grassy Woodland. Supports numerous significant flora and fauna species. Large high quality habitat with intact and relatively undisturbed ground-storey, mid-storey, and canopy habitat. Supports a range of major habitats and microhabitats including hollow-bearing trees. Supports at least 4 EVCs. Remnant vegetation within the RBGC consists predominantly of Heathy Woodland EVC although varied microhabitats are present within the linkage supporting varied habitat for fauna.	Supporting habitat and providing structural connectivity for most fauna guilds. Significant as stronghold for the threatened Southern Brown Bandicoot along with supporting numerous threatened species.	Barriers to faunal movement and occupation include major freeway/highway barrier(s), and increasing isolation due to urbanisation of surrounding land.				Mostly Royal Botanic Gardens but also Melbourne Water and crown land
High' priority															
Linkages within Frankston															
1	001ECR	Boggy Creek Link	Frankston	existing	C	Riparian corridor	High		Important native vegetation remnants. A number of national and state significant fauna species located along the creek. Contains two Sites of Biodiversity Significance (SOBS) by Melbourne Water and DSE Biosites. Identified by Melbourne Water as a potential linkage. High habitat quality identified in Marr et al. (2008). Highly modified vegetation in some sections, particularly upper reaches. Mid reaches of Boggy Creek contain the highest ecological values. However, lower and upper reaches are substantially modified and have much lower feasibility. A relatively wide riparian linkage running through both densely urban (centre) and some peri-urban landscapes to the north and south. Varied habitat for fauna along the linkage composed of canopy, mid-storey and groundstorey habitat. A diverse range of habitats within the linkage with at least 7 EVCs present. Indigenous vegetation principally composed of EVCs Heathy Woodland and Swampy Riparian Woodland.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include high-density urban infrastructure, habitat fragmentation, major roads, and minor roads, and peri-urban residential infrastructure.	>25m	>50m	south section (Cranbourne-Frankston Rd): >25m; northern: >50-100m	Melbourne Water
5	005ECR	Sweetwater Creek	Frankston	existing	C	Riparian corridor	High		Relatively wide riparian linkage through largely urban landscape. Habitat composed of canopy cover, aquatic habitats, some mid-storey and groundcover habitat. Provides connectivity between coastal habitats and Frankston reservoir. Several EVCs present, potentially up to nine present. Fragmented and modified remnants of Gully Woodland, Swamp Riparian Woodland, and Grassy Woodland EVCs along the watercourse with larger patches of Grassy Woodland at the south-eastern end near Frankston reservoir.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include in-stream artificial barriers (e.g. weirs, dams), high-density urban infrastructure, habitat fragmentation, and major roads, and minor roads.	n/a	n/a	>50m	Mostly Parks Victoria and also Melbourne Water
6	006ECR	Kananook Creek	Frankston	existing	C	Riparian corridor	High		Linear coastal linkage supporting varied habitat for fauna. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Coast Banksia Woodland / Swamp Scrub Mosaic EVC.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include in-stream artificial barriers (e.g. weirs, dams), habitat fragmentation, major roads, and minor roads, and ecological inappropriate burning regimes.	>25m	>50m	>100m	Mostly Frankston City Council but also Melbourne Water and crown land

Linkage Identification			Location and type of linkage						Description of Biological Values and Threats			Corridor Parameters			Tenure
Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
15	015ECR	Pines FFR to Studio Park Link	Frankston	existing	C	Riparian corridor	High		Important native vegetation remnants. A number of national and state significant fauna species occur along the creek. Links to the Tamarisk Waterway Reserve (SOBS) identified by Melbourne Water. High habitat quality identified in Marr et al. (2008). Relatively high quality remnant vegetation fauna habitat with high structural complexity. Linkage also incorporates agricultural land and borders sand quarries. A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Faunal movement and occupation restricted by peri-urban residential infrastructure, habitat fragmentation, major roads, and minor roads.	>50m	>100m	>200m	Crown land
24	024PCT	Pines FFR to Langwarrin FFR Stepping Stone Link	Frankston	potential	C	Terrestrial corridor	High		Heathy Woodland, Swamp Scrub and other remnants along the alignment route. Also includes the significant Willow Road Reserve wetlands and remnants along the rail reserve. Scattered and fragmented linear habitat running adjacent to a freeway easement under construction. A diverse range of habitats within the linkage with at least 6 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Potential for providing lower quality habitat and connectivity for birds, insects, arboreal mammals, microbats, and more urban-tolerant ground-dwelling fauna but dependent on provision of crossing structures for overcoming freeway barrier.	Barriers to faunal movement and occupation include Peninsula Link (freeway), residential/commercial infrastructure, habitat fragmentation, and major roads, and minor roads.	n/a	n/a	>25m (where feasible)	Mostly Melbourne Water but also VicRoads, VLine, public road and crown land
25	025PCT	Studio Park to Seaford Wetlands Stepping Stone Linkage	Frankston	potential	C	Terrestrial corridor	High		Linkage running largely through densely urban areas. Supports limited extant habitat values in the northern half and very high habitat values in the southern half. Provides connectivity between large habitat patches to the south and north. Several EVCs present, potentially up to nine present. Remnant vegetation consisting mostly of EVCs Heathy Woodland and Sand Heathland.	Potential for providing lower quality habitat and connectivity for birds, insects, arboreal mammals, microbats, and more urban-tolerant ground-dwelling fauna but dependent on provision of crossing structures for overcoming freeway barrier.	Barriers to faunal movement and occupation include Peninsula Link (freeway), habitat fragmentation, minor roads, and major roads.	south section: >50m	south section: >50m	south section: >100m; north section: >25m	Crown land but also Melbourne Water and VicRoads
61	061ECR	Sweetwater Creek	Frankston	existing	C	Riparian corridor	High		Riparian linkage through largely urban landscape. Habitat mostly in the form of canopy cover, aquatic habitats, some mid-storey and groundcover habitat. Supports at least 4 EVCs. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include habitat fragmentation and minor roads.	n/a	n/a	>50m	Mostly Parks Victoria
68	068PCT	Robinsons Park to 'Westerfield' property Linkage	Frankston	potential	C	Terrestrial corridor	High		Short linkage through urban parkland with current limited extant habitat values. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation consisting mostly of EVCs Lowland Forest and Valley Heathy Forest.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation and major roads.	>25m	>25m	>50m	Mostly Frankston City Council
70	070PCT	Boggy Creek to Stringybark Reserve Linkage	Frankston	potential	C	Terrestrial corridor	High		Varied habitat quality but canopy cover present and indigenous vegetation components present. A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation and minor roads.	n/a	n/a	>50m	Mostly Frankston City Council
92	092ECT	McClelland Dr/Mornington Railway Line (Langwarrin)	Frankston	existing	C	Terrestrial corridor	High		A significant roadside/railway (Mornington Railway Line) fauna habitat corridor with the greatest value in a canopy and mid-strata habitat component. Bordered by McClelland Drv, Peninsula Link Fwy and adjacent Langwarrin FFR. Provides connectivity between Langwarrin FFR and Mt Eliza Regional Park. Canopy and patchy understorey habitat present. A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Habitat and structural connectivity mostly for birds, insects, microbats, and arboreal mammals. Some potential use by urban tolerant reptile species and facilitating connectivity for ground-dwelling fauna between Langwarrin FF Reserve and adjacent nodes.	Barriers to faunal movement and occupation include habitat fragmentation, minor roads, and major roads.	>25m	>25m	>50m	Mostly crown road reserve
95	095PCT	Frankston-Seaford Foreshore to Kananook Creek Link-Gould Street	Frankston	potential	C	Terrestrial corridor	High		Connection between Frankston-Seaford Foreshore and habitat along Kananook Creek near the intersection of the Nepean Highway and Gould Street. Indigenous vegetation principally composed of EVCs Coast Banksia Woodland / Swamp Scrub Mosaic.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation, minor roads, and major roads.	n/a	n/a	>25m (where feasible)	Crown land
99	099ECT	Warrandyte Rd Link	Frankston	existing	C	Terrestrial corridor	High		Significant roadside fauna habitat with the greatest value in a canopy and mid-strata habitat component. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Mostly birds, insects, and arboreal mammals.	Faunal movement and occupation restricted by peri-urban residential infrastructure, habitat fragmentation, major roads, and minor roads.	n/a	n/a	>50m	Mostly Parks Victoria
306	306EPC	Seaford Wetlands	Frankston	existing	P	Core areas (more fragmented)		High	Seaford wetlands supporting various aquatic and terrestrial fauna habitats. A diverse range of habitats are present, constituting of mostly aquatic EVC. Remnant vegetation within the linkage consists mostly of Tall Marsh EVC.	Supporting habitat and providing structural connectivity for wetland birds, some aquatic fauna, semi-aquatic fauna including frogs, and a stepping stone for migratory wader bird species.	Barriers to faunal movement and occupation include major freeway/highway barrier(s), minor roads, and habitat fragmentation.				Mostly Frankston City Council but also Melbourne Water and crown land
319	319EPC	Burdett's Quarry and Gumnut Reserve (Langwarrin)	Frankston	existing	P	Core areas (more fragmented)		High	Core area contained largely within 'Burdett's Quarry' but also Gumnut Bushland Reserve (2.3 hectares). Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC, significant within Frankston by being one of the largest remaining areas supporting this habitat type. Also supports Swamp Scrub EVC remnants. Large relatively intact remnant vegetation fauna habitat with high structural complexity. Linkage also incorporates agricultural land and borders sand quarries. Several EVCs present within linkage, constituting varied habitat where remnant	Supporting habitat and providing structural connectivity for most fauna guilds.	Barriers to faunal movement and occupation include peri-urban residential infrastructure, habitat fragmentation, minor roads, and freeway/highway(s), and ecological inappropriate burning regimes.				Mostly private but also Melbourne Water

Linkage Identification			Location and type of linkage						Description of Biological Values and Threats			Corridor Parameters			Tenure
Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
									vegetation is present.						
323	323EPN	Bunarong Park	Frankston	existing	P	Nodes (more fragmented)		High	Remnant Heathy Woodland, Sand Heathland and Damp Heathy Woodland. Small to medium isolated habitat patch of mostly remnant vegetation. Moderate quality ground-storey habitat and relatively good quality mid-storey and canopy habitat. Supports at least 4 EVCs. Indigenous vegetation principally composed of EVCs Heathy Woodland and Sand Heathland.	Fragmentation tolerant species and more mobile fauna groups such as birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include peri-urban residential infrastructure, habitat fragmentation, and minor roads.				Mostly Frankston City Council
333	333EPN	Taylors Rd/Halls Rd Heathy Woodlands	Frankston	existing	P	Nodes (less fragmented)		High	Remnant Heathy Woodland and Swamp Scrub. Small to medium isolated habitat patch of mostly remnant vegetation. Moderate quality ground-storey habitat but good mid-storey and canopy habitat. Supports at least 4 EVCs. Indigenous vegetation principally composed of EVCs Damp Heathy Woodland and Heathy Woodland.	Supporting habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include peri-urban residential infrastructure, habitat fragmentation, and minor roads.				Mostly private
335	335EPSS	Centenary Park Golf Course	Frankston	existing	P	Stepping stone		High	Golf course supporting important hollow-bearing tree, canopy, and mid-storey habitat along with scattered occurrences of fragmented ground-storey habitat. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include major freeway/highway barrier(s) and habitat fragmentation.				Mostly Frankston City Council
336	336EPSS	Old Land Fill/Tip	Frankston	existing	P	Stepping stone		High	Fragmented fauna habitat with an intact remnant groundstorey present in isolated occurrences. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation and minor roads.				Mostly Frankston City Council
358	358EPN	Kananook Creek Reserve	Frankston	existing	P	Nodes (more fragmented)		High	Linear coastal linkage supporting varied habitat for fauna. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Coast Banksia Woodland / Swamp Scrub Mosaic EVC.	Fragmentation tolerant species and more mobile fauna groups such as birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include in-stream artificial barriers (e.g. weirs, dams), habitat fragmentation, major roads, and minor roads, and ecological inappropriate burning regimes.				Mostly Frankston City Council but also Melbourne Water, VLine and crown land
359	359EPN	Seaford Foreshore Reserve	Frankston	existing	P	Nodes (less fragmented)		High	Linear coastal linkage supporting varied habitat for fauna. A diverse range of habitats within the linkage with at least 6 EVCs present. Remnant vegetation within the linkage consists mostly of Coast Banksia Woodland/Coastal Dune Scrub Mosaic EVC.	Supporting habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include minor roads, habitat fragmentation, and ecological inappropriate burning regimes.				Mostly Frankston City Council
363	363EPC	Frankston Reservoir, Frankston South	Frankston	existing	P	Core areas (more fragmented)		High	Large high quality habitat patch with intact and relatively undisturbed ground-storey, mid-storey, and canopy habitat. Supports a range of major habitats and microhabitats including hollow-bearing trees. Several EVCs present, potentially up to nine present. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Supporting habitat and providing structural connectivity for most fauna guilds.	Barriers to faunal movement and occupation include peri-urban residential infrastructure, minor roads, and ecological inappropriate burning regimes.				Mostly Parks Victoria
365	365EPSS	Robinsons Park	Frankston	existing	P	Stepping stone		High	Small to medium isolated habitat patch of mostly remnant vegetation. Moderate quality ground-storey habitat but good mid-storey and canopy habitat. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Faunal movement and occupation restricted by habitat fragmentation and minor roads.				Mostly Frankston City Council but also crown land and VicRoads
372	372EPSS	Lloyd Park	Frankston	existing	P	Stepping stone		High	Small isolated habitat patch of mostly remnant vegetation on the northern end of Lloyd Park. Variable understorey habitat but good mid-storey and canopy habitat. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation and minor roads.				Mostly Frankston City Council
373	373EPSS	Lloyd Park	Frankston	existing	P	Stepping stone		High	Small isolated remnant on the southern end of Lloyd Park supporting fauna habitat largely within a densely urbanized landscape. Indigenous vegetation principally composed of EVCs Heathy Woodland and Swampy Riparian Woodland.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include peri-urban residential infrastructure and habitat fragmentation.				Mostly Frankston City Council
382	382EPSS	McClelland Drive Railway (south of Robinsons Road)	Frankston	existing	P	Stepping stone		High	Significant roadside fauna habitat with the greatest value in a canopy and mid-strata habitat component. Remnant vegetation within the linkage consists mostly of Valley Heathy Forest EVC.	Habitat and structural connectivity mostly for birds, insects, microbats, and arboreal mammals. Some potential use by urban tolerant reptile species.	Faunal movement and occupation restricted by habitat fragmentation and minor roads.	n/a	n/a	>25m (where feasible)	Mostly VLine but also public road and crown land
390	390EPN	Former KTRI (Keith Turnbull Research Institute) land	Frankston	existing	P	Nodes (more fragmented)		High	Area subject to intensive revegetation efforts. A diverse range of habitats within the linkage with at least 6 EVCs present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	Fragmentation tolerant species and more mobile fauna groups such as birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include major freeway/highway barrier(s), habitat fragmentation, and ecological inappropriate burning regimes.				Mostly Parks Victoria
423	423EPSS	McClelland Dr/railway/freeway reserve node	Frankston	existing	P	Stepping stone		High	Roadside patches of habitat with good canopy and mid-storey habitat. Supports at least 4 EVCs. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles,	Barriers to faunal movement and occupation include habitat fragmentation, minor roads, and				Mostly VLine but also public road and crown land

Linkage Identification			Location and type of linkage						Description of Biological Values and Threats			Corridor Parameters			Tenure
Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
										and a limited number of urban-tolerant ground-dwelling mammals.	major roads.				
433	433EPSS	Raphael Reserve	Frankston	existing	P	Stepping stone		High	Small to medium isolated habitat patch of mostly remnant vegetation. Moderate quality ground-storey habitat but good mid-storey and canopy habitat. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Faunal movement and occupation restricted by habitat fragmentation and minor roads.				Mostly Frankston City Council
434	434EPSS	Frankston Waterfront and Foreshore	Frankston	existing	P	Stepping stone		High	Small linear coastal remnant fauna habitat, largely within a densely urbanized landscape. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation consisting mostly of EVCs Coast Banksia Woodland and Coastal Dune Scrub.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Barriers to faunal movement and occupation include habitat fragmentation and minor roads.				Mostly Frankston City Council
Linkages with adjoining municipalities															
3	003ECR	Troups Creek	Casey	existing	C	Riparian corridor	High		A corridor running along Troups Creek from Hallam Main Drain to the foothills of Beaconsfield. Possibly small degraded remnants of Valley Grassy Forest EVC along this corridor although the EVCs Grassy Woodland, Grassy Forest, and Swamp Riparian Complex occur along the most eastern extent of the corridor extening into the foothills. Aquatic vegetation types also likely occur within constructed and natural wetlands along the corridor including just north of the MOnash Freeway.	Provides some habitat connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, and insects. Largely supporting aquatic habitats but also scattered riparian vegetation, particularly along the eastern-most extent of the corridor. Land to either side of Troups Creek has a relatively wide buffer of undeveloped land to either side along much of its length, although surrounding land use is intensive residential or commercial. Provides a linkage between a number of wetland habitats and between the lowlands and foothills.	Habitat fragmentation and loss but also minor and major roads	n/a	n/a	>25m (where feasible)	crown land
8	008ECT	Moorooduc Highway Linkage	Mornington	existing	C	Terrestrial corridor	High		A roadside linkage within a largely agricultural matrix and supporting fragmented linear remnant vegetation. Principle importance to fauna is the canopy habitat along this roadside linkage. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include agricultural land use activities and habitat fragmentation.	>25m	>25m	>50m	public road
18	018ECT	South-west (Mornington) Railway Linkage	Mornington	existing	C	Terrestrial corridor	High		Relatively continuous but narrow habitat linkage along the disused Mornington Railway Line. Combined with other linkages along the railway line, this corridor provides connectivity between Langwarrin FFR, Mt Eliza Regional Park, and to Tanti Creek riparian habitats. Tanti Creek connects eventually to a habitat corridor along Port Phillip foreshore corridor. A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include agricultural land use activities and habitat fragmentation.	>25m	>25m	>50m	Mostly VLine but also Melbourne Water
27	027PCT	North Frankston to Braeside Park Linkage	Frankston-G Dandenong-Kingston	potential	C	Terrestrial corridor	High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Supports at least 4 EVCs. Remnant vegetation within the linkage consists mostly of Plains Grassland/Plains Grassy Woodland Mosaic EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include agricultural land use activities, habitat fragmentation, major roads, and minor roads.	>50m	>100m	>200m	Mostly private and also crown land
31	031PCR	Yaringa to Devilbend Reservoir Linkage	Mornington	potential	C	Riparian corridor	High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Indigenous vegetation principally composed of EVCs Heathy Woodland and Swamp Scrub.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Barriers to faunal movement and occupation include Dandenong-Hastings Rd/Western Port Hwy, agricultural land use activities, and habitat fragmentation.	>25m	>25m	>50m	Mostly private
38	038PCT	Southward Langwarrin FFR Linkage	Frankston-Mornington	potential	C	Terrestrial corridor	High		Roadside fauna habitat linkages providing connectivity in the form of largely canopy habitat and connectivity north to south from large core fauna habitat. A diverse range of habitats within the linkage with at least 5 EVCs present. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include agricultural land use activities, habitat fragmentation, major roads, and minor roads.	>50m	>100m	>100m	public road and also VLine
39	039PCT	North-South Linkage (1)	Frankston-Mornington-Casey	potential	C	Terrestrial corridor	High		Linkage running largely through peri-urban to semi-rural landscape with scattered occurrences of remnant vegetation of varying quality. Principle extant fauna habitat is a canopy cover and mid-storey. At least ten (10) EVCs present, representing a diverse range of fauna habitats. Remnant vegetation consisting mostly of EVCs Grassy Woodland and Heathy Woodland.	Principally birds, microbats, insects, arboreal mammals, and to a limited extent some more mobile and urban tolerant ground-dwelling mammals and reptiles.	Barriers to faunal movement and occupation include the Dandenong-Hastings Rd/Western Port Hwy, agricultural land use activities, peri-urban residential infrastructure, and habitat fragmentation, and major roads, and minor roads.	>25m	>50m (where feasible)	peri-urban: >50m; agricultural: >150m	Mostly private but also Melbourne Water
40	040PCT	Langwarrin FFR to Sweetwattle Drive node Linkage	Frankston-Casey	potential	C	Terrestrial corridor	High		Linkage running largely through peri-urban to semi-rural landscape with scattered occurrences of remnant vegetation of varying quality. Principle extant fauna habitat is a canopy cover and mid-storey although some groundstorey habitat is present. A diverse range of habitats within the linkage with at least 5 EVCs	Principally birds, microbats, insects, arboreal mammals, and to a limited extent some more mobile and urban tolerant ground-dwelling mammals and reptiles.	Barriers to faunal movement and occupation include the Dandenong-Hastings Rd/Western Port Hwy, agricultural land use activities, peri-urban residential infrastructure, and	n/a	n/a	>50m	Mostly private

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Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
									present. Indigenous vegetation principally composed of EVCs Grassy Woodland and Heathy Woodland.		habitat fragmentation, and major roads, and minor roads.				
50	050PCT	Abotts Road Rodds Drain Linkage	Frankston-Greater Dandenong	potential	C	Terrestrial corridor	High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Remnant vegetation within the linkage consists mostly of Plains Grassland/Plains Grassy Woodland Mosaic EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include agricultural land use activities, habitat fragmentation, and major roads.	>50m	>100m	>200m	Mostly private
62	062ECA	Patterson River-Dandenong Creek Linkage	Kingston-Greater Dandenong	existing	C	Aquatic corridor	High		Important aquatic habitat linkage. Modified waterway but supporting habitat for aquatic and semi-aquatic fauna as well as wetland birds. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Indigenous vegetation principally composed of EVCs Heathy Woodland and Swampy Riparian Woodland.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include in-stream artificial barriers (e.g. weirs, dams), habitat fragmentation, major roads, and minor roads.	n/a	n/a	>50m	Mostly Melbourne Water but also crown land
77	077ECR	Watsons Creek Linkage	Frankston-Mornington	existing	C	Riparian corridor	High		Index of Stream Condition score of 'moderate'. Remnants of Grassy Woodland, Swamp Scrub and Heathy Woodland present. A drainage line linkage that runs mostly through agricultural land with some scattered occurrences of remnant vegetation and terrestrial and aquatic fauna habitat A diverse range of habitats within the linkage with at least 6 EVCs present. Remnant vegetation within the linkage consists mostly of Swamp Scrub EVC.	Potential habitat and connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where provision of habitat is relatively continuous and of greater width. Has high potential to provide a significant linkage between Frankston habitat patches and large, high quality fauna habitat along Western Port coast. High potential for habitat restoration, and a large corridor width.	Barriers to faunal movement and occupation include Dandenong-Hastings Rd/Western Port Hwy, agricultural land use activities, peri-urban residential infrastructure, habitat fragmentation, and major roads.	>25m	>100m	>200m	Mostly private but also Melbourne Water
78	078PCT	Baxter Park to Langwarrin FFR Linkage	Frankston-Mornington	potential	C	Terrestrial corridor	High		A linkage running through a peri-urban landscape and with limited extant fauna habitat values with the exception of intersections at node habitat patches. Supports at least 4 EVCs. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Potential for providing habitat and connectivity for a large range of fauna guilds dependent on whether freeway barrier is overcome. Otherwise, mostly of use to urban tolerant birds and possibly some microbat species.	Barriers to faunal movement and occupation include Peninsula Link (freeway), habitat fragmentation, minor roads, and major roads.	>50m	>50m	>150m	Mostly private but also Melbourne Water and VicRoads
93	093PCT	Nth-Sth Langwarrin Woodlands Linkage (1)	Frankston-Mornington	potential	C	Terrestrial corridor	High		Linkage running largely through peri-urban to semi-rural landscape with scattered occurrences of remnant vegetation of varying quality. Principle extant fauna habitat is a canopy cover and mid-storey although some groundstorey habitat is present. Several EVCs present, potentially up to seven present. Indigenous vegetation principally composed of EVCs Grassy Woodland and Heathy Woodland.	Principally birds, microbats, insects, arboreal mammals, and to a limited extent some more mobile and urban tolerant ground-dwelling mammals and reptiles.	Faunal movement and occupation restricted by peri-urban residential infrastructure, habitat fragmentation, major roads, and minor roads.	n/a	n/a	peri-urban: >50m; agricultural: >150m	Mostly private but also Melbourne Water
94	094PCT	Boggy Creek to Langwarrin Woodlands Linkage (2)	Frankston-Mornington	potential	C	Terrestrial corridor	High		Linkage running largely through peri-urban to semi-rural landscape with scattered occurrences of remnant vegetation of varying quality. Principle extant fauna habitat is a canopy cover and mid-storey although some groundstorey habitat is present. Several EVCs present, potentially up to seven present. Remnant vegetation consisting largely of EVCs Grassy Woodland and Heathy Woodland.	Principally birds, microbats, insects, arboreal mammals, and to a limited extent some more mobile and urban tolerant ground-dwelling mammals and reptiles.	Barriers to faunal movement and occupation include peri-urban residential infrastructure, agricultural land use activities, habitat fragmentation, and minor roads, and major roads.	n/a	n/a	peri-urban: >50m; agricultural: >150m	Mostly private but also Melbourne Water
104	104PCT	Frankston to Mornington Central Link	Mornington	potential	C	Terrestrial corridor	High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Faunal movement and occupation restricted by agricultural land use activities and habitat fragmentation.	>25m	>100m	>200m	Mostly private
107	107PCT	Langwarrin FFR to RBGC drain Linkage	Frankston-Casey	potential	C	Terrestrial corridor	High		A very narrow linkage running along a drainage line through both densely urban (west) and peri-urban to agricultural (east) landscapes. Limited present fauna habitat and where present riparian or semi-aquatic in nature. Several EVCs present, potentially up to seven present. Indigenous vegetation principally composed of EVCs Grassy Woodland and Heathy Woodland.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Barriers to faunal movement and occupation include Dandenong-Hastings Rd/Western Port Hwy, peri-urban residential infrastructure, habitat fragmentation, and major roads, and minor roads.	n/a	n/a	>25m (where feasible)	Mostly Melbourne Water but also Melbourne Water, VLine and crown land
111	111ECA	Pillars Rd Drain Link	Kingston	existing	C	Aquatic corridor	High		Linkage runs mostly through agricultural land with very limited and scattered occurrences of remnant vegetation Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Dominant EVCs include Plains Grassy Wetland, Plains Grassy Woodland and Swampy Riparian Woodland/Swamp Scrub Mosaic.	Important habitat and structural connectivity for aquatic and semi-aquatic (e.g. frogs) fauna but also birds, microbats, insects, arboreal mammals, and ground-dwelling mammals and reptiles where habitat is relatively continuous and of greater width.	Barriers to faunal movement and occupation include in-stream artificial barriers (e.g. weirs, dams), agricultural land use activities, and habitat fragmentation.	>50m	>100m	>200m	Mostly Melbourne Water but also Melbourne Water, public road and crown land
112	112ECR	Chelsea Heights Wetland Link	Kingston	existing	C	Riparian corridor	High		Limited remnant vegetation but important wetland and aquatic habitats. Remnant vegetation within the linkage consists mostly of Plains Grassy Wetland EVC.	Limited current utilisation but possible utilisation by more fragmentation tolerant fauna guilds including birds, insects, microbats, and arboreal mammals. Potential for improving to facilitate greater habitat potential for ground-dwelling fauna.	Faunal movement and occupation restricted by agricultural land use activities and habitat fragmentation.	>50m	>100m	>200m	Mostly Melbourne Water but also Melbourne Water and crown land

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Link ID#	ID-code	Name	LGA	Status	Form	Connectivity Type	Corridor Priority	Patch Priority	Description	Fauna use	Barriers	buffer	core	average width	Tenure within Linkage
327	327EPN	Coolart Rd node	Mornington	existing	P	Nodes (less fragmented)		High	Large Grassy Woodland remnant Small to medium isolated habitat patch of mostly remnant vegetation. Moderate quality ground-storey habitat but good mid-storey and canopy habitat. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Supporting habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Faunal movement and occupation restricted by agricultural land use activities and habitat fragmentation.				Mostly private
328	328EPN	Firth Road node	Mornington	existing	P	Nodes (less fragmented)		High	Small isolated habitat patch of mostly remnant vegetation. Highly variable understorey habitat but good mid-storey and canopy habitat. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Supporting habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Faunal movement and occupation restricted by agricultural land use activities and habitat fragmentation.				Mostly private
344	344EPC	Western Port coast-Yaringa	Mornington	existing	P	Core areas (more fragmented)		High	Large continuous high quality fauna habitat with intact ground-storey, mid-storey, and canopy habitat. Highly significant coastal habitat. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Heathy Woodland EVC and is generally of high quality.	Supporting habitat and providing structural connectivity for most fauna guilds.	Barriers to faunal movement and occupation include habitat fragmentation, adjacent land use activities, and ecological inappropriate burning regimes.				Mostly Parks Victoria
362	362EPN	Baxter Park	Frankston-Mornington	existing	P	Nodes (less fragmented)		High	Larger remnant vegetation fauna habitat patch providing a node linkage to larger habitat patches to the south. Several EVCs present within linkage, constituting varied habitat where remnant vegetation is present. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	Supporting habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Barriers to faunal movement and occupation include major roads and minor roads.				Mostly Frankston City Council
384	384EPSS	Water Reserve/Tyabb Bushland Reserve	Mornington	existing	P	Stepping stone		High	Small isolated habitat patch of mostly remnant vegetation. Highly variable understorey habitat but good mid-storey and canopy habitat. Indigenous vegetation principally composed of EVCs Grassy Woodland and Swamp Scrub.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Faunal movement and occupation restricted by habitat fragmentation and minor roads.				Parks Victoria and also crown land
397	397EPN	Bicentennial Park	Kingston	existing	P	Nodes (less fragmented)		High	Limited remnant vegetation but important wetland and aquatic habitats. Remnant vegetation within the linkage consists mostly of Plains Grassy Wetland EVC.	Supporting habitat and providing structural connectivity for wetland birds, some aquatic fauna, semi-aquatic fauna including frogs, and a stepping stone for migratory wader bird species.	Barriers to faunal movement and occupation include habitat fragmentation and adjacent land use activities.				Mostly Melbourne Water but also Melbourne Water and crown land
422	422EPSS	Kirton Reserve	Mornington	existing	P	Stepping stone		High	Small node habitat patch with possible remnant vegetation. Remnant vegetation within the linkage consists mostly of Grassy Woodland EVC.	A range of species but generally more mobile fauna groups including birds, insects, microbats, arboreal mammals, small reptiles, and a limited number of urban-tolerant ground-dwelling mammals.	Faunal movement and occupation restricted by habitat fragmentation and minor roads.				Crown land
427	427EPN	Watson Creek-Western Port Hwy node	Mornington	existing	P	Nodes (less fragmented)		High	Small to medium isolated habitat patch of mostly remnant vegetation. Moderate quality ground-storey habitat but good mid-storey and canopy habitat. Remnant vegetation present mostly consists of the EVCs Heathy Woodland and Swamp Scrub.	Supporting habitat and providing structural connectivity for a large range of fauna groups including birds, arboreal mammals, frogs, microbats, reptiles, insects, and ground-dwelling mammals.	Principle factor influencing faunal movement include low habitat availability and agricultural land use activities.				Mostly private

APPENDIX 3. Linkage Scores and Ranking

Table 7. Details of all linkages assessed including type, criteria scores, and priority ranking. Standardised scores for each of the criteria categories (conservation significance, feasibility, and opportunity) are illustrated in APPENDIX 4. Existing and proposed corridor are illustraded in Figure 5 and Figure 6 respectively. Patch linkages assessed are illustrated in Figure 34 (APPENDIX 5).

[a] refers to whether the linkage is an existing one (E) or a potential one (P)
[b] refers to the form of linkage i.e. whether it is a corridor (C) or patch (P) type linkage
[c] the major form of connectivity provision for each linkage within the landscape. See Section 8.2.3 for definition of categories.

					Individual Criteria Scores																							
					Conservation Significance							Feasibility								Opportunity				Standardised Score			Priority Rank Category	
Link #	Scale	Status[a]	Form [b]	Assessment Type[c]	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	Cons Sig.	Feas.	Opp.	Corridors	Patches
1	Local	E	C	Riparian	5	6	3	5	6	4	5	0	7	7	7	7	5	10	7	3	6	3	3	32	65	44	High	
2	Landscape	E	C	Riparian	10	10	3	10	9	2	5	0	4	2	3	0	3	9	6	0	4	3	3	64	89	29	Very High	
3	Landscape	E	C	Riparian	10	4	0	5	1	0	0	0	0	0	1	0	5	8	6	0	9	0	2	29	91	32	High	
4	Local	E	C	Riparian	3	1	2	9	6	4	3	0	5	6	10	9	7	10	7	0	1	1	1	23	55	9	Low	
5	Local	E	C	Riparian	5	2	2	9	7	10	4	0	4	5	7	9	5	9	8	6	8	5	3	34	48	65	High	
6	Local	E	C	Riparian	5	6	4	5	7	4	4	0	5	7	9	10	3	9	9	8	9	8	2	34	51	79	High	
7	Local	E	C	Aquatic	3	6	0	5	2	2	5	4	0	4	1	2	5	9	9	2	9	2	2	19	52	44	Medium	
8	Local	E	C	Terrestrial	8	10	0	7	2	0	2	0	4	2	2	1	5	2	5	0	0	0	3	40	83	9	High	
9	Local	E	C	Terrestrial	8	1	0	8	2	4	0	0	0	2	1	1	5	0	5	0	0	0	3	26	91	9	Medium	
10	Landscape	E	C	Terrestrial	1	4	0	7	1	4	2	0	4	2	2	1	4	2	6	0	1	0	2	12	66	9	Low	
11	Landscape	E	C	Terrestrial	1	1	6	7	2	4	2	0	4	3	1	1	5	2	3	0	0	0	2	12	69	6	Low	
12	Local	E	C	Terrestrial	5	10	4	7	7	2	4	0	0	2	2	2	2	2	7	7	8	8	4	44	83	79	Very High	
13	Landscape	P	C	Terrestrial	10	10	3	7	9	4	5	4	9	3	4	2	4	2	7	1	4	3	4	60	77	35	Very High	
14	Landscape	E	C	Terrestrial	3	10	6	7	5	0	4	0	0	0	3	2	4	2	6	0	8	5	2	36	84	44	Very High	
15	Local	E	C	Riparian	8	6	3	5	6	4	4	0	4	3	3	2	3	9	7	1	6	5	3	40	63	44	High	
16	Local	E	C	Aquatic	3	8	0	5	2	2	4	8	5	3	4	7	6	9	8	3	8	0	2	22	34	38	Medium	
17	Local	E	C	Terrestrial	8	6	3	8	2	4	3	0	4	2	2	1	4	2	7	1	3	3	3	39	70	29	Medium	
18	Landscape	E	C	Terrestrial	5	6	6	6	4	0	3	0	0	2	2	2	6	2	7	0	3	1	2	31	82	18	High	
20	Landscape	E	C	Terrestrial	1	4	0	6	3	4	4	6	0	2	2	1	5	2	6	0	1	0	3	14	49	12	Low	
21	Landscape	E	C	Terrestrial	5	2	0	5	1	2	3	0	1	6	7	7	8	2	5	0	0	0	1	15	45	3	Low	
22	Local	E	C	Terrestrial	8	0	0	5	2	4	0	0	0	2	1	1	5	0	3	0	0	0	4	19	78	12	Medium	
23	Landscape	E	C	Terrestrial	1	4	0	7	1	4	2	0	1	6	7	7	6	2	5	0	0	0	1	12	52	3	Low	
24	Landscape	P	C	Terrestrial	3	10	3	7	6	4	5	8	7	2	3	2	5	9	9	4	8	3	3	38	49	53	High	
25	Landscape	P	C	Terrestrial	3	10	3	6	8	4	5	10	8	4	5	4	7	9	10	3	8	3	4	44	6	53	High	
26	Landscape	P	C	Terrestrial	10	10	0	5	2	2	3	0	6	3	4	1	6	2	7	0	2	0	4	44	88	18	Very High	
27	Landscape	P	C	Terrestrial	10	10	3	4	2	2	3	4	6	3	4	1	6	2	7	0	5	0	5	44	81	29	High	
28	Landscape	P	C	Terrestrial	5	10	3	7	7	10	5	4	5	4	4	2	4	2	9	1	5	3	4	46	70	38	Very High	
31	Landscape	P	C	Riparian	10	6	0	6	2	4	2	0	0	2	3	1	4	1	6	0	2	2	4	38	94	24	High	
34	Landscape	P	C	Terrestrial	10	10	10	7	10	4	8	0	0	0	2	1	4	2	5	0	9	6	10	68	95	74	Very High	
38	Landscape	P	C	Terrestrial	5	10	3	8	2	10	2	0	8	3	3	1	4	2	8	1	2	2	3	40	73	24	High	
39	Landscape	P	C	Terrestrial	8	10	0	7	5	4	5	0	10	7	6	2	5	2	7	0	1	0	2	48	82	9	High	
40	Local	P	C	Terrestrial	3	10	3	7	4	4	3	0	6	4	5	2	5	2	7	1	2	2	3	34	73	24	High	
41	Landscape	P	C	Terrestrial	5	10	2	8	3	4	2	0	4	3	3	1	4	2	5	0	2	0	2	38	75	12	Medium	

					Individual Criteria Scores																							
					Conservation Significance							Feasibility								Opportunity				Standardised Score			Priority Rank Category	
Link #	Scale	Status[a]	Form [b]	Assessment Type[c]	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	Cons Sig.	Feas.	Opp.	Corridors	Patches
49	Landscape	P	C	Aquatic	4	10	0	5	1	2	2	0	6	1	2	0	5	9	3	0	0	0	5	26	81	15	Medium	
50	Landscape	P	C	Terrestrial	10	4	3	4	4	2	2	0	4	3	2	2	6	2	6	0	4	0	5	35	76	26	High	
53	Local	P	C	Terrestrial	8	10	0	8	2	4	2	0	0	3	2	1	3	2	6	0	2	0	4	44	84	18	Very High	
54	Local	P	C	Terrestrial	10	1	3	8	9	2	4	0	4	2	3	2	3	2	6	0	4	3	4	44	84	32	Very High	
55	Local	P	C	Terrestrial	1	10	2	7	4	4	2	8	6	3	4	7	7	4	7	2	3	0	2	27	21	21	Low	
57	Local	P	C	Terrestrial	1	10	0	7	3	4	2	0	0	4	4	1	6	2	5	2	2	2	1	25	71	21	Medium	
58	Local	P	C	Terrestrial	8	4	2	8	2	4	4	0	5	2	4	1	5	2	6	1	3	0	1	36	73	15	Medium	
59	Local	P	C	Terrestrial	10	6	4	6	4	2	6	4	0	2	2	2	6	3	7	7	9	6	3	47	64	74	Very High	
60	Local	E	C	Riparian	1	1	0	9	3	4	0	0	4	3	5	9	7	9	5	5	5	5	1	11	29	47	Medium	
61	Local	E	C	Riparian	5	2	2	9	6	10	3	0	0	3	3	10	5	8	6	5	5	5	1	32	8	47	High	
62	Landscape	E	C	Aquatic	3	8	0	5	4	0	4	0	4	0	3	0	5	9	7	0	10	0	3	24	87	38	High	
63	Local	P	C	Terrestrial	3	6	3	7	4	4	3	5	5	6	5	2	6	2	8	1	4	4	3	27	51	35	Medium	
64	Landscape	E	C	Aquatic	3	8	0	7	2	0	2	8	2	1	3	2	4	9	6	0	8	0	2	24	58	29	Medium	
65	Local	P	C	Terrestrial	1	2	2	6	2	4	0	0	0	6	2	1	9	4	5	4	4	3	1	8	37	35	Low	
66	Local	P	C	Terrestrial	1	2	2	7	3	2	2	0	0	6	2	1	8	1	6	4	7	3	1	11	46	44	Low	
67	Local	P	C	Terrestrial	3	2	0	0	3	4	2	0	0	2	2	6	5	9	5	5	5	0	2	4	34	35	Low	
68	Local	P	C	Terrestrial	8	2	0	7	3	4	0	0	4	0	1	2	6	4	6	7	6	0	3	28	66	47	High	
69	Local	P	C	Terrestrial	3	6	3	9	1	10	2	0	5	3	3	1	5	2	7	0	3	3	3	28	51	26	Low	
70	Local	P	C	Terrestrial	5	2	0	7	2	10	2	0	0	0	2	1	6	2	5	9	9	4	2	22	62	71	High	
71	Local	P	C	Terrestrial	1	6	2	5	2	2	3	0	0	3	3	1	9	2	7	7	8	2	1	14	36	53	Medium	
72	Local	P	C	Terrestrial	3	6	2	6	3	2	2	0	0	4	2	1	7	2	8	8	9	3	1	22	46	62	Medium	
73	Landscape	P	C	Terrestrial	8	8	0	7	2	4	2	0	4	2	2	1	6	2	3	0	0	0	2	38	56	6	Medium	
74	Landscape	E	C	Riparian	10	4	0	5	1	0	2	0	0	0	2	3	5	8	5	0	8	0	1	30	77	26	Medium	
75	Local	P	C	Riparian	3	6	3	5	1	4	0	0	4	2	2	0	4	9	5	0	2	2	2	18	50	18	Low	
76	Landscape	P	C	Terrestrial	5	10	0	7	1	4	2	0	4	0	2	1	5	2	5	0	2	0	2	33	70	12	Medium	
77	Landscape	E	C	Riparian	10	10	3	5	7	4	5	0	7	2	6	2	4	9	7	1	3	2	3	54	82	26	High	
78	Landscape	P	C	Terrestrial	5	10	3	8	4	4	2	6	7	2	3	2	4	1	9	5	6	3	4	40	59	53	High	
79	Landscape	P	C	Terrestrial	10	10	2	8	5	2	4	0	4	2	4	2	5	2	7	3	3	0	3	55	86	26	Very High	
81	Landscape	P	C	Terrestrial	10	10	3	5	4	4	5	0	0	2	3	2	6	2	6	0	3	2	5	50	87	29	Very High	
82	Landscape	P	C	Aquatic	10	10	0	7	1	2	0	0	0	0	2	0	4	9	3	0	0	0	8	44	88	24	Very High	
83	Landscape	P	C	Terrestrial	10	10	0	8	2	4	3	0	0	2	3	1	6	2	6	0	6	0	3	49	95	26	Very High	
88	Landscape	P	C	Terrestrial	10	10	3	8	3	4	3	0	0	0	2	2	6	2	5	0	3	3	3	53	86	26	Very High	
89	Local	P	C	Terrestrial	3	1	3	5	5	4	4	6	4	5	3	4	9	2	9	2	8	0	1	16	51	32	Medium	
90	Local	P	C	Terrestrial	1	2	3	5	4	4	5	6	0	3	2	5	8	2	7	1	7	0	2	12	27	29	Low	
91	Local	E	C	Terrestrial	1	4	2	8	3	10	3	0	6	6	5	1	5	2	6	0	1	0	1	20	77	6	Medium	
92	Local	E	C	Terrestrial	1	10	6	8	4	10	4	0	4	0	1	2	3	2	6	0	9	0	2	35	77	32	High	
93	Local	P	C	Terrestrial	5	4	0	8	3	4	4	0	6	3	5	2	5	2	6	4	4	2	1	28	75	32	High	
94	Local	P	C	Terrestrial	5	10	0	8	4	4	5	0	7	3	5	2	5	2	6	3	4	2	2	40	79	32	High	
95	Local	P	C	Terrestrial	1	4	2	7	3	2	0	0	4	2	1	1	3	0	6	7	8	5	4	13	71	71	High	
96	Local	P	C	Terrestrial	1	4	2	8	1	4	0	0	4	0	1	1	4	0	6	8	8	8	4	13	69	82	Medium	
97	Local	P	C	Terrestrial	1	6	2	7	3	4	5	0	4	7	5	1	8	2	8	5	6	5	2	21	19	53	Medium	

					Individual Criteria Scores																							
					Conservation Significance							Feasibility								Opportunity				Standardised Score			Priority Rank Category	
Link #	Scale	Status[a]	Form [b]	Assessment Type[c]	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	Cons Sig.	Feas.	Opp.	Corridors	Patches
98	Local	P	C	Terrestrial	1	4	2	7	3	2	0	0	4	2	1	1	4	0	6	8	8	8	4	13	66	82	Medium	
99	Local	E	C	Terrestrial	1	6	3	8	3	10	3	0	4	2	2	1	5	2	6	1	5	5	7	24	53	53	High	
100	Local	E	C	Terrestrial	1	4	0	8	1	10	2	0	0	3	2	1	6	1	3	0	0	0	1	15	65	3	Low	
101	Local	P	C	Terrestrial	1	2	2	6	2	4	0	0	0	10	5	1	7	4	7	8	8	4	2	8	52	65	Medium	
102	Local	P	C	Terrestrial	3	1	0	8	2	4	0	0	0	3	1	1	6	4	5	10	10	0	1	13	59	62	Medium	
103	Local	P	C	Terrestrial	1	2	2	7	2	4	0	0	6	6	3	1	8	4	7	3	3	3	1	9	22	29	Low	
104	Landscape	P	C	Terrestrial	10	10	0	9	1	4	0	0	0	2	2	0	5	2	3	0	0	0	4	48	95	12	High	
105	Landscape	P	C	Aquatic	5	10	3	6	4	4	4	5	0	2	5	2	6	2	7	0	6	1	3	38	87	29	Very High	
106	Landscape	P	C	Terrestrial	10	10	2	8	3	0	4	0	0	2	3	1	6	2	6	0	7	0	2	51	93	26	Very High	
107	Landscape	P	C	Terrestrial	3	8	3	6	6	4	5	0	6	8	3	2	7	2	9	2	7	2	2	32	78	38	High	
108	Local	P	C	Terrestrial	3	4	0	8	1	4	2	0	4	4	2	1	6	2	6	2	6	0	1	19	53	26	Medium	
109	Landscape	E	C	Riparian	10	8	0	5	3	4	2	0	0	2	2	0	4	9	6	0	1	1	4	41	80	18	Medium	
110	Local	P	C	Riparian	3	1	0	4	3	0	2	0	4	3	2	1	9	2	5	3	3	7	1	7	36	41	Low	
111	Landscape	E	C	Aquatic	3	8	0	4	2	0	2	0	0	0	1	0	5	9	6	0	10	0	3	18	89	38	High	
112	Landscape	E	C	Riparian	10	8	5	5	5	0	10	0	0	0	4	3	6	9	7	0	8	0	2	51	75	29	High	
113	Local	E	C	Terrestrial	3	6	0	7	1	4	2	0	0	2	2	1	5	2	4	2	2	2	2	28	66	24	Medium	
114	Landscape	P	C	Terrestrial	8	10	3	6	8	4	5	2	6	4	5	2	2	6	6	3	8	3	4	44	77	53	Very High	
301	Landscape	E	P	Core areas (more fragmented)	10	10	10	8	10	10	8	0	0	0	1	1	3	2	4	0	9	4	10	98	88	68		Very High
302	Landscape	E	P	Core areas (more fragmented)	10	10	6	9	10	10	6	0	0	1	2	1	3	3	4	0	10	9	7	96	83	76		Very High
303	Landscape	E	P	Core areas (more fragmented)	10	10	6	9	9	10	6	0	0	0	2	1	1	2	4	0	10	10	10	95	91	88		Very High
304	Landscape	E	P	Core areas (more fragmented)	10	10	6	9	9	10	6	3	0	0	1	1	2	2	4	0	10	9	8	95	83	79		Very High
306	Landscape	E	P	Core areas (more fragmented)	10	10	10	7	5	2	6	0	0	0	4	2	5	3	8	8	10	7	3	86	64	82		High
307	Landscape	E	P	Nodes (more fragmented)	6	8	0	7	2	4	2	0	5	2	5	1	6	1	6	1	1	0	1	49	58	9		Low
308	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	1	4	2	0	4	4	4	1	5	2	3	0	0	0	1	49	67	3		Low
309	Local	E	P	Nodes (less fragmented)	8	10	0	9	1	10	0	0	5	0	2	1	5	4	7	3	3	0	2	66	65	24		Medium
310	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	1	4	0	0	0	2	5	0	4	1	3	0	0	0	1	48	78	3		Medium
312	Landscape	E	P	Stepping stone-p	4	10	0	9	1	10	0	0	0	3	2	1	5	4	7	9	10	0	2	45	70	62		Medium
315	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	3	10	2	0	4	3	3	1	5	1	5	2	2	2	2	54	69	24		Medium
316	Landscape	E	P	Nodes (more fragmented)	6	8	4	8	4	4	4	0	0	2	2	2	5	2	3	0	0	0	3	57	77	9		Medium
317	Landscape	E	P	Nodes (more fragmented)	6	8	0	9	1	4	0	0	0	0	2	0	4	1	5	0	0	0	2	50	86	6		Medium
319	Landscape	E	P	Core areas (more fragmented)	10	10	0	9	8	4	2	0	0	2	3	1	3	2	7	2	2	0	5	84	77	26		High
320	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	1	10	2	0	4	4	6	1	5	2	6	0	2	0	1	51	57	9		Low
321	Landscape	E	P	Nodes (more fragmented)	6	8	2	9	3	10	2	0	4	5	5	1	4	2	6	0	1	0	1	57	62	6		Low
322	Landscape	E	P	Nodes (more fragmented)	6	8	5	6	3	4	4	6	0	3	2	1	6	2	8	7	7	7	3	53	51	71		Medium
323	Local	E	P	Nodes (more fragmented)	6	4	4	9	2	10	0	0	0	2	2	1	3	4	7	10	10	10	2	49	77	94		High
324	Landscape	E	P	Nodes (more fragmented)	6	4	0	7	1	4	2	0	4	0	1	1	5	2	6	0	0	0	5	41	74	15		Medium
327	Landscape	E	P	Nodes (less fragmented)	8	10	0	8	1	10	0	0	0	2	2	1	2	1	3	0	0	0	5	64	90	15		High
328	Landscape	E	P	Nodes (less fragmented)	8	10	0	9	1	10	0	0	0	2	2	0	4	2	5	0	0	0	3	66	83	9		High
333	Landscape	E	P	Nodes (less fragmented)	8	10	0	8	1	4	0	0	0	2	2	0	2	1	5	0	0	0	3	62	90	9		High
335	Landscape	E	P	Stepping stone-p	4	10	3	5	2	2	3	0	0	0	1	1	4	2	6	10	10	2	5	40	83	79		High
336	Landscape	E	P	Stepping stone-p	4	10	0	3	1	0	2	0	0	2	1	0	7	1	6	10	10	0	2	32	77	65		High

					Individual Criteria Scores																							
					Conservation Significance							Feasibility								Opportunity				Standardised Score			Priority Rank Category	
Link #	Scale	Status[a]	Form [b]	Assessment Type[c]	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	Cons Sig.	Feas.	Opp.	Corridors	Patches
337	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	4	10	3	0	5	4	3	2	6	2	8	5	6	3	1	56	55	44		Medium
338	Landscape	E	P	Stepping stone-p	4	10	0	7	1	10	0	0	0	0	2	1	6	0	6	0	10	0	2	41	77	35		Medium
342	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	1	4	4	0	5	4	3	1	5	2	5	0	1	0	1	51	65	6		Low
344	Landscape	E	P	Core areas (more fragmented)	10	10	10	9	10	10	8	0	0	2	3	1	2	2	5	0	7	6	4	100	83	50		High
345	Landscape	E	P	Nodes (less fragmented)	8	10	0	8	4	10	3	0	0	6	4	2	4	2	7	3	4	0	2	70	65	26		Medium
353	Landscape	E	P	Stepping stone-p	4	2	0	5	1	0	4	0	0	0	1	1	5	2	3	0	10	0	5	23	84	44		Medium
354	Landscape	E	P	Nodes (less fragmented)	8	10	0	3	2	0	5	0	0	0	2	1	6	2	7	0	10	0	4	56	72	41		Medium
355	Landscape	E	P	Nodes (less fragmented)	8	10	0	7	1	10	3	0	4	0	4	1	5	2	5	0	0	0	2	64	67	6		Medium
356	Landscape	E	P	Nodes (more fragmented)	6	8	0	9	1	4	0	0	0	2	4	0	4	1	3	0	0	0	2	50	81	6		Medium
357	Landscape	E	P	Nodes (less fragmented)	8	10	0	5	1	2	0	0	0	0	1	0	5	0	3	0	0	0	2	56	90	6		Medium
358	Landscape	E	P	Nodes (more fragmented)	6	6	4	8	7	10	5	0	5	9	9	2	3	2	9	9	10	9	2	60	41	88		High
359	Landscape	E	P	Nodes (less fragmented)	8	10	4	9	7	4	4	0	0	8	4	2	0	2	7	10	10	9	5	77	75	100		High
360	Landscape	E	P	Stepping stone-p	4	6	0	5	1	4	2	0	0	2	2	1	6	2	4	0	1	0	4	30	75	15		Low
361	Local	E	P	Stepping stone-p	4	6	4	10	2	10	0	0	0	3	2	1	4	4	6	9	9	9	1	44	75	82		Medium
362	Landscape	E	P	Nodes (less fragmented)	8	10	0	8	4	4	0	0	5	4	2	1	3	1	7	8	8	2	5	66	72	68		High
363	Landscape	E	P	Core areas (more fragmented)	10	10	4	8	7	4	3	0	0	4	3	2	4	2	9	4	9	3	6	85	67	65		High
364	Local	E	P	Stepping stone-p	4	6	0	8	3	10	2	0	0	3	4	1	6	1	6	4	4	0	2	40	67	29		Low
365	Local	E	P	Stepping stone-p	4	4	0	9	4	10	0	0	0	2	2	2	3	0	6	10	10	2	3	38	81	74		High
366	Local	E	P	Stepping stone-p	4	2	0	8	1	10	0	0	0	3	2	1	5	4	6	10	10	0	1	29	72	62		Medium
367	Local	E	P	Stepping stone-p	4	2	0	0	1	4	0	0	0	0	1	0	8	4	5	9	10	0	2	13	72	62		Medium
368	Landscape	E	P	Stepping stone-p	4	6	0	8	1	0	0	0	0	2	2	1	6	4	5	10	10	0	1	32	71	62		Medium
369	Landscape	E	P	Stepping stone-p	4	10	0	9	1	10	0	0	0	0	2	1	2	1	3	0	0	0	2	45	91	6		Medium
370	Landscape	E	P	Nodes (less fragmented)	8	10	4	8	9	2	4	0	4	2	3	2	3	2	6	0	3	5	4	77	70	35		Medium
371	Local	E	P	Stepping stone-p	4	2	0	5	1	4	0	0	0	2	2	0	7	4	5	9	9	0	2	22	71	59		Medium
372	Landscape	E	P	Stepping stone-p	4	2	0	9	1	2	0	0	0	2	2	0	4	0	6	10	10	0	3	28	84	68		High
373	Landscape	E	P	Stepping stone-p	4	2	0	9	2	4	2	0	0	0	1	1	5	2	5	10	10	0	3	31	81	68		High
374	Landscape	E	P	Nodes (less fragmented)	8	10	2	8	2	4	2	0	0	3	3	1	4	2	7	3	6	0	2	66	73	32		Medium
375	Landscape	E	P	Core areas (more fragmented)	10	10	6	9	7	10	5	0	0	0	2	1	1	2	4	1	10	10	6	91	91	79		Very High
376	Landscape	E	P	Stepping stone-p	4	10	0	8	1	10	0	0	0	0	2	1	5	0	6	0	9	0	2	43	80	32		Medium
377	Landscape	E	P	Stepping stone-p	4	2	0	9	1	4	0	0	0	3	1	0	8	0	5	2	2	0	1	29	76	15		Medium
378	Landscape	E	P	Stepping stone-p	4	2	0	0	1	2	2	0	0	2	1	1	8	1	5	4	4	0	2	14	72	29		Low
379	Landscape	E	P	Stepping stone-p	4	2	0	5	1	4	0	0	0	4	3	0	10	0	6	3	3	0	1	22	62	21		Low
380	Landscape	E	P	Stepping stone-p	4	10	3	10	1	10	0	3	0	0	2	1	3	4	8	4	4	0	1	49	68	26		Medium
381	Landscape	E	P	Nodes (less fragmented)	8	10	3	9	1	10	0	0	0	3	3	1	4	4	5	1	1	0	2	68	73	12		Medium
382	Landscape	E	P	Stepping stone-p	4	10	6	10	1	10	0	0	0	0	1	0	3	0	3	0	10	0	2	51	96	35		High
383	Landscape	E	P	Stepping stone-p	4	6	6	9	1	10	0	0	0	2	1	0	5	0	3	0	0	0	1	42	88	3		Medium
384	Landscape	E	P	Stepping stone-p	4	8	0	8	2	10	2	0	0	2	2	1	3	2	5	0	8	8	2	42	83	53		High
385	Landscape	E	P	Stepping stone-p	4	6	0	8	1	10	0	0	0	2	2	0	5	2	3	0	0	0	2	36	83	6		Medium
386	Landscape	E	P	Stepping stone-p	4	10	0	8	1	4	5	0	4	0	2	1	3	2	6	0	1	0	2	44	77	9		Medium
387	Landscape	E	P	Stepping stone-p	4	10	0	8	2	4	3	0	0	0	2	1	4	2	5	0	2	0	1	44	81	9		Medium
388	Local	E	P	Stepping stone-p	4	2	0	0	1	0	2	0	0	0	1	1	7	2	3	0	0	10	2	13	78	35		Medium

					Individual Criteria Scores																							
					Conservation Significance							Feasibility								Opportunity				Standardised Score			Priority Rank Category	
Link #	Scale	Status[a]	Form [b]	Assessment Type[c]	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	Cons Sig.	Feas.	Opp.	Corridors	Patches
389	Local	E	P	Stepping stone-p	4	2	4	7	1	4	2	0	0	4	3	1	5	2	7	9	9	9	1	29	70	82		Medium
390	Landscape	E	P	Nodes (more fragmented)	6	10	3	5	5	4	4	3	0	0	2	1	4	2	6	7	10	7	5	56	71	85		High
392	Landscape	E	P	Nodes (less fragmented)	8	10	6	8	3	2	2	0	0	0	2	1	4	2	6	0	1	0	2	69	80	9		Medium
397	Landscape	E	P	Nodes (less fragmented)	8	10	10	7	4	0	10	0	0	0	2	1	6	3	7	0	10	0	2	76	71	35		High
403	Landscape	E	P	Stepping stone-p	4	2	0	7	2	10	2	0	0	4	3	1	8	2	5	9	9	0	1	30	64	56		Low
404	Landscape	E	P	Stepping stone-p	4	2	0	9	1	0	2	0	0	3	2	1	8	2	5	10	10	0	1	29	67	62		Low
405	Landscape	E	P	Stepping stone-p	4	6	0	8	1	10	0	0	0	4	2	0	5	0	6	9	9	0	2	36	80	59		Medium
422	Landscape	E	P	Stepping stone-p	4	6	0	9	2	0	0	0	0	2	1	1	4	0	5	0	7	8	2	35	86	50		High
423	Landscape	E	P	Stepping stone-p	4	10	3	8	3	10	5	0	0	0	1	1	3	2	6	0	7	0	3	51	86	29		High
424	Landscape	E	P	Nodes (more fragmented)	6	8	2	8	4	10	3	0	7	6	8	2	5	2	6	2	2	1	1	57	42	18		Medium
425	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	2	10	3	0	0	4	5	1	4	2	3	0	0	0	1	53	72	3		Medium
426	Landscape	E	P	Nodes (more fragmented)	6	8	0	9	1	10	0	0	4	2	3	0	5	2	3	0	0	0	1	52	74	3		Medium
427	Landscape	E	P	Nodes (less fragmented)	8	10	0	9	1	10	2	0	0	0	1	0	1	1	3	0	0	0	3	67	100	9		High
428	Landscape	E	P	Nodes (less fragmented)	8	4	0	9	1	10	0	0	0	0	2	1	3	1	3	0	0	0	3	55	88	9		Medium
429	Landscape	E	P	Nodes (more fragmented)	6	8	0	8	1	10	0	0	0	0	2	0	4	1	3	0	0	0	2	50	88	6		Medium
431	Local	E	P	Stepping stone-p	4	2	0	5	4	10	0	0	0	0	1	1	7	4	5	10	10	0	1	27	72	62		Medium
432	Local	E	P	Stepping stone-p	4	2	0	8	1	10	0	0	0	0	1	0	7	4	5	10	10	0	1	29	75	62		Medium
433	Local	E	P	Stepping stone-p	4	2	0	7	1	0	0	0	0	2	1	0	6	0	5	10	10	0	1	24	83	62		High
434	Landscape	E	P	Stepping stone-p	4	10	0	9	1	0	2	0	0	0	1	0	6	1	3	10	10	0	1	43	86	62		High
435	Landscape	E	P	Stepping stone-p	4	10	4	3	1	0	0	0	0	0	6	1	2	0	6	0	9	0	3	34	77	35		Medium
436	Landscape	E	P	Stepping stone-p	4	10	4	5	2	0	2	0	0	0	3	1	7	2	7	0	6	0	4	40	67	29		Low
437	Landscape	E	P	Stepping stone-p	4	6	0	3	1	2	3	0	0	10	10	1	8	2	7	1	1	0	5	26	36	21		Low
438	Landscape	E	P	Stepping stone-p	4	6	3	4	2	0	8	0	0	0	1	1	6	3	5	0	10	0	4	34	77	41		Medium
439	Landscape	E	P	Stepping stone-p	4	4	0	7	2	2	3	0	0	2	2	1	5	2	5	0	0	0	3	31	77	9		Low
440	Landscape	E	P	Stepping stone-p	4	10	0	6	2	0	3	0	4	5	5	1	8	2	7	4	7	3	1	39	49	44		Medium
441	Local	E	P	Stepping stone-p	4	2	0	0	1	2	0	0	4	2	1	0	7	4	5	9	9	0	3	12	68	62		Medium
442	Landscape	E	P	Nodes (more fragmented)	6	8	6	4	7	2	9	3	0	2	3	2	6	3	7	0	10	0	6	58	55	47		Medium
443	Landscape	E	P	Stepping stone-p	4	2	0	5	1	2	2	0	0	0	1	0	7	1	5	0	0	0	5	22	80	15		Medium
444	Landscape	E	P	Stepping stone-p	4	2	0	6	1	2	2	0	0	0	2	1	5	2	3	0	0	0	5	24	81	15		Medium
445	Landscape	E	P	Stepping stone-p	4	2	0	7	1	4	2	0	0	0	2	1	5	2	6	0	8	0	3	26	77	32		Medium
446	Local	E	P	Stepping stone-p	4	2	0	4	2	2	0	0	4	3	1	1	7	4	5	10	10	0	3	20	64	68		Medium

APPENDIX 4. Linkage value based on conservation significance, feasibility, and opportunity

Linkages were assessed for their conservation significance, feasibility in implementing, and level of existing opportunity for implementation. Scoring was comparative and relative only to one another within the study area extent. The methods employed successfully differentiated a large number (n=187) of existing and proposed linkages within the investigation area based on the three criteria categories. Below are summaries of main analysis results. Scores for all linkages assessed are given in APPENDIX 3.

Conservation Significance

All core area linkages attained scores in the highest conservation significance category (70-100; Fig. 5). These included Quail Island-Warneet, Yaringa, RBG Cranbourne, Langwarrin Flora and Fauna Reserve, The Pines Flora and Fauna Reserve (including the former DARA land patch), Frankston Reservoir, and Seaford Wetlands. Variation was greater for node type linkages. Nodes of highest conservation significance included Frankston-Seaford Foreshore and Chelsea Heights/Aspendale Garden wetlands (ID #397). The Langwarrin Woodlands (ID# 424 and 425), Boggy Creek nodes (ID # 345, 355, and 374), Melbourne Water's Eastern Treatment Plant, Studio Park, and the DPI Keith Turnbull Research Institute farm (ID# 390) were amongst the larger sized higher scoring nodes. Of stepping stone patch linkages, golf courses and nodes incorporating riparian habitats attained the highest conservation significance.

Corridor linkages of highest conservation significance included a proposed linkage (ID #13) connecting The Pines FFR and Boggy Creek nodes to the Royal Botanic Gardens Cranbourne core area, the Watson Creek linkage (ID#77) connecting Langwarrin FFR to Yaringa and other Western Port core areas, and linkages (ID# 422, 106, 8, 79, and 2) connecting Frankston core areas to ones south in the Mornington Peninsula (i.e. Mount Eliza Regional Park). Lowest scoring linkages were generally within the stepping stone corridor linkage or adjacent to roadsides.

It is important to consider that both existing and proposed linkages are compared in this analysis and consequently, existing linkages may have a much higher significance when considered alone as they comprise the only current structural connectivity within the landscape. For example, roadside corridors generally attained low scores, but in many cases they comprise the only existing structural connectivity on public land and therefore are of current high significance. The reader is referred to the objective of comparing linkages based on future investment and conservation priority in providing structural connectivity among fauna habitats.

Feasibility

Most core areas attained high feasibility scores and were generally of higher feasibility than node linkages or stepping stones (Fig. 6). The Langwarrin FFR, Quail Island-Warneet, and the Pines FFR (former DARA land section ID # 375) core areas were amongst the highest scoring. Node linkages achieving a high feasibility included Studio Park, an un-named node on private land in Baxter (ID # 327), Frankston-Seaford Foreshore Reserves, Boggy Creek (ID# 374), Craig Rd-Devon Meadows (ID# 357), smaller nodes in Cranbourne South (ID# 317), Pearcedale (ID# 429), Skye (ID# 333), and within the Eastern Treatment Plant land (ID# 353). The Burdett Quarry patch linkage (ID# 319), along with nodes in proximity to the Watson Creek corridor linkage in Somerville (ID # 427-428), also attained relatively high feasibility scores. Generally, larger node or stepping stone linkages with higher levels of parcel subdivision exhibited lower feasibility. Consequently, many of the golf course stepping stone linkages attained equivalent feasibility scores to node type linkages. Feasibility scores of a small number of core areas and less fragmented node patches on public land are likely underestimated due to artificial characteristics such as being segmented into numerous parcels when in fact these distinctions are unimportant as they generally have the same zoning (i.e. PCRZ) and are managed under a single public agency.

Corridor linkages having the highest feasibility of implementation based on the analysis undertaken included several southward running routes intersecting Mount Eliza Regional Park and one potential linkage running directly south and providing connectivity between Langwarrin FFR and Devilbend Reservoir. All these linkages provide connectivity between Frankston core areas and nodes with large core area fauna habitat in Mornington. High feasibility corridor linkages to the north of Frankston included Eel Race Drain, Pillars Road Drain (linkage to Braeside Park and wetlands to the south) and one linkage connecting north Frankston to Dandenong core areas (ID# 26). Higher feasibility linkages connecting Frankston core areas to one ones directly east in Casey included the Pines-Burdett's Quarry-RBGC linkage (ID# 13) and a narrow corridor along Melbourne Water land in Langwarrin (ID # 107). Linkages connecting the RBGC to other fauna habitat patches east and south all scored high on feasibility, as did corridor linkages connecting patches along the Western Port coast. Local-scale linkages connecting several node and core area patches in the Boggy Creek area all achieved a relatively high feasibility score, most likely due to a comparatively lower level of current urbanization and associated lower density of permanent infrastructure in this area. Generally, there was marked distinction in the feasibility scores of corridor linkages east and west of the Peninsula Link Freeway (under construction), with ones to the west in more highly urbanised environments achieving much lower feasibility scores. An exception to this rule was the coastal corridor linkages incorporating Frankston-Seaford Foreshore.

Opportunity

Patterns exhibited in opportunity scores for patch linkages (Fig. 7) included:

i) public owned core area and node linkages managed for conservation purposes (i.e. RBGC, The Pines Flora and Fauna Reserve Area, Langwarrin FFR, Seaford Wetlands, Frankston-Seaford Foreshore Reserves and Kananook Creek Reserve) generally scoring the highest opportunity scores,

ii) lower opportunity scores on private land and on public land managed for non-conservation purposes, and

iii) lower opportunity for Frankston City Council to implement linkages outside the municipality.

Habitat patches within the Melbourne Water's Eastern Treatment Plant, Frankston Reservoir, and the Frankston City Council managed Baxter Park also attained high opportunity scores, largely driven by being under public authority management.

Corridor linkages of note which attained a high opportunity score (Fig. 7) include the Frankston-Seaford Foreshore and Kananook Creek linkages (ID# 12 and 6 respectively), Pines-Burdett's Quarry-RBGC linkage (ID# 13), a narrow corridor along Melbourne Water land in Langwarrin (ID# 107), a linkage between Langwarrin FFR and Baxter Park (ID# 78), Boggy Creek linkages (ID# 1 and 16), Studio Park to Seaford Wetlands stepping stone linkage (ID# 25), Sweetwater Creek linkage between Frankston Reservoir and Frankston-Seaford Foreshore, and the Western Port coast linkage (ID# 34). A short linkage (ID# 72) connecting Seaford Wetlands to both Kananook Creek Reserve and Frankston-Seaford Foreshore also attained a high opportunity score.

Figure 31. Conservation Significance Scores for linkages. Higher scores (0-100) represent greater conservation significance of a linkage.

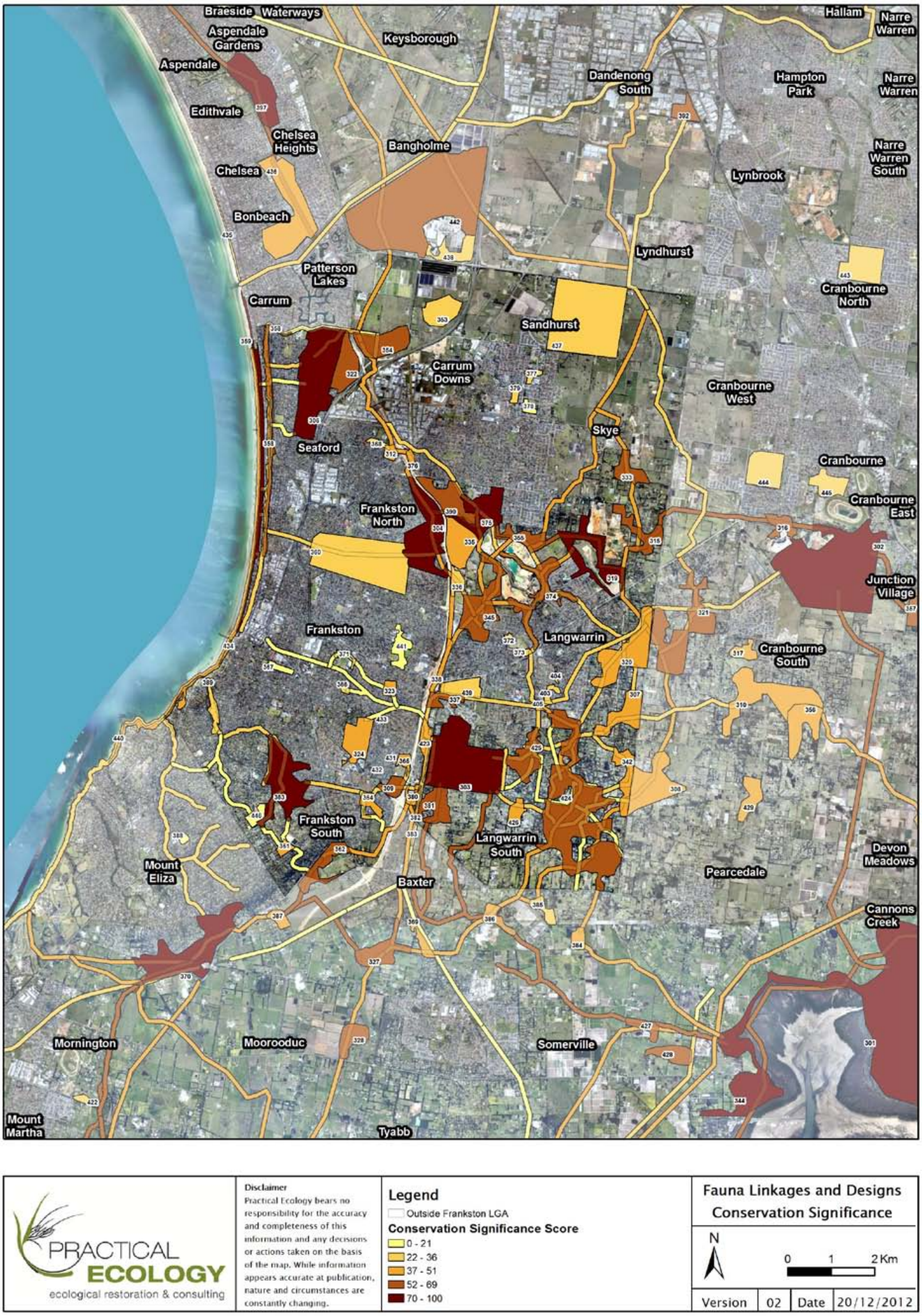


Figure 32. Feasibility scores for existing and proposed linkages. Higher scores (0-100) represent greater feasibility of implementing a linkage and/or managing for conservation purposes as part of a habitat linkage network.

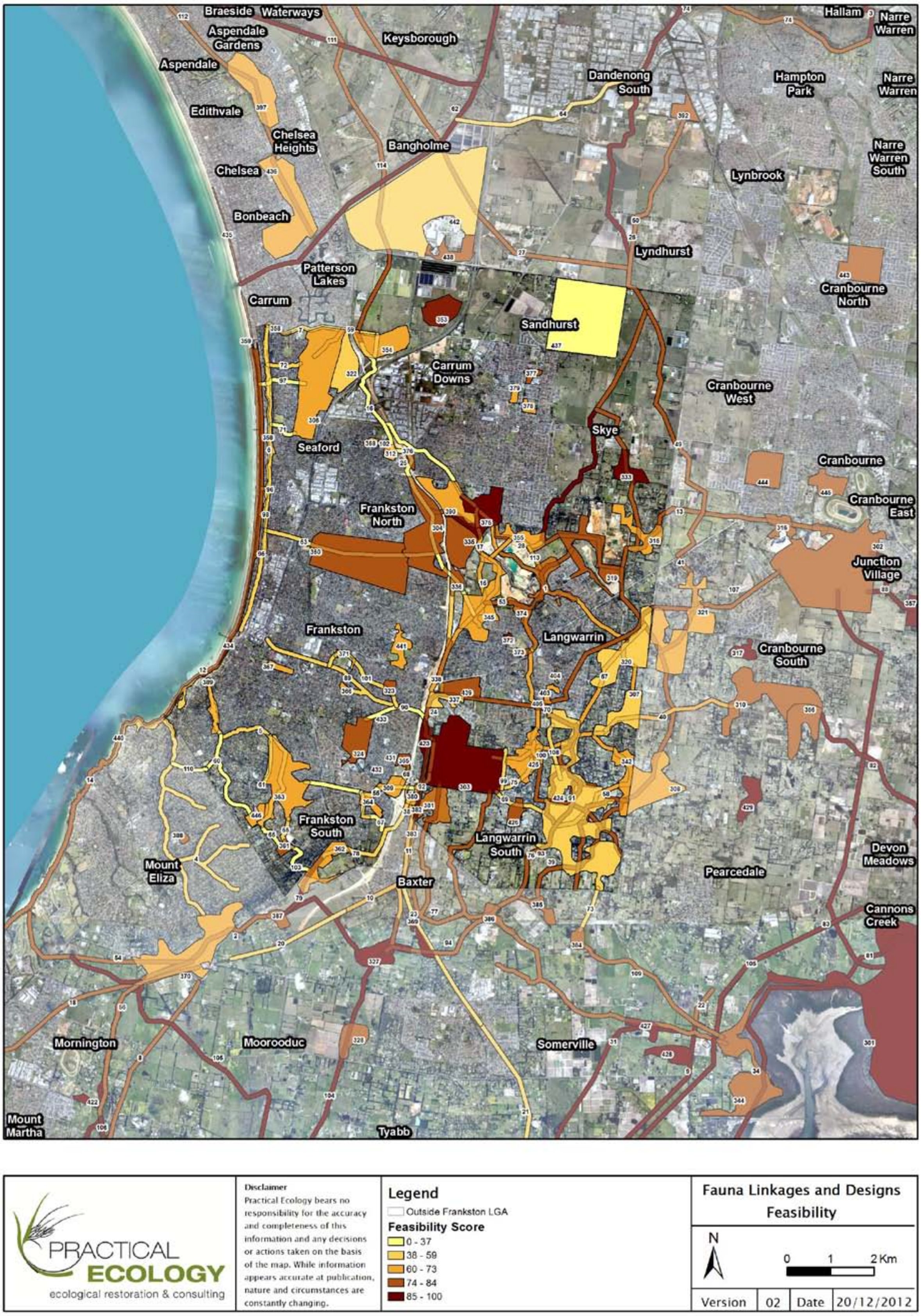
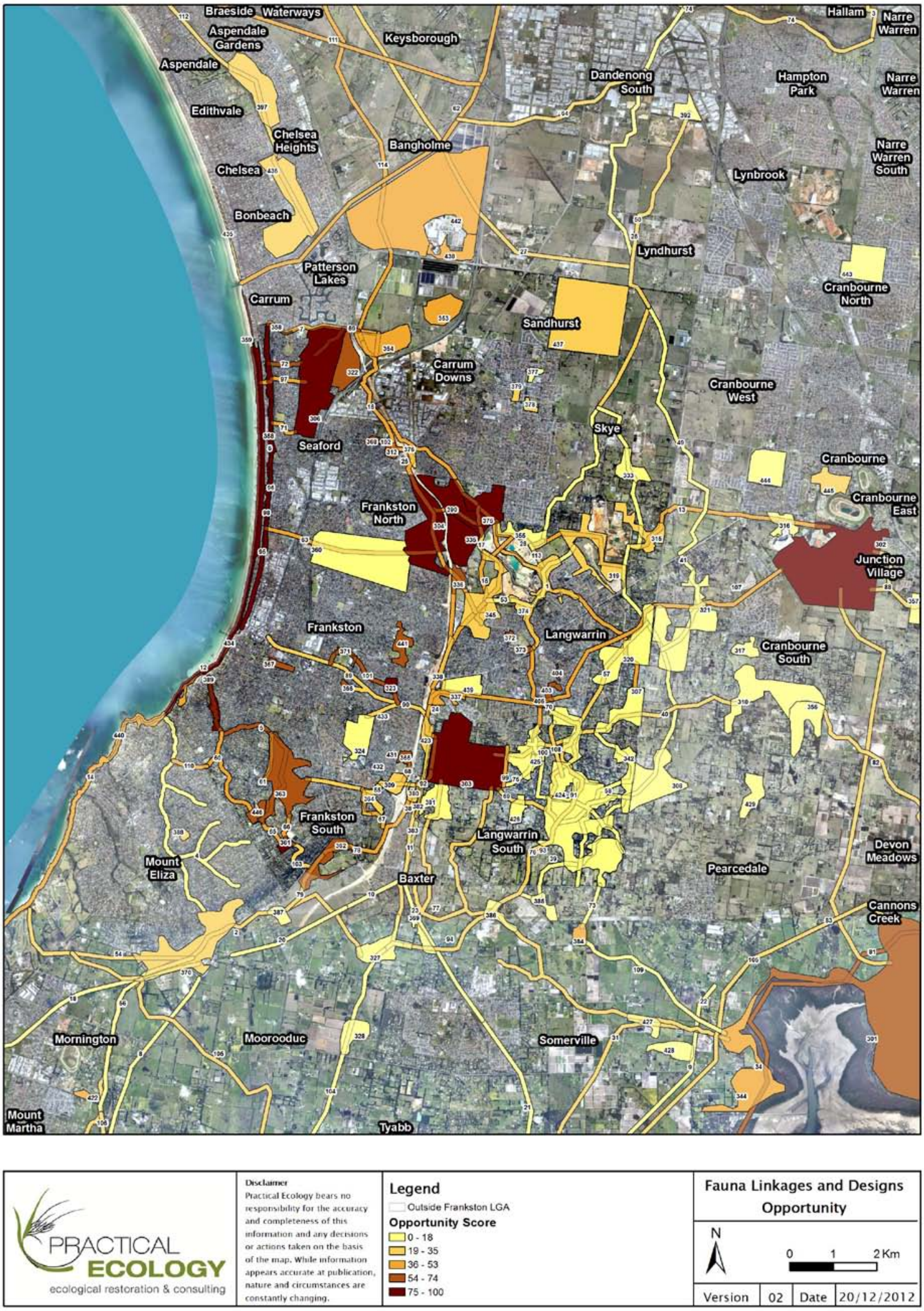


Figure 33. Opportunity scores for existing and proposed linkages. Higher scores (0-100) represent greater opportunity for linkage implementation and/or management for conservation purposes as part of a habitat linkage network.



APPENDIX 5. Priority of patch linkages

The analysis also assessed habitat patch linkages according to the same general methods (see Section 2.1.2) as corridor linkages, following the detailed methods provided in APPENDIX 8. Habitat patches were assessed against the criteria detailed in Table 11 and ranked according to the same method as corridor linkages (see Section 2.1.2 and APPENDIX 8). The following text and associated map below shows the results of the analysis for future consideration and prioritization. The management of patches is an integral part of achieving connectivity for fauna, particularly those intersecting higher priority linkages and the recommended two fauna corridors for urgent implementation.

Results of habitat patch analysis

Higher priority patch linkages were largely higher quality core areas composed of relatively intact bushland remnants, wetlands, or coastal habitats (Figure 34). A large proportion of higher priority patches are managed reserves on public land or located on agricultural land. Lower priority patches were associated with fragmented habitat in peri-urban rural land used largely for residential purposes, habitat on golf courses, and public or private lands used for primarily for recreational purposes. Generally, less fragmented areas of habitat achieved a higher overall priority rank. However, most habitat nodes within Frankston are support fragmented habitat to some degree.

Within Frankston LGA, Very High priority patches included Langwarrin FFR (ID# 303), the Pines FFR (ID# 304, 390, and 375) and adjacent Centenary Park Golf Course (ID# 335), the Frankston-Seaford Foreshore (ID# 96), and Baxter Park (ID# 363). High priority patches included Seaford Wetlands, Frankston Reservoir, Kananook Creek Reserve, Boggy Creek node (ID# 374), Burdett's Quarry and Gumnut Reserve node, a habitat node in the northern half of the Melbourne Water Treatment Plant (ID# 354), and several smaller nodes distributed across Frankston. Medium priority habitat patches include the Langwarrin Woodland nodes (ID# 424, 425, and 426), Studio Park node (ID# 345), Bayside Christian College node (ID# 380), Monique Reserve (ID# 403), and several other smaller nodes.

In adjoining municipalities, Very High priority patches included Royal Botanic Gardens Cranbourne to the east, Western Port-Yaringa (ID# 344) and Quail Island-Warneet (ID# 301) core areas to the south-east, and the smaller Coolart Road (Baxter; ID# 327) and Tyabb Bushland Reserve nodes (ID# 384) to the south. Larger High priority patches included northern sections of the Melbourne Water Treatment Plant (ID# 442), Edithvale-Seaford Wetlands (ID# 397), and Abotts Road Reserve (ID# 392) to the north, Browns Road (Cranbourne South; ID# 317) and East Road node (Pearcedale; ID# 429) to the east, and Mount Eliza Regional Park (ID# 370) to the south.

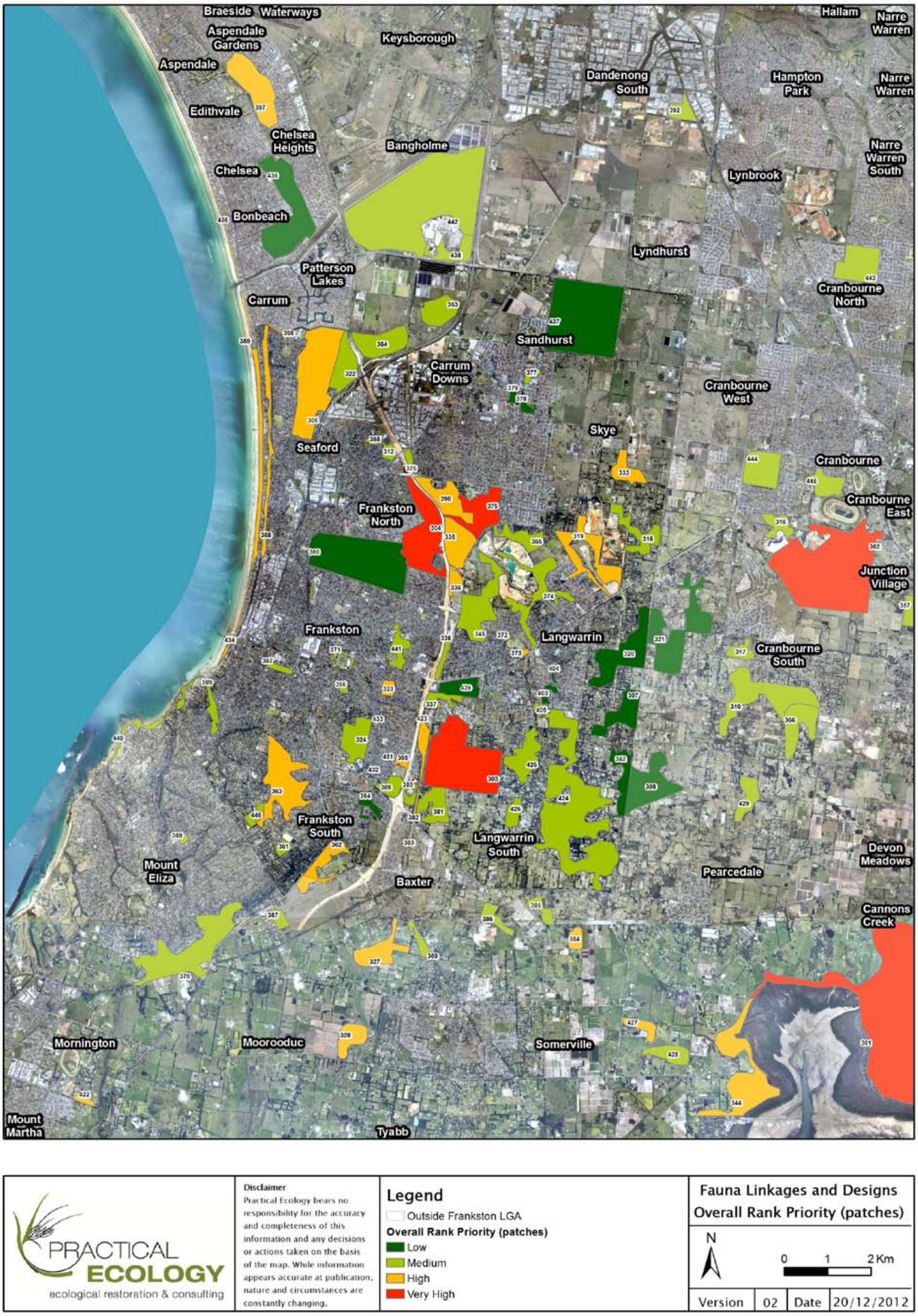
Overall, connectivity between Very High and High priority patches should be a primary goal for a network of fauna habitat within the study area. A network should also incorporate medium priority patches wherever possible. Consequently, the analysis results suggest that connectivity should be achieved:

- eastward between the Pines FFR and Royal Botanic Gardens Cranbourne incorporating intervening nodes
- between the Pines FFR and Langwarrin FFR incorporating Boggy Creek and Langwarrin Woodland nodes
- in the north between the Seaford Wetlands and Melbourne Treatment Plant core areas

- southward from Langwarrin FFR to Baxter Park and nodes south in the Mornington Peninsula

Large core areas exist beyond the study area to the south in Mornington Peninsula. These are generally larger core areas supporting high quality habitat of significance at a regional scale. These include Devilbend Reservoir, Mount Martha Public Park, Arthurs Seat State Park, and several large core habitat areas along the Western Port coastline (e.g. Tyabb and Hastings patches, Stony Point, Crib Point, and HMAS Cerberus).

Figure 34. Rank priority of patch linkages assessed in the analysis.



APPENDIX 6. FAUNA CROSSING FEASABILITY AND RECOMENDED TYPES

				FEASABILITY							
ID	SCORE100	URGENCY RANK	CURRENTLY REQUIRED	ENGINEERING	ECOLOGICAL	TYPE OF STRUCTURE FEASIBLE	RATIONALE	BARRIER	ROAD	WATERWAY	CORRIDOR ID#
21	64.1	Very High	✗	✓	✓	small box culvert (T3)	corridor	Minor Road	OVERPORT RD	SWEETWATER CREEK	5
23	52.7	High	✓	✗	✓	small box culvert (T3) [1]	corridor	Major Road	NEPEAN HWY	KANANOOK CREEK	6
25	44.6	High	✗	✓	✓	small pipe culvert (T5)	habitat link	Major Road	NEPEAN HWY		N/A
26	46.0	High	✗	✓	✓	small pipe culvert (T5)	habitat link	Major Road	NEPEAN HWY		N/A
27	50.3	High	✓	✓	✓	none	corridor	Minor Road	NEPEAN HWY		95
30	41.4	High	✗	✓	✓	small box culvert (T3) and rope-bridge [2]	corridor	Major Road	CRANBOURNE-FRANKSTON RD	LITTLE BOGGY CREEK D.S.	1
31	54.3	High	✓	✓	✓	small box culvert (T3) [1] and rope-bridge	corridor	Major Road	CRANBOURNE-FRANKSTON RD	BOGGY CREEK (UPPER)	1
32	41.6	High	✓	✓	✓	large box culvert (T2) [3] and rope bridge	corridor	Minor Road	QUARRY RD	BOGGY CREEK (UPPER)	1
36	60.0	Very High	✓	✓	✓	small box culvert (T3)	corridor	Major Road	NORTH RD	BOGGY CREEK (UPPER)	1
37	81.4	Very High	✓	✓	✓	large box culvert (T2) [1, 4]	corridor	Major Road	ROBINSONS RD		77
38	88.3	Very High	✗	✓	✓	large pipe culvert (T4)	corridor	Major Road	ROBINSONS RD	WATSONS CRK (HEADWATERS)	77
39	41.4	High	✓	✓	✓	small box culvert (T3) and rope-bridge	corridor	Major Road	SAGES RD		79
40	62.9	Very High	✓	✓	✓	small box culvert (T3) [1, 4] and rope-bridge [3]	corridor	Major Road	ROBINSONS RD		91
41	76.5	Very High	✓	✓	✓	large box culvert (T2) and rope bridge	corridor	Major Road	ROBINSONS RD		91
42	91.2	Very High	✓	✓	✓	small box culvert (T3) [1] and rope bridge	corridor	Major Road	WARRANDYTE RD		40
43	53.9	High	✗	✓	✓	small pipe culvert (T5)	corridor	Major Road	NORTH RD	LANGWARRIN SOUTH D.S.	40
44	74.2	Very High	✓	✓	✓	small box culvert (T3) and rope-bridge	corridor	Major Road	NORTH RD		93
45	36.5	High	✗	✓	✓	large box culvert (T2) and rope bridge	corridor	Major Road	DANDENONG-HASTINGS RD		13
46	36.1	High	✗	✓	✓	small pipe culvert (T5)	corridor	Major Road	BALLARTO RD		39
47	79.5	Very High	✗	✓	✓	large box culvert (T2) [4] and rope-bridge [2 (canopy)]	corridor	Major Road	CRANBOURNE-FRANKSTON RD		39
48	61.2	Very High	✗	✓	✓	small box culvert (T3)	corridor	Major Road	DANDENONG-HASTINGS RD		107
49	58.6	High	✓	✓	✓	large box culvert (T2) and rope bridge	corridor	Major Road	DANDENONG-HASTINGS RD		39
50	68.5	Very High	✗	✓	✓	small box culvert (T3)	corridor	Major Road	DANDENONG-HASTINGS RD		40
51	54.7	High	✗	✓	✓	large box culvert (T2) and rope bridge	corridor	Major Road	DANDENONG-HASTINGS RD		39
52	67.7	Very High	✗	✓	✓	small box culvert (T3)	corridor	Major Road	ROBINSONS RD		39
53	37.2	High	✗	✓	✓	small pipe culvert (T5)	corridor	Major Road	BAXTER-TOORADIN RD		39
54	40.3	High	✗	✓	✓	large box culvert (T2)	corridor	Major Road	BAXTER-TOORADIN RD		76
56	83.9	Very High	✓	✓	✓	large box culvert (T2) and rope bridge [5]	corridor	Major Road	MCCLELLAND DRV		24
57	100.0	Very High	✓	✓	✓	small box culvert (T3) [3] and rope bridge [4]	corridor	Major Road	MCCLELLAND DRV		24
58	86.1	Very High	✓	✓	✓	small box culvert (T3) [1, 3, 4, 7] and rope-bridge [1, 7]	corridor	Major Road	MCCLELLAND DRV/ROBINSONS RD		38
59	64.7	Very High	✓	✓	✓	small box culvert (T3) [1, 6] and rope-bridge [6]	corridor	Major Road	ROBINSONS RD		68
61	80.1	Very High	✗	✗	✓	none	habitat link	Freeway	MORNINGTON PENINSULA FWY		N/A
75	51.5	High	✗	✓	✓	rope-bridge	corridor	Major Road	GOLF LINKS RD	TRIB. WATSONS CREEK	77
77	51.3	High	✗	✓	✓	small box culvert (T3)	corridor	Major Road	GOLF LINKS RD		38
78	48.7	High	✗	✓	✓	small box culvert (T3)	corridor	Major Road	FRANKSTON-FLINDERS RD		78

				FEASABILITY							
ID	SCORE100	URGENCY RANK	CURRENTLY REQUIRED	ENGINEERING	ECOLOGICAL	TYPE OF STRUCTURE FEASIBLE	RATIONALE	BARRIER	ROAD	WATERWAY	CORRIDOR ID#
80	85.9	Very High	✓	✓	✓	rope-bridge	habitat link	Major Road	NORTH RD		N/A
81	80.8	Very High	✓	✓	✓	large box culvert (T2), [1, 3] rope bridge, and fish-passage	corridor	Major Road	MCCLELLAND DRV	LITTLE BOGGY CREEK	13
82	80.4	Very High	✗	✓	✓	small box culvert (T3)	corridor	Major Road	MCCLELLAND DRV		15
86	63.3	Very High	✗	✓	✓	small pipe culvert (T5)	corridor	Major Road	MCCLELLAND DRV		N/A
87	53.5	High	✓	✗	✗	none	corridor	Major Road	CRANBOURNE-FRANKSTON RD/MCCLELLAND DRV		24
97	77.2	Very High	✗	✗	✗	none	corridor	Major Road	SKYE RD		24
100	54.1	High	✗	✗	✗	none	corridor	Minor Road	NEPEAN HWY		98
101	50.9	High	✗	✗	✗	none	corridor	Major Road	NEPEAN HWY		96
102	42.8	High	✗	✗	✓	none	habitat link^	Major Road	GOLF LINKS RD		N/A
105	62.1	Very High	✓	✗	✓	none	habitat link	Freeway	MORNINGTON PENINSULA FWY		N/A
106	61.2	Very High	✗	✗	✓	none	habitat link	Freeway	PENINSULA LINK		N/A
109	53.1	High	✗	✓	✓	none	habitat link^	Major Road	MOOROODUC HWY		N/A
116	97.0	Very High	✗	✓	✓	small box culvert (T3)	habitat link^	Major Road	ROBINSONS RD		N/A
119	36.0	High	✗	✓	✓	large box culvert (T2)	corridor	Freeway	EASTLINK	WADSLEYS DRAIN	27
122	42.1	High	✗	✓	✓	large pipe culvert (T4)	corridor	Major Road	NORTH RD		39
124	38.4	High	✓	✓	✓	fish-passage	corridor	NA	N/A	PATTERSON RIVER WATERWAY	62
128	59.3	Very High	✓	✓	✓	fish-passage	corridor	NA	N/A	SWEETWATER CREEK	5
131	46.0	High	✓	✓	✓	small box culvert (T3) [1] and rope-bridge	corridor	Minor Road	PINDARA BOULEVARD	BOGGY CREEK (UPPER)	1

^ wildlife casualty hotpots were also important rationale for these crossing locations which suggest current movement of animals between areas of suitable habitat.

[1] investigate further as potentially cost-prohibitive.

[2] habitat revegetation/restoration is required prior to crossing structure implementation.

[3] further detailed investigation of engineering feasibility and location is required.

[4] further detailed investigation of existing infrastructure (e.g. underground utilities) constraints is required.

[5] more detailed investigation on precise location is required. Preference is for rope bridge linking Flame Robin Reserve to Pobblebonk Wetland Reserve.

[6] more detailed investigation on precise location is required.

[7] requires crossing structures for both McClelland Drive and Robinsons Road

APPENDIX 7. FAUNA CROSSING STRUCTURES, CONTEXT, SUITABILITY, FAUNA REQUIREMENTS, DETAILS AND COSTS

Fauna crossing structure type		Details (as described in QLD Dept of Transport and Main Roads (2010) – to maintain continuity with terminology)	Context in which structure could be implemented	Detailed specifications	Fauna subgroups likely to benefit	Specific fauna requirements	References	Technical drawings	Source	Photographs	Source	General maintenance requirements	Estimated costs
Land bridges	over road	A bridge extending over a road, typically 20-70 m wide. The bridge is covered in soil, planted with vegetation and enhanced with other habitat features (e.g. logs, rocks etc).	Crossings across large, busy roads with large, high quality areas of fauna habitat bisected by freeways and multi-lane highways	Width of 50m or greater will be used by the widest variety of species	All species excluding aquatic species	Arboreal mammals will require a certain degree of connectivity across a bridge (trees, canopy bridge and/or glider poles)	QDTMR vol. 2 (2010)	Fig. 9.2.3, Ch. 9, p. 34 - QDTMR vol. 2 (2010)	Chambers and Ingram (2005)	Fig. 9.2.2, Ch. 9, p. 33 - QDTMR vol. 2 (2010)	Robinson-Wolrath (2008)	Ongoing maintenance of vegetation, furniture and structural stability, initial establishment of vegetation.	$1.385 mill (20m x 70m) Veage 2007
				Soil depth for vegetation = 300mm for grasses and herbs, 600mm for shrubs and 1.5-2m for trees (choose species that will attract target species)			QDTMR vol. 2 (2010)						
	small (dual purpose) road overpass	A narrow bridge (not hour-glass shaped) above a major road, which allows human or vehicular access across the major road. The road on the overpass is typically a minor road, which may be unsealed or a single lane. Additional areas adjacent to the road may be used for fauna movement.	Crossings across large, busy roads with large, high quality areas of fauna habitat bisected by freeways and multi-lane highways	Ensure a section of at least 8m in width solely dedicated to fauna passage (species dependant)	All species excluding aquatic species	Arboreal mammals will require a certain degree of connectivity across a bridge (trees, canopy bridge and/or glider poles)	QDTMR vol. 2 (2010)					Ongoing maintenance of vegetation, furniture and structural stability, initial establishment of vegetation.	
				Structure is usually waterproofed to provide a barrier between plants, soil and bridge structure			QDTMR vol. 2 (2010)						
				Furniture should be used according to the target fauna group			QDTMR vol. 2 (2010)						
				Fencing should be considered to separate human activity from the crossing structure			QDTMR vol. 2 (2010)						
	cut-and-cover road tunnel	The road passes below ground level through a tunnel with the area above available for revegetation and use by some fauna species.	Crossings across large, busy roads with large, high quality areas of fauna habitat bisected by freeways and multi-lane highways		Small to large ground-dwelling mammal, semi-arboreal & arboreal mammals, reptile, amphibian	Arboreal mammals will require a certain degree of connectivity across a bridge (trees, canopy bridge and/or glider poles)	QDTMR vol. 2 (2010)					Ongoing maintenance of vegetation, furniture and structural stability, initial establishment of vegetation.	
Underpasses	Bridge underpass	A structure that maintains the grade of the road or elevates the traffic above the surrounding land, allowing animals to pass under the road. Facilitates water drainage or the movement of local human traffic and secondarily facilitates fauna passage. Vegetation clearing can also be minimised (clearing only required for bridge piers or pylons) and allow natural vegetation to grow under the structure.	For roads that are wide, busy and/or high-speed that crosses over waterways or uneven landscape and travels above a landform with enough clearance to maintain clearance for a range of fauna and any waterways with adjacent riparian vegetation	Provide light wells, such as gaps or grated decking on multilane bridges	All fauna subgroups	To encourage greater use by arboreal mammals consider combining with fauna furniture or rope bridge	Abson et al (2003)	Fig. 9.1.3, Ch. 9, p. 6 - QDTMR vol. 2 (2010)	adapted from PacificLink Alliance (2006e)	Fig. 6.1, p. 31 - QDMR vol. 1 (2000)	QDMR	Ongoing maintenance of vegetation including weed control, monitoring bank erosion near waterways or maintaining rock and habitat features, initial establishment of vegetation.	3 mill (70m with multiple peirs)Abson et al 2003
				Consider all water flow conditions (i.e. flooding) and erosion management		Install rocks and logs to increase habitat for small mammals, reptiles and frogs	QDTMR vol. 2 (2010)			Fig. 9.2.6, Ch. 9, p. 38 - QDMR vol. 2 (2010)	Bond and Jones (2006)		
				Minimise impact on high quality habitat, particularly fish habitat		Construct wet and dry fauna paths for different mammal requirements and access during flooding	QDTMR vol. 2 (2010)			Fig. 9.3.1 and 2, Ch. 9, p. 46 - QDMR vol. 2 (2010)	Scott (2008)		
				Span the entire waterway with no in-stream supports, wherever possible						Fig. 1	Abson et al (2003)		
	Box culverts	Square, rectangular, or half-circle in shape and may be purpose-built for fauna passage or water drainage, or a combination of both. They are typically pre-cast concrete cells, or arches made of steel.	For smaller roads (less than 30-35 metres wide) along known fauna movement passages, particularly between breeding and foraging areas	3 x 3 metre box culverts are ideal for macropod and/or koala passage	Small to large ground-dwelling mammal, semi-arboreal & arboreal mammals, reptile, amphibian and fish	For fish and amphibian movement create a central channel	QDTMR vol. 2 (2010)	Fig. 9.1.8, Ch. 9, p. 10 - QDMR vol. 2 (2010)	adapted from drawing 3003181-DNR-020-3096	Fig. 6.5, p. 34 - QDMR vol. 1 (2000)	QDMR	Maintenance of vegetation at openings, clearing blockages especially after flooding and ensuring that pools don't form at entrances.	$225 000 (3 metres wide x 3 metres high) Van der Ree 2003 $118 000 (2.4m height x 48m long with 4 levels) $500 000 Koala
				Culverts should be installed at regular intervals along a road		Box culverts are more fauna user friendly than pipe culverts	QDTMR vol. 2 (2010)	Fig. 9.1.6 (a), Ch. 9, p.8 - QDMR vol. 2 (2010)	adapted from PacificLink Alliance (2006c)	Fig. 6.6, p. 34 - QDMR vol. 1 (2000)	QDMR		
				Ends of the culvert needs to be visible, with suitable habitat present near both entrances		Install fauna furniture (rails etc.) to encourage use by arboreal mammals	QDTMR vol. 2 (2010)			Fig. 6.10, p. 36 - QDMR vol. 1 (2000)	QDMR		

Fauna crossing structure type	Details (as described in QLD Dept of Transport and Main Roads (2010) – to maintain continuity with terminology)	Context in which structure could be implemented	Detailed specifications	Fauna subgroups likely to benefit	Specific fauna requirements	References	Technical drawings	Source	Photographs	Source	General maintenance requirements	Estimated costs
			Provide furnishing to allow connectivity for more arboreal species						Fig. 9.1.6 (b), Ch. 9, p.8 - QDMR vol. 2 (2010)	QDMR		Overpass Gantry, Baath 2012
Pipe (concrete) culvert	Typically round, concrete pipes of varying diameter (e.g. small: < 0.5 m and large: > 0.5 m, some even approaching 1.8 m in diameter).	For smaller roads (less than 30-35 metres wide) along known fauna movement passages, particularly between breeding and foraging areas	Culvert passages longer than 20 metres are less likely to be utilised	Small terrestrial mammals and amphibians	Larger sized pipe culverts are utilised more by a greater variety of fauna	QDTMR vol. 2 (2010)	n/a	n/a	Fig. 6.7, p. 35 - QDMR vol. 1 (2000)	QDMR	Maintenance of vegetation at openings, clearing blockages especially after flooding and ensuring that pools don't form at entrances.	$50 000 (1.8m diameter) Van der Ree 2003
	small pipe culverts (< 0.5 m)		Use fauna exclusion fencing along adjacent roadsides to encourage fauna to use the culvert	Mainly smaller terrestrial mammals, reptiles, and amphibians.	Install fauna furniture (rails etc.) to encourage use by arboreal mammals	QDTMR vol. 2 (2010)						
	larger pipe culverts (> 0.5 m)		Provide furnishing for arboreal species, as well as on-ground habitat features, such as earth covering the base of the culvert, rocks and logs	Most, including larger, terrestrial animals, and if furnished appropriately, potentially arboreal mammals also.		QDTMR vol. 2 (2010)						
Rope (canopy) bridge	A rope or pole suspended above the traffic, either from vertical poles or from trees. Used by arboreal and climbing species.	For a wide range of situations, including small, but busy roads, or larger dual carriageway freeways/highways, where there is arboreal habitat present on either side of the roadway	14mm diameter marine grade 'silver rope' woven into a rectangular tube 300mm wide and 200mm high.	Semi-arboreal & arboreal mammals	Use ropes to connect bridges to existing canopy so fauna don't need to use ground	Bax (2006)	Bax (2006)	Appendix A	Fig. 9.2.10, Ch. 9, p. 42 - QDTMR vol. 2 (2010)	Scott (2007)	Inspect on an annual or biannual basis, and after storm events, to see if ropes have deteriorated and/or heavy vegetation is not growing on the structure. Single ropes require more regular maintenance	$15 000 - $20 000 (for smaller mammals 30m wide), $100 000 + for larger arboreal mammals Bax 2006 $44 000 rope bridge, Veage 2007
			Bridge should span across entire roadway and not join at median strips to discourage fauna using roads		Rope bridges in high predation areas can be made into a square tube shaped ladder for fauna to move within the structure.	Bax (2006)			Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 7 and Fig. 8	Bax (2006)		
Fish passage (i.e. fish ladder) -> short section	Usually a short passage beneath a road, generally via a bridge underpass or box culvert. Structurally designed so that fish can travel through, unimpeded. Generally structured with concrete base and/or pre-cast concrete cells/arches.	All locations where waterways, including drains, pass underneath a roadway and can include a broader fauna crossing structure. Anywhere culverts are installed for waterway connectivity.	weathered 'angular' rocks/boulders of various sizes, grouting, and loose gravel, in incorporation with mechanical and hydrological engineering of the waterway	Frogs, aquatic mammals and fish	Movement through waterways is critical for survival of native fish, for access to food and shelter, avoid predation and for reproduction	QDTMR vol. 2 (2010)	Fig. 9.1.9, Ch. 9, p. 11 - QDTMR vol. 2 (2010)	adapted from drawing 3003181-DNR-020-3116	n/a	n/a	Monitoring for sedimentation and debris build up especially after flooding	
			water flow be at a minimum of 0.2 – 0.3 metres, to allow passage for small to medium-sized fish		Needs to be provided in ephemeral and non-ephemeral water bodies with a range of water levels.	QDTMR vol. 2 (2010)	Fig. 9.1.10, Ch. 9, p. 11 - QDTMR vol. 2 (2010)	adapted from drawing DNR-020-3116				

APPENDIX 8. Detailed methods for fauna connectivity analysis

8.1 Fauna linkages: present connectivity and future opportunities

Existing and future opportunities for fauna linkages in the municipality were partly derived from previous studies covering Frankston LGA (McCaffrey and Henry 2010). Areas within Frankston not investigated by McCaffrey and Henry (2010) were assessed in the current study for existing habitat linkages and future opportunities to establish them. Identification of routes followed methods in this previous study: primarily based on visual identification of linear areas supporting native vegetation and undeveloped land that may provide connectivity for the fauna groups investigated (see below).

The identification of connectivity within the municipality also made reference to previous studies investigating broader landscape scale linkages within the Port Phillip and Westernport Bioregion (McCaffrey 2010; O'Malley et al. 2011) as well as proposals for corridor routes and habitat creation for threatened species (DSE 2011; O'Malley 2010), regional scale connectivity proposals (Cardinia Environment Coalition 2008; Hamer, Ainley and Hipler 2010), municipal scale connectivity (FCC 2012: MSS Clause 21 06) and the results of connectivity modelling at a landscape scale covering the study area (O'Malley *et al.* 2012).

The latter study used a modelling GUI platform called the Connectivity Analysis Toolkit (CAT; http://www.klamathconservation.org/science_blog/software/) to estimate least-cost pathways (e.g. corridor routes) at a landscape scale between patches of habitat. CAT outputs were produced for several fauna groups (e.g. ground-dwelling mammals, woodland birds) across the Melbourne Water management area, including Frankston LGA. The model uses 'resistance maps' which represent the landscape along a gradient of high to low resistance to faunal movement (see Section 8.2.2). Reference was made to these modelling results when mapping potential corridor routes and in identifying larger landscape (as opposed to local) corridor linkages (see Figure 30).

8.2 Linkage scores

Linkages were assessed for their *conservation significance*, *feasibility* in implementing, and level of existing *opportunity* for implementation. An output of the analysis was the scoring of each linkage segment under each of three criteria categories. Results of these analyses are provided in APPENDIX 4 (illustrated in Figure 31, Figure 32, and Figure 33).

8.2.1 Fauna groups

Four broad fauna groups were used as surrogates for assessing connectivity within Frankston with the goal of achieving connectivity for a wide range of fauna species (Table 1). Each grouping aimed to encompass different habitat utilisation, movement behaviours, and connectivity requirements exhibited by indigenous fauna species. Selected fauna groups were:

- arboreal marsupials (e.g. possums and gliders);

- ground-dwelling vertebrate fauna (reptiles and terrestrial mammals);
- birds (focus on woodland birds); and
- aquatic fauna (e.g. fish)

Ideally microbats would also have been included as they provide important ecosystem services and represent a significant proportion of mammalian biodiversity in urban environments. However, records for microbats across Frankston and the broader region are sparse while the distribution of critical resources (i.e. roost trees) is also lacking. These factors limit inferences on potential movement or corridor use. Nonetheless, as with woodland birds, high structural complexity in shrub and tree strata along with a mix of open and more cluttered (i.e. for 'clutter specialist' bat species) habitats would similarly benefit this group.

Reference species were selected for each group for assisting the development of resistance layers and the assessment of corridor routes (Table 8). Species were largely sourced from McCaffrey and Henry (2010) and selected based on five considerations:

- higher recorded frequency within the municipality;
- a high or low probability of persistence in a predominantly urbanised landscape (van der Ree and McCarthy 2005);
- threatened status within the study area (e.g. Southern Brown Bandicoot);
- within-group consistency in broad habitat utilisation, movement behaviour[2] and connectivity requirements; and
- availability of spatial datasets to broadly represent landscape resistance to movement and habitat utilisation.

Species were selected based on a number of criteria (Table 8). Basing criteria on more urban tolerant species would ensure that structural connectivity is provided for species that have been shown to persist in urbanised landscapes, while urban sensitive species are likely to be those most needing the provision of connectivity for continued persistence in the municipality. At least one common species (to Frankston LGA) in each group was included as a reference species AND where present, one threatened or urban sensitive species. Woodland dependent birds were sourced from a list of declining species summarised in Watson *et al.* (2011) and only included species recorded in Frankston within the last 50 years.

Urban tolerance was inferred from literature references including Danger & Walsh (2008), van der Ree & McCarthy (2005), and Hamer and McDonnell (2010). The last two studies estimated the probability of persistence of numerous fauna into the future across Melbourne based on historical declines or extinctions. This measure was used as a surrogate for whether species were sensitive to urbanisation.

[2] Movement behaviour in response to the identity of the physical environment (e.g. road, native vegetation, park, residential, water-body etc.) in each 25m x 25m cell of the landscape. We asked the following question for each feature: what is approximate likelihood of movement occurring through different landscape components (e.g. highways, residential blocks, farmland, native vegetation etc.) during normal movement or dispersal events.

An underlying assumption is that urbanisation has increased over time and this process will continue into the future, including within the Frankston LGA.

Although Frankston LGA was considered an 'outer local government area' (>10km from the city centre; van der Ree and McCarthy 2005) in the before mentioned studies, we used the probability of persistence of species for the 'inner' LGA (<10km form the city centre). Each species persistence within these more urbanised environments was considered to reflect their likelihood of surviving increasing urbanisation within Frankston over time. Species were considered urban tolerant if their probability of persistence ranged between 0.95 – 1.0 ('A'), urban sensitive if between 0.94 – 0.50 ('B'), and urban intolerant if <0.50 ('C'). These ranges are deliberately conservative as the original source did not account for declines in populations but rather species presence only. Where species were not recorded in the inner LGA (or data was insufficient), reference was made to each species persistence probability within the 'outer' LGAs and a conservative designation of all species being at least 'urban sensitive' unless a 100% probability of persistence was predicted. Urban sensitive species are those that 'struggle to persist in urban environments' (Hamer and McDonnell 2010).

Table 8. Target ('surrogate') species within fauna groups for which fauna linkages were considered. Groups highlighted in green were those for which 'resistance to movement' maps were referenced to. Each species is shown with the number of records within Frankston LGA and the percentage (%) each species constitutes within the respective fauna subgroup.

Fauna Group	Subgroup	Status		Common Name	Scientific Name	# records (% within-group)^
		Threatened species*	Urban sensitivity †			
Arboreal	Mammal		C	Feathertail Glider	*Acrobates pygmaeus*	11 (4%)
			A	Koala	*Phascolarctos cinereus*	92 (30%)
			A	Common Ringtail Possum	*Pseudocheirus peregrinus*	112 (36%)
			A	Sugar Glider	*Petaurus breviceps*	26 (8%)
Ground-dwelling	Mammal		A	Black Wallaby	*Wallabia bicolor*	56 (5%)
			A	Short-beaked Echidna	*Tachyglossus aculeatus*	45 (4%)
		X	D	Southern Brown Bandicoot	*Isoodon obesulus obesulus*	45 (4%)
			A	Swamp Rat	*Rattus lutreolus*	144 (12%)
			A	Agile Antechinus **	*Antechinus agilis*	15 (1%)
Ground-dwelling	Reptile		A	Blotched Blue-tongued Lizard	*Tiliqua nigrolutea*	15 (7%)
			A	Garden Skink	*Lampropholis guichenoti*	44 (21%)
			C	Glossy Grass Skink	*Pseudemoia rawlinsoni*	3 (1%)
			D	Lowland Copperhead	*Austrelaps superbus*	16 (8%)
		X	D	Swamp Skink	*Egernia coventryi*	6 (3%)
			C	Tree Dragon	*Amphibolurus muricatus*	11 (5%)
			C	White-lipped Snake	*Drysdalia coronoides*	8 (4%)
Birds	Woodland Birds		C	Eastern Yellow Robin	*Eopsaltria australis*	345 (48%)
			C	Rufous Whistler	*Pachycephala rufiventris*	127 (18%)
			C	Dusky Woodswallow	*Artamus cyanopterus*	96 (13%)
			C	Varied Sittella	*Daphoenositta chrysoptera*	61 (9%)
			C	Crested Shrike-tit	*Falcunculus frontatus*	47 (7%)
Semi-aquatic	Frogs		A	Common Froglet	*Crinia signifera*	138 (35%)
			A	Southern Brown Tree Frog	*Litoria ewingii*	61 (15%)

Fauna Group	Subgroup	Status		Common Name	Scientific Name	# records (% within-group)^
		Threatened species*	Urban sensitivity †			
			A	Southern Bullfrog	*Limnodynastes dumerilii*	46 (12%)
		X	C	Southern Toadlet	*Pseudophryne semimarmorata*	19 (5%)
	Reptile		A	Common Long-necked Turtle	*Chelodina longicollis*	4 (1%)
Aquatic	Fish		A	Common Galaxias	*Galaxias maculatus*	25 (15%)
		X	C	Dwarf Galaxias	*Galaxiella pusilla*	15 (9%)
			C	Southern Pygmy Perch	*Nannoperca australis*	4 (2%)
			B	Tupong	Pseudaphritis urvillii	5 (3%)

† Key for Urban sensitivity: A = urban tolerant species, B = transient species, C = urban sensitive species, D = urban intolerant species. Source – primarily Danger & Walsh (2008), van der Ree & McCarthy (2005) and Hamer & McDonnell (2010) using the 'inner local government area' assessment (or 'outer local government area' where data was insufficient). * threatened status under state or federal lists. ** scansorial (Johnstone, Lill and Reina 2012); note also that the Agile Antechinus is incorrectly referred to as the 'Brown Antechinus' in van der Ree and McCarthy (2005). ^ sourced from Atlas of Victorian Wildlife (AVW) (DSE 2007).

8.2.2 Existing fauna connectivity and resistance to movement

Existing fauna connectivity was assessed using the development of a resistance layer (McCaffrey and Henry 2010; O'Malley et al. 2011) for each of four broad fauna groups: woodland birds, ground-dwelling mammals, frogs, and aquatic vertebrates. A resistance map for aquatic fauna was constrained to water features and was excluded from further summary. Overall connectivity was assessed by calculating the summed resistance of land for the remaining three fauna groups. Resistance maps estimate areas of low or high resistance to faunal movement and occupation. Resistance maps were used to inform the identification of existing and potential fauna corridors and potential barriers to movement. Reference was made to previous studies for broader regional connectivity. Where areas of low resistance between patches of habitat in resistance maps corresponded broadly to corridor routes in McCaffrey and Henry (2010), the latter routes were used to avoid duplication. A detailed explanation of calculations used in developing resistance maps for faunal movement can be found in McCaffrey and Henry (2010) and O'Malley *et al.* (2012).

8.2.3 Describing and classifying existing connectivity in the landscape

Several methods can be applied in estimating and representing existing connectivity for fauna in the landscape (Hargrove, Hoffman and Efroymson 2004; Majka, Jenness and Beier 2007; Norton and Nix 1991). Although previous maps of connectivity developed by McCaffrey and Henry (2010) cover part of the study area, they do not cover the entire area of investigation. In addition, a finer-scale estimation of existing connectivity was requested by Frankston City Council taking into account smaller and more modified areas of fauna habitat. Consequently, a map of connectivity (i.e. linkages) had to be created for the study in a GIS environment. The determination of existing connectivity in the landscape was largely informed by maps of native vegetation extent and quality (GIS file name 'NV_2005_QUAL_SC') constructed using modelling techniques combined with aerial photo interpretation and on-ground survey information (DSE 2004; Parkes, Newell and Cheal 2002). This mapping is based largely on the habitat hectares method (Parkes et al. 2003; DSE 2004). As the distribution of remnant native vegetation can miss important areas of fauna habitat, numerous other resources were also referred to. These included fauna studies covering the study area and DSE 'Biosite' mapping (Brereton et al. 2004; Brunner and Courtney 1996; DNRE 2002; Fairbridge 2008; McCaffrey et al. 2010; Muir et al. 1997; Natural Resources and Environment 2002; Yugovic 2003).

Faunal linkages were divided into two major classes:

- **Patch linkages**: Non-linear areas of habitat forming a discrete patch of faunal habitat (e.g. native vegetation) or visually recognizable collections of smaller patches (e.g. such as habitat within golf courses) were termed as a 'patch linkage'.

- **Corridor linkages**: more linear areas of existing *or* potential habitat for fauna and providing structural connectivity among patch linkages (in most cases) *or* overall permeability of the landscape (in all cases).

To re-iterate, patch linkages are non-linear areas of faunal habitat that along with faunal corridors, increase the permeability of the landscape for fauna and hence, increase overall landscape structural connectivity. Similarly, faunal corridors are considered in this study to be linear areas of habitat providing structural connectivity for fauna and are termed 'corridor linkages' in this study. Corridor and patch linkages are each referred to within this report as constituting a different 'class' of linkage. This is to reflect their different function for fauna in provision of habitat.

The collection of patch linkages (i.e. habitat patches) across Frankston LGA, referred to as 'node' and 'core' following McCaffrey and Henry (2010), were used to identify where potential linkages were desirable. The categorization of different patches of habitat largely followed McCaffrey and Henry (2010) although larger areas of habitat considered 'stepping stones' by McCaffrey and Henry (2010) were also included in the analysis. The mapping in the previous report was updated to cover the entire Frankston LGA and to include smaller stepping stone habitat patches to reflect the smaller spatial scale of the current study. Following McCaffrey & Henry (2010), 'node' and 'core' patches linkages were considered as part of a habitat connectivity network and were assessed against the same conservation significance criteria as extant or proposed corridors (see Section 2.1.4).

Patch and corridor linkages were further classified into subgroups reflecting their value as habitat and in providing connectivity in the landscape to fauna. The types of connectivity identified in the landscape for the purposes of this study include the following types of habitat:

Patch linkages:

- **Core areas** – large patches of native vegetation and/or fauna habitat which are >50ha, generally with a LC score of >10 and are reserved for conservation purposes. 50 ha is the size threshold used for the habitat hectare method, which is defined as *"any patch of native vegetation greater than 50 ha regardless of type, quality or tenure"* (DSE 2004). Core areas were further divided into 'more fragmented' and 'less fragmented'. Areas with scores 19-20 were defined as 'less fragmented'; areas with scores 1-18 were defined as 'more fragmented'. Note that only 'more fragmented' core areas are extant within the study area.

- **Nodes** – medium-sized patches of native vegetation with LC scores ranging between 9 and 12, and generally 20-50ha in size. Nodes were further divided into 'more fragmented' and 'less fragmented' nodes, where less fragmented applies to sites which occur on public land or private land which are on titles greater than 5 hectares in size.

- **Stepping stones** – more fragmented collections of smaller-sized patches of native vegetation defined by LC scores of <9 or fauna habitat such as water-bodies or more dense areas of tree canopy habitat. Examples of the latter two groups include wetland/water-body habitats within Melbourne Water's Eastern Treatment Plant and public reserves with significant tree-canopy habitat respectively.

Corridor linkages

- **Terrestrial corridors** – linear links of native vegetation generally >1km long with <0.5km gaps. Linear patterns were identified by eye. Average width was determined by pixel display size, which shows patches of vegetation >20m wide.

- **Riparian corridors** – linear links along waterways supporting riparian habitat, at least some of which is composed of remnant vegetation. Major watercourses and drains were identified using the centreline of the 100 year flood level (Melbourne Water data).

- **Aquatic corridors** – waterways (natural of artificial) with little or no riparian habitat and primarily providing aquatic habitats or connectivity for fauna.

Connectivity in the landscape was identified at a scale of 1:100,000. Each core area, node, terrestrial and waterway corridor was given a unique identifying code, which was used to track individual linkages through the analysis process, and for subsequent illustration and descriptive purposes.

8.2.4 Prioritisation of linkages in Conservation Significance

Qualities used to compare the biological merits (conservation significance) of existing and potential corridors and habitat patches broadly followed those detailed in McCaffrey and Henry (2010; Table 9). A linkage network composed of node and core habitat patches and linkages (i.e. corridors or 'stepping stones') connecting them was first prioritised according to conservation and connectivity values. Each linkage (core, node, or corridor) was assessed against several conservation criteria that could be estimated from available spatial datasets (Table 9). Linkages were assessed first against the level of structural connectivity they may provide to fauna within the municipality and secondly by their biological value.

The conservation significance criteria assessed were:

- linkage type and scale: the size and quality of the linkage spatial extent of linkage: whether the habitat element (core, node, corridor etc) forms part of the provision of structural connectivity for fauna at a larger, regional or landscape scale (Criterion 1);

- linkage provision: the level of structural connectivity linkages provide between patch linkages (Criterion 2);

- how unique and easily replaced (redundancy) the linkage is estimated from the Biosite database (sites of biological significance) (Criterion 3):

- native vegetation cover and habitat condition (DSE modelled habitat hectare score OR on-ground rapid habitat hectare assessment score) OR stream condition if linkage primarily functions in the present as an aquatic linkage (i.e. little to no current habitat extent). These values are used to estimate the extent and quality of fauna habitat incorporated within each habitat patch or linkage (Criterion 4);

- range of fauna guilds that the habitat element provides habitat or potential structural connectivity (Criterion 5);

- linkage benefit to the threatened Southern Brown Bandicoot. This is the only nationally or state threatened fauna species for which habitat suitability modelling was available (Criterion 7);

- linkage benefit for threatened species based on species records data (Criterion 8)

Refer to McCaffrey and Henry (2011) for further details on the criteria.

Table 9. Criteria for assessing conservation significance of connectivity linkages within Frankston LGA.

Components	**Breakdown of score (where applicable)**			**Score**	**Weighting**	**Maximum score (after weighting)**
Structural connectivity in the landscape						
Criterion 1 – linkage type and scale						
Select one of the habitat types below:						
A. Patches					1.50	10 (15.0)
Core area (>50ha AND generally LC score>10)				10		
Nodes (~20-50ha AND LC score>9) – less fragmented				8		
Nodes (~20-50ha AND LC score>9) – more fragmented				6		
Stepping stones (~<20ha AND LC score<9)				4		
B. Terrestrial corridors*					0.75	
>150m wide				10		
100-150m wide				8		
50 - 100m wide				5		
20 - 50m wide				3		
<20m wide				1		
C. Riparian corridors (vegetated)*					0.85	
>150m wide				10		
100-150m wide				8		
50 - 100m wide				5		
20 - 50m wide				3		
<20m wide				1		
D. Aquatic corridors (level of naturalness)					0.75	
5 (natural watercourse)				10		
4				8		
3				5		
2				3		
1 (concrete drain)				1		
* average current or attainable (whichever is greater) width along >50% of corridor length considering existing infrastructure and land uses.						
Criterion 2 – linkage provision						
Provision of landscape- and local-scale connectivity among 'patch' elements, inclusive of the patch elements themselves in providing connectivity among higher value linkages i.e. core areas providing landscape-scale connectivity (A), nodes providing connectivity among core areas (B), and stepping stones among nodes (C)*. Select the highest level of connectivity provision from the list of options below:					0.50	10 (5.0)
A. Landscape-scale connection (core to core connection)				10		
B. Local-scale core to core connection**				8		
C. Connects to a core area from a node				6		
D. Connects at least two or more nodes				4		
E. Connects a node or core to a stepping stone				2		
F. Connects two or more stepping stones				1		
*A minimum level of connectivity is assigned to patch linkages with stepping stones=2, nodes (more fragmented) =4, nodes (less fragmented) =6, and core area =8. **or forms part of direct connection						
Criterion 3 - Biological uniqueness						
Ratings for sites of biological significance (choose one only)	Coverage (area)				0.20	10 (2.5)
	none	1-50%	>50%			
International (covered by Ramsar area)	0	5	10	10		
National	0	4	8	8		
State	0	3	6	6		
Regional	0	2	4	4		
Local (default significance if not covered by Biosite)	0	0.5	1	1		

Components	Breakdown of score (where applicable)			Score	Weighting	Maximum score (after weighting)
Biological Values						
Criterion 4 - Present native vegetation cover and condition within linkage						
Estimated proportion of linkage supporting native vegetation and the average score for quality. Source: DSE native vegetation extent quality score or FCC rapid HH assessment score. Native vegetation cover calculated within patch or 100m of corridor centreline (i.e. 200m width).					0.50	10 (5.0)
A. Native vegetation cover	Standardised Score (0-5)			5		
B. Vegetation quality	Standardised Score (0-5)			5		
If the habitat is an aquatic corridor and covered by Index of Stream Condition (ISC), use average ISC score						
C.ISC score	Standardised Score (0-10)					
Criterion 5 - Range of fauna guilds that the linkage currently benefits						
Fauna guilds – number of species records within 200m of habitat patch (e.g. core, node) or linkage centreline (score for each group)					0.35	10 (3.5)
Amphibians	Standardised Score (0-1.25)			1.25		
Reptiles				1.25		
Fish				1.25		
Woodland birds				1.25		
Wetland birds				1.25		
Ground-dwelling terrestrial mammals				1.25		
Arboreal mammals				1.25		
Water-dependent mammals				1.25		
Criterion 6 - Linkage benefit to threatened species A						
Southern Brown Bandicoot habitat suitability model (DSE) based on geographic location of records, preferred vegetation types and other habitat preferences.	Coverage of area likely to support SBB habitat (range score 0.75-1.00) based on a 200m core width corridor				0.10	10 (1.0)
	<10%	10-50%	>50%			
Small mammals – Southern Brown Bandicoot	2	4	10			
Criterion 7 - Linkage benefit to threatened species B						
Number of threatened fauna species (species richness) recorded within 200m of linkage	Standardised Score (0-10)				0.20	10 (2.0)
				Standardised Score	(1-100)	

For criterion 3, a visual estimate was made of the proportion of the linkage overlapping an area of international, national, state, regional or local significance. This proportion was assigned to one of three categories: 'none', 1-50%, or >50%, overlap and is termed as 'coverage (area)' in Table 9. For example, a linkage entirely overlapping a state significant Biosite or Internationally significant RAMSAR site was considered to have >50% of its area overlapped by such a site.

For all other criteria that considered variables on a continuous scale (i.e. native vegetation cover) and were subject to standardisation, measurements were made either in ArcGIS 9.3, the freeware Hawth's Tools, or Geospatial Modelling Environment (Beyer 2012). Resulting scores for each criterion were weighted (Table 1) according to their relative importance based on expert opinion and consultation with land manager stakeholders through workshops as recommended by previous research (Beier, Majka and Jenness 2006). The final weighting for each criterion was the median value of weightings provided by individual land managers in workshops.

8.2.5 Fauna Linkage feasibility and opportunity

Numerous factors can influence the feasibility of implementing individual fauna linkages and likelihood of long-term success. These include planning, cost, and land use constraints on land intersecting linkage routes in addition to the level of resistance land poses to faunal movement.

For aquatic fauna, only the number of physical barriers along each aquatic corridor, and an average resistance value for the waterway itself were considered. Criteria considered for the remaining three fauna groups (Table 10): birds, ground-dwelling fauna, and arboreal mammals, included estimates of:

- The number of times the linkage intersects freeways, major roads (highway, arterial or sub-arterial) and minor roads (all other roads which are not freeways or major roads);
- Number of parcels intersected (i.e. property crossings);
- Median size of intersected parcels; Proportion (%) of parcels <0.4 ha;
- Average resistance value within 100m of fauna linkage centreline;
- Maximum resistance value within 25m of fauna linkage centreline;
- Number of different tenures along linkage.

Higher scores for these criteria represent a lower feasibility for implementing a linkage. However, the final prioritisation of linkages accounts for the conservation significance, feasibility, and opportunity score of each linkage. To allow relative comparison and combination of these different criteria categories, an inverse value was calculated for 'feasibility' criteria so that higher scores represented higher feasibility. Values estimated for each of the above criteria were rescaled between 0 and 1.

Finally, each corridor route was assessed for opportunities ('opportunity' criteria in Table 10) in additional stakeholder involvement in implementation and additional gains in conservation security, thereby improving opportunities for a linkage to be managed solely for fauna conservation purposes as part of a habitat network.

Opportunity Criteria included:

- Proportion of linkage intersecting with FCC managed land;
- Proportion of linkage length intersecting with public land ;
- Proportion of linkage intersecting land managed for conservation purposes: defined as land zoned as Public Conservation and Resource Zone (PCRZ) or land with a legal covenant protecting native vegetation into the future. Note that not all land with covenants are included due to the constraints of the GIS layers available and privacy issues;
- Total area of fauna habitat (node or core native vegetation patches) connected by linkage that are currently secure for conservation purposes (PCRZ or Covenant);

All resulting scores for each criterion were rescaled to be between 0 and 1. Resistance values were sourced from the average calculated for the several fauna groups. The present % cover of native vegetation (i.e. fauna habitat) within the footprint of a proposed fauna linkage is an important feasibility criterion due to the high cost of revegetation and restoration works. However, it was considered that this criterion would largely be reflected in the conservation significance score calculated for each linkage. In addition, establishing habitat values within the linkage can be achieved over time once land has been designated and put aside as a fauna linkage.

Table 10. Criteria for feasibility of implementing linkages within Frankston LGA. All values were standardised to scale between 0 and 1.

Criteria Category	#	Criteria	Description	Criteria Weighting
Feasibility (inverse value)	1	No. of freeway crossings	Number of crossings the linkage makes over a freeway. Calculated within a 10m wide corridor. A minimum score of 4 was assigned to corridor linkages running directly parallel to any freeway.	2.00
	2	No. major road crossings	Number of major roads the link 'crosses'. Major road type inclusive of highway, arterial or sub-arterial road classes.	1.00
	3	No. minor road crossings	Number of all other roads which are not freeways or major roads. Calculated within a 10m wide corridor.	0.50
	4	No. parcels intersected	Representing the number of properties to be crossed. A higher score for this criterion represents a greater number of landholders that must be engaged to implement a linkage. Scores for linkages intersecting mostly crown land/public managed land were halved to account for a reduced influence when multiple adjoining parcels on public land are managed as a single area by one public authority For example, a single park can be divided into multiple parcels within the planning scheme but are managed in the same way by a single land manager.	1.00
	5	Proportion (%) of parcels <0.4 ha	The indicative proportion of land parcels which the linkage intersects which are <0.4ha in size. This criterion recognizes that state legislation protecting native vegetation (i.e. Native Vegetation Framework) cannot be enforced on parcels <0.4 ha in size. In addition, landholders cannot gain credit for any environmental works undertaken in such parcels under the Native Vegetation Framework due to the lack of security for any works undertaken. Consequently, a higher proportion of parcels <0.4 ha in size within a linkage constitutes a lower feasibility for protecting fauna habitat or protecting any future habitat restoration. Parcels of this low size also broadly represent higher density urban areas in which conservation of natural values and adequate provision of fauna habitat are unlikely to be met. Calculated within a 10m wide corridor.	1.00
	6	Average Resistance Value	A measure of the level of resistance to faunal movement within the corridor and adjacent land (within 100m of corridor linkage centerline). Assessing this value within a larger distance of a linkage centerline acknowledges that linkages adjacent to areas with higher resistance to faunal movement are likely to be harder to implement but also may pose a greater risk to fauna within the linkage. Higher resistance land generally supports greater infrastructure such as roads, urban housing or buildings. Bushfire prevention setbacks and vegetation modifications required between dwellings and native vegetation under the Victorian Planning Scheme may also reduce the quality of habitat which can be protected or created in linkages. High resistance = low feasibility.	1.00
	7	Maximum resistance value	Measures the greatest level of resistance within a fauna corridor footprint and scales linkages according to bottlenecks or high resistance features intersected at a minimum average width. Highest resistance = lowest feasibility.	0.50

Criteria Category	#	Criteria	Description	Criteria Weighting
	8	No. of different tenures along linkage	Increasing the number of different land tenures may increase the difficulty with implementing corridors through requiring a greater number of different mechanisms for setting aside or conserving fauna habitat, management regimes and agencies. Private land was considered as one single tenure type, while public land tenure was associated with the public management authority.	0.50
			Standardized score	(1-100)
Opportunity	1	Proportion intersecting FCC land	A greater proportion within FCC managed land may increase the likelihood of implementation through Council initiated mechanisms and consistent management. Calculated with a 50m corridor width.	1.00
	2	Proportion intersecting public land	Decreased potential cost of implementation and long-term land security. Includes crown land and land managed/owned by public authorities. Exception is crown land which is presently occupied by infrastructure or in the near future will be encumbered with infrastructure (i.e. freeways). Calculated within a 50m corridor width.	1.00
	3	Proportion intersecting conservation land	Infers increased security gains along route. Includes PCRZ (Public Conservation and Resource Zone) zoning of land.	1.00
	4	Average size of intersected parcels	Increasing size of parcels along route may reflect a greater potential to set aside land for conservation purposes and a lower likelihood of commercial or residential buildings or infrastructure being present which would present a lower feasibility of implementation. Calculated within a 50m corridor width. Greater size = higher feasibility/opportunity	1.00
			Standardized score	(1-100)

Where possible, a visual assessment of 'coverage' (i.e. the percentage cover of native vegetation) was replaced by continuous type measurements calculated in ArcGIS 9.3 and associated extensions. Due to non-normal distributions exhibited by variables (i.e. criteria) measured in this way, square-root transformations were applied to improve normality and reduce bias towards criteria heavily exhibiting high skewness in the frequency of estimated values. Resulting transformed variables were standardised to a common scale (i.e. from 0 to 1) and weighted according to their relative importance based on expert opinion and consultation with land-manager stakeholders (Beier, Majka and Jenness 2006)..

Unless otherwise indicated, all continuous values within a 100m of the corridor route centreline were included (i.e. a 200m wide area) in calculations based on an assumption that a 200m core width would be an upper end attainable for any implemented corridor in an urbanised landscape. We acknowledge that a corridor may benefit adjacent land and associated biological values (including fauna species) but this conservative limit was required to honestly compare existing corridors and potential corridor routes in a manner that was unbiased by the surrounding landscape matrix and solely included values potentially protected or enhanced within the corridor footprint. Conversely, this measure may overestimate the potential values within a corridor narrower than 200m wide. The mean value for all measured variables was attained through segmenting all corridors into 100m lengths, calculating the value within each segment and averaging across the corridor identity. This ensured that corridor length did not influence comparisons.

For criteria in which the intersection between a landscape feature and a linkage was being assessed, such as intersections between corridors and roads, a more narrow line (e.g. a 10m wide one) was used. This was to ensure that the present or future width of any corridor linkage did not influence comparisons of corridor linkages and also to ensure that spatial inaccuracy in a GIS road layer would not bias results.

8.2.6 Linkage categorization

Generally, wildlife corridors are considered to be linear areas of habitat connecting two or more larger areas of habitat. Along with core and node type categories used in this report, *continuous* linear areas of habitat with only small gaps bridged by crossing structures, constitute habitat connectivity for the vast majority of arboreal (urban sensitive) and ground-dwelling fauna species in a largely urban landscape.. Habitat connectivity for more mobile fauna species (particularly those capable of flight such as birds, microbats, and insects) can be attained through the provision of discontinuous (i.e. isolated) areas of habitat ('stepping stones'). On their own, clusters of 'stepping stone' patches may also provide increased landscape permeability and sufficient habitat for more fragmentation tolerant species. Another type of connectivity considered in this report is for species largely restrained to aquatic habitats (e.g. fish). Consequently, it was useful to categorise linkages according to the type of connectivity they provide. Corridor linkages were assigned to one of three different categories defining the type of connectivity they provide for fauna:

i) continuous (ground-dwelling and urban sensitive arboreal fauna),

ii) stepping stone (birds and urban tolerant arboreal fauna); or

iii) aquatic linkage.

An assessment was made for each corridor route in whether a relatively *continuous* fauna linkage could feasibly be attained for ground-dwelling or arboreal vertebrate fauna. As discussed, this characteristic is particularly important for most ground-dwelling faunal species that have limited gap-crossing abilities (see Glossary in Section 7 for definition). Each linkage was visually assessed to determine whether it intersected with an impermeable landscape feature for which a crossing structure could not feasibly provide connectivity between two or more areas of habitat (such as land with existing residential or commercial buildings or major infrastructure). Linkages failing this criterion were considered to be solely ones for groups capable of flight (e.g. birds) and designated as 'stepping stone' linkages. Aquatic linkages were determined from a waterways GIS layer.

This categorization allowed us to identify for which fauna groups corridors could provide structural connectivity for between node and core elements within the connectivity network. It would further allow the prioritization of different fauna crossing structures at locations across the municipality

Linkages were further categorised according to whether they were largely 'existing' or 'potential' linkages in the landscape. Existing linkages were ones that were assessed to support native vegetation and/or fauna habitat. Potential linkages were areas of land that could potentially support fauna habitat in the future through conservation works.

Additional categorization was based on the type of linkage provided based on three broad groupings: i) local node to node linkage, ii) local core to core linkage, iii) and landscape linkage. Landscape linkages were ones identified in a previous modelling study undertaken for Melbourne Water (O'Malley et al. 2012) as of high importance in providing larger scale connectivity between larger areas of fauna habitat for three terrestrial fauna groups (ground-dwelling mammals, woodland birds, and frogs).

8.2.7 Overall fauna linkage prioritization

The prioritisation of linkages was only investigated for linkages within a five kilometre radius of the Frankston LGA boundary due to constraints on the project scope. Priority of linkages was calculated as the summed rank across the three criteria categories: conservation significance, feasibility, and opportunity (Table 11). For each criteria category, linkages were ordered according to their respective score (1-100) and their rank order determined. Linkages were then assigned a rank order category from 1-4 (i.e. 1= first quarter of records, 4=bottom quarter in rank order) based on their position within a four quarter range. This was undertaken for each criteria category (i.e. conservation significance, feasibility, and opportunity). The subsequent priority was calculated as the sum rank score for each linkage varying from 3 to 12. Consequently, a linkage achieving the highest priority (rank=1) in all three criteria groups would have a rank sum score of 3. A linkage falling into the lowest priority (4) for each of the three criteria categories would have a sum rank score of 12 (i.e. 4 + 4 + 4 = 12). Linkages were again ordered according to their sum rank score (3-12) and divided into four quartile ranges to provide a final rank priority and qualitative assignment of priority varying from Very High (1) to Low (4) relative to one another. These calculations were undertaken on all types of linkages and separately for corridors and patch linkages to acknowledge that corridors may be unfairly compared to patches on multiple criteria. The overall priority was determined as the highest priority (Very high to Low) in any of these three groups of calculations (all linkages, corridors, or patches). The prioritisation is broken up into low, medium, high, and very high, based on the priority to implement.

Table 11. Scoring and ranking of linkages to provide a final prioritization for faunal linkage implementation

Category	Criteria Group	Description
Conservation Significance Value	Conservation Significance Score	Conservation Significance scores are given in APPENDIX 3. Based on both existing ecological values and potentially to provide connectivity for fauna as detailed in Section 2.1.3. Sum of seven (7) weighted conservation significance criteria and rescaled to vary between 1- and 100
	Conservation Significance ranking	Conservation priority scores were placed into four categories based on whether the rank order of the linkage was within the 1st, 2nd, 3rd, or 4th quarter of all linkages when ordered according to Conservation Significance Score. 1st quarter (top): Very High ('1' in Appendix 3) 2nd quarter: High 3rd quarter: Moderate 4th quarter (bottom): Lower
Feasibility Value	Feasibility Score	Sum of eight (8) feasibility criteria and rescaled to vary between 1- and 100. Feasibility score subsequently placed into three major categories based on the position of each linkage's score relative to all others in rank order:
	Feasibility ranking	1st quarter (top): Very High 2nd quarter: High

Category	Criteria Group	Description
		3rd quarter: Moderate 4th quarter (bottom): Lower
Opportunity Value	Opportunity Score	Sum of four (4) opportunity criteria and rescaled to vary between 1- and 100. Resulting score placed into 4 categories based on rank order of linkage (n=187) relative to all others:
	Opportunity ranking	1st quarter (top): Very High 2nd quarter: High 3rd quarter: Moderate 4th quarter (bottom): Lower
Combined Value	Overall Score	The overall score combines scores for Conservation Significance, Feasibility and Opportunity achieved by each linkage. It was calculated as the sum rank of all three criteria categories with the score varying between 3 and 12. Consequently, a linkage achieving the highest priority (rank=1) in all three criteria groups would have a rank sum score of 3. A linkage falling into the lowest priority (4) for each of the three criteria categories would have a sum rank score of 12 (i.e. 4 x 3). These calculations were undertaken on all types of linkages and separately for corridors and patch linkages to acknowledge that corridors may be unfairly compared to patches on multiple criteria. The overall priority was determined as the highest priority in any of these three groups of calculations:
	Overall Rank	1st quarter (top): Very High 2nd quarter: High 3rd quarter: Moderate 4th quarter (bottom): Lower

APPENDIX 9. Detailed information on potential distribution of target fauna species and movements

Table 12. Estimated distribution and potential movement patterns of target fauna species across the study area with estimates of home range size (in hectares; see Glossary in Section 7). Under 'HR Reference' column, 'est A' denotes estimates based on related species with similar ecology. Group column refers to target fauna groups: AQUA=aquatic fauna (fish), SEMAQ=semi-aquatic fauna (frogs and turtles), GDM=ground-dwelling mammals, GDR=ground-dwelling reptiles, and WB=woodland birds

Group	Species	Fauna distribution and movement	Home Range (ha)	HR reference
AQUA	Common Galaxias *Galaxias maculatus*	Core populations along Kananook Creek, Eel Race Drain, eastern section of Sweetwater Creek (Frankston Reservoir), and possibly Kackeraboite Creek. Also a record within drain extending into Maple Street Reserve branching off Boggy Creek. In the surrounding landscape, several records of Common Galaxias have been made within Balcombe Creek (Mount Eliza Regional Park), Watsons Creek, and Langwarrin Creek. Movement could be occurring upstream along Boggy Creek during high flow events, Watsons Creek, and Langwarrin Creek into Frankston. Habitat within Watsons Creek south of Robinsons Rd could be significant for the species along with reaches of Langwarrin Creek extending into Frankston within the eastern Langwarrin Woodland node ID#308.	0.01	est A
AQUA	Dwarf Galaxias *Galaxiella pusilla*	Core populations of Dwarf Galaxias have recently been recorded (last 10 years) along Boggy Creek between Ballarto Rd and Cranbourne-Frankston Rd along with a record just east of the Rocla Quarry and west of Potts Rd (node ID#355) and another potentially associated with a waterbody in Skye west of Potts Rd. A number of older records (<10 yrs) at the intersection of Boggy Creek and McClelland Drive and at the intersection of Boggy Creek and North Rd. Outside Frankston, populations are recorded within Balcombe Creek, Watsons Creek, Langwarrin Creek, and a waterbody along the Eastern Contour Drain in Cranbourne South. Movement may occur up Langwarrin Creek along the eastern branch tributary to south of North Rd (near Leisureland Drive) and up Watsons Creek to south of Langwarrin FFR (between Robinsons Rd and Golf Links Rd). Movements along drains to the north are less likely due to poorer overall waterway health compared to creeks and drains to the south of Frankston. Balcombe and Langwarrin Creeks are healthier waterways with lower resistance to fish movement than Boggy Creek although no movements are likely between the Boggy Creek population and those south due to there being no connecting waterways or drains.	0.01	est A
AQUA	Southern Pigmy Perch *Nannoperca australis*	Only recorded in Frankston at three locations: one just east of Peninsula Link in a waterbody adjacent to McClelland Drive between North Rd and the railway reserve (i.e. Pobblebonk Reserve, ID#337); in a dam just east of the Lyppards Rd node (ID#315); and a waterbody now removed within the Peninsula Link freeway. Recent damage (2010) to the Pobblebonk Reserve Wetland also casts doubt on the species persistence at this locality. Outside Frankston, there are several records along Balcombe Creek to the south and Mordialloc Creek to the north. Movement could potentially occur during flooding events along the Barakee Reserve outfall Drain northward from Balcombe creek and east towards Watsons Creek. Rare dispersal may also occur from Mordialloc Creek via Eel Race Drain and Melbourne Water treatment plant drains to Boggy Creek. The current distribution of the species in Frankston is poorly understood and further surveys are required. Linking occupied waterbodies with viable connectivity to watercourses such as Boggy Creek is likely important for the species persistence along with rehabilitation of existing waterways and drains. Establishing connectivity between the Boggy Creek and Watson Creek (via Baxter East Drain) may also broadly assist fish species persistence within Frankston.	0.01	est A
AQUA	Tupong *Pseudaphritis urvillii*	The Tupong has been recorded within Eel Race Drain north-east of Seaford Wetland at the intersection with the Mornington Peninsula Freeway. Within 5 km of the municipality the species is also recorded near the intersection of the freeway and Dandenong Creek and also along Watsons Creek. Rare movement could occur during high flow events within Boggy Creek and connecting drains. Upstream movements along Watsons Creek towards the Langwarrin Woodland nodes are less likely although the species distribution is poorly surveyed and additional populations may be present.	0.01	Crook 2004 (Golden Perch)
ARB	Common Ringtail Possum *Pseudocheirus peregrinus*	Recent (1-10 years) records for the species indicate the species is widely distributed across Frankston with clusters of records associated with the Frankston-Seaford Foreshore Reserve, the Pines FFR, Studio Park, Frankston Reservoir, and northern Langwarrin Woodland nodes (ID# 307 and 321). The greatest densities of records are within Langwarrin FFR although these are 20-30 years old. Records are relatively sparse across Frankston considering the abundance of suitable habitat for the species and it's tolerance of urbanization. Current records may be underestimating the distribution and abundance of the species across Frankston. Further surveys are required to determine the species prevalence across Frankston. However, based on mortality/injury records for the species, it would appear to be less abundant than the Common Brushtail Possum. Also, a large proportion of movements resulting in casualties have been located amongst canopy habitat between the Peninsula Country Golf Club and Golf Links Rd (west of McClelland Drive). Based on modelled distribution of canopy habitat and records, movements are likely to be occurring between most larger nodes of suitable habitat between Ballarto Rd and Cranbourne-Frankston Rd although the Peninsula Freeway may be currently inhibiting movement. Movements are also likely amongst the Langwarrin Woodland nodes and Langwarrin FFR.	0.70	Lindenmayer et al 2008
ARB	Feathertail Glider *Acrobates pygmaeus*	Two recent (1-10yrs) record of this cryptic species, one within Studio Park and another which appears to associated with Frankston Cemetery. The latter is suspect considering the absence of any suitable canopy habitat for the species at the locality. Older historical records have been made near Robinsons Rd south of the Frankston Golf Course although poor current canopy habitat and connectivity strongly suggests no current occupation or movement within this vicinity. One casualty record has been made south of Frankston Reservoir (western end of Mountain Rd) in an area which supports extensive canopy habitat amongst residential developments. This arboreal mammal species is rarely detected in fauna surveys due to its small size, rapid movement in the canopy, and cryptic behaviour. Movement could be occurring between Frankston Reservoir, Paratea Flora and Fauna Reserve and Mount Eliza Regional Park through this area. An older record has been made of the species in the latter reserve. Where the Studio Park record is verified, movement could be occurring along Boggy creek and habitat west of Rocla Quarry north to the Greater Pines FFR (former DARA Lands only). However, it is unknown whether the species could utilise underpasses under the Peninsula Link freeway for connectivity to the Pines FFR (i.e. west of Peninsula Link).	2.10	Johnstone and Shaw 2000
ARB	Koala *Phascolarctos cinereus*	Patchy distribution across Frankston although strongly associated with land supporting remnant vegetation or higher tree density. Density of recent records (1-10 years) greatest south of Cranbourne-Frankston Rd and North Rd, west of Warrandyte Rd. Core remnant habitat likely includes Frankston Reservoir and Sweetwater Creek, followed by Langwarrin FFR, the Pines FFR, and Boggy Creek. Movements are likely occurring along Sweetwater and Boggy Creeks and more infrequent movements through some residential areas.	135.00	Ellis et al 2002
ARB	Sugar Glider *Petaurus breviceps*	Recent records restricted to the Pines FFR, Studio Park, Lloyd Park Reserve, Stringybark Bushland Reserve, Robinsons Reserve, Baxter Park, Frankston Reservoir, along the powerline easement within the Langwarrin Woodlands node ID#425, remnant vegetation north of Escarpment Natural Reserve, and southern sections of Sweetwater Creek. Dispersal movements from these populations are likely to be rare due to the fragmented nature of canopy habitat across Frankston and surrounding occupied habitat.	3.50	Quin et al 1992
GDM	Agile Antechinus *Antechinus agilis*	Within Frankston, the Agile Antechinus is recently record as having extant populations in Robinsons Reserve and Baxter Park. The large distances between these populations and absence of suitable habitat and presence of hostile environments (i.e. residential land) suggest they are currently isolated from one another. Very rare long-distance movements could occur through remnants in the Bayside Christian College and agricultural land to the south to Baxter Park. The Peninsula Link freeway has affectively isolated this population from large remnants to the east and potentially connectivity along pre-existing remnants north to the Greater Pines FFR. There are older records of the species presence in these remnants along	1.00	est A (Fisher 2005: *A. stuartii)*

Group	Species	Fauna distribution and movement	Home Range (ha)	HR reference
		with ones within Langwarrin FFR (>20 years). Further surveys are required in Langwarrin FFR and Frankston Reservoir to establish to species current presence and abundance within this significant reserve. East of Frankston, the species has been recorded within the Royal Botanic Gardens Cranbourne and could be used as a source population for re-colonisation of suitable north-eastern habitat patches within Frankston where suitable habitat connectivity is provided. Recent fauna surveys (Practical Ecology 2007), however, did not detect the species and further observations are required to confirm a population at the RBGC.		
GDM	Black Wallaby *Wallabia bicolor*	Core populations/habitat associated with Langwarrin FFR, the Greater Pines FFR, Burdett's Quarry-Gumnut Reserve node, Studio Park, southern Langwarrin Woodland nodes (ID#: 424-25), Baxter Park, Mount Eliza Regional Park, and the RBGC. Likely to be more widespread than records would suggest based on cryptic nature of species. Movement could potentially be occurring between the former DARA Lands node, Centenary Park Golf Course, and Studio Park and also between the former DARA Lands and Burdett's Quarry and south to Studio Park. Movements also likely between Studio Park and Boggy Creek habitats. High levels of movements may also be occurring between Langwarrin FFR and adjacent remnant patches, particularly those associated with the railway reserve and McClelland Drive. Based on fauna casualty records, movement may also be occurring across North Rd and Robinsons Rd within the southern Langwarrin Woodlands node ID# 424.	16.00	Troy and Coulson 1993
GDM	Short-beaked Echidna *Tachyglossus aculeatus*	Widely distributed across Frankston and adjoining areas within areas supporting remnant vegetation. Core populations within the Greater Pines FFR, the RBGC, Langwarrin FFR, Studio Park, and Mount Eliza Regional Park. Recent records within Stringybark Bushland Reserve, Baxter Park, and woodland remnants directly north of Seaford Wetlands. Casualty records suggest potential movement between remnants east and west of McClelland Drive (north of Skye Rd), between Langwarrin FFR and smaller remnants to the north (ID#439) and directly adjacent along McClelland Drive (ID#338). Movement may also be occurring across Old Wells Rd between habitats in the Seaford Wetlands and remnants to the east (ID#322). This species is highly mobile and may cross residential landscapes if there are no significant physical barriers to movement.	107.00	Nicol et al 2011
GDM	Southern Brown Bandicoot *Isoodon obesulus obesulus*	Core population within the RBGC and large areas of suitable core habitat located in the Greater Pines FFR, Burdett's Quarry, and Langwarrin FFR. Likely to be locally extinct within the Pines FFR. Dispersal opportunities from the RBGC into Frankston reserves highly unlikely due to road barriers. Absence of suitable continuous groundstorey habitat, and high exotic predator threats. Key connectivity provision is between the RBGC population and the Greater Pines FFR although dependent on management of feral predator threats within corridor and currently unoccupied habitat.	3.50	several studies
GDM	Swamp Rat *Rattus lutreolus*	Most records associated with Frankston Reservoir, Langwarrin FFR, and to a lesser degree the Pines FFR and RBGC. Several resident populations are also present in smaller public reserves (including Studio Park, Monique Reserve, Paratea Reserve, Lexton Reserve, Lloyd Park, Gumnut Reserve, Baxter Park, Robinsons Park, and Stringybark Bushland Reserve). Many populations are likely to be largely landlocked by residential developments and road barriers in a number of locations with only very infrequent dispersal to other areas of suitable habitat or populations. Movement possibly occurring between the Pines FFR, former DARA Lands, Studio Park, Burdett's Quarry, northern reaches of Boggy Creek between Ballarto Rd and Cranbourne-Frankston Rd, and the Lyppards Road node (ID#: 315). Dispersal opportunities south to Langwarrin FFR are likely to be highly restricted due to infrastructure barriers and absence of groundstorey habitat. Although there are only two recent records within the Langwarrin Woodland nodes (ID#s: 320-21, 424-25), the species may be present and some rare movements occurring between the southern nodes and Langwarrin FFR. The Frankston Reservoir population is likely to be largely isolated and landlocked by residential development, as are the Baxter Park, Bunarong, and Frankston-Seaford Foreshore populations. However, some dispersal movements may be occurring along Sweetwater Creek and associated tributaries.	0.30	Stephens et al 2013
GDR	Blotched Blue-tongue Lizard *Tiliqua nigrolutea*	In recent years (1-10yrs), the Blotched Blue-tongue Lizard has been recorded in Frankston-Seaford Foreshore Reserve, woodland remnants directly north of Seaford Wetlands, the Pines FFR, Studio Park, Bunarong Park (ID#323), bushland immediately north of Escarpment Natural Reserve (ID#364), Robinsons Park (ID#365), Frankston Reservoir, Baxter Park, remnants along the Peninsula Freeway easement. It is unknown whether populations are still resident in bushland remnants along the freeway including Pobblebonk Reserve. Movements up and down Frankston-Seaford Foreshore are likely and rare movements may possibly occur across to Kananook Creek Reserve through undeveloped residential land, and to Seaford Wetlands through Armstrong Reserve and residential gardens or vegetation along Eel Race Drain. Movements between the Pines FFR and Studio Park could feasibly occur through fauna underpasses although this requires confirmation. Dispersal southward from Studio Park is considered less likely due to the fragmented nature of groundstorey habitat and numerous infrastructure barriers. Based on casualty records movements are attempted across McClelland between Valley Rd and Skye Rd and across North Rd and Robinsons within the Langwarrin Woodlands node (ID#424). The greatest density of causality records are within the south-west corner of Frankston, south of Cranbourne-Frankston Rd and west of McClelands Drive. Attempts at dispersal are potentially occurring between Bunarong Park, Robinsons Park, Frankston Golf Course, Frankston Reservoir and Sweetwater Creek remnants through residential gardens and easements.	12.70	Koenig et al 2002
GDR	Garden Skink *Lampropholis guichenoti*	Scattered occurrence across Frankston with a large number of records associated with Studio Park and Frankston Reservoir. Likely to be more widely distributed than records would suggest. Dispersal movements likely to be occurring between most areas of suitable occupied habitat unless significant barriers are present such as residential areas, large areas of land supporting little suitable habitat, freeways and multi-lane roads.	0.01	est A
GDR	Glossy Grass Skink *Pseudemoia rawlinsoni*	Populations recently (1-10 yrs) recorded in Seaford Wetlands, Studio Park, and Stringybark Bushland Reserve Reserve. Populations are distant from one another and considering the high resistance to movement of surrounding residential land, are likely currently isolated from one another. Movement is more likely between Studio Park and habitats along Boggy Creek and possibly north to the former DARA lands (within the Greater Pines FFR). Rare movements could also feasibly occur from the population in Stringybark Bushland Reserve to habitats south within the Langwarrin Woodland node ID#424 and south-west through node ID#425 and remnants bordering the transmission line easement towards Langwarrin FFR. Further surveys are required to determine the extent of the species throughout Frankston, particularly in optimal habitats such as along stretches of Boggy Creek supporting optimal habitat comprised of low dense vegetation near wet and damp habitats (e.g. watercourses, swamps, and waterbodies).	0.01	est A
GDR	Lowland Copperhead *Austrelaps superbus*	Recent (2011) records of the Lowland Copperhead have been made at Seaford Wetlands, Studio Park, Wittenberg Reserve, Baxter Park, and Stringybark Bushland Reserve. The species has also been recorded along McCormicks Rd (Skye), immediately east of the Peninsula Country Golf Club, Robinsons Park, Langwarrin Woodland nodes (ID#425 and 308) along North Rd and just west of Middle Rd in Pearcedale. An older record also exists for the Frankston-Seaford Foreshore although the species current status in the reserve is unknown. Movement is likely occurring between Studio Park and Boggy Creek and north to the Pines Reserves and adjoining habitat nodes, particularly between areas connected by waterways or by stepping stones of waterbodies. Rare dispersal could potentially occur along Eel Race Drain to Kananook Creek habitats and less likely along Boggy Creek southward towards habitats associated with the Pines FFR. Movements along Boggy Creek further south to Langwarrin Woodland nodes are also likely. Any resident population at Baxter Park is likely to be restricted in the potential to dispersal due to low connectivity to nearby suitable habitat, although nearby drains to the south may be important for rare dispersal events.	5.80	est A (Whitaker and Shine 2003)
GDR	Swamp Skink *Egernia coventryi*	Recent surveys (Legg 2012 has recorded Swamp Skinks at three distant localities across Frankston: the Seaford Wetlands, Studio Park, and Stringybark Bushland Reserve. Existing databases also contain a record for the species within Escarpment Bushland Reserve and Stotts Link node (ID#363). Considering the species habitat preferences, the Seaford Wetlands	<0.01	est A

Group	Species	Fauna distribution and movement	Home Range (ha)	HR reference
		are likely to be core habitat for the species. Accounting for recent sightings, movement could be occurring along Boggy Creek between Stringybark Bushland Reserve and Studio Park, although Cranbourne-Frankston Rd is likely a significant barrier. Connectivity north from Studio Park to the Seaford Wetlands is very poor and it is likely these populations are isolated from one another, as is the Stotts Link node population due to the Peninsula Link freeway barrier. Rare dispersal movements could also feasibly occur from the Stotts Link node population across residential gardens north-east to the Golf Link Road node (ID#309; i.e. Bayside Christian College land) and further north to Robinsons Park.		
GDR	Tree Dragon *Amphibolurus muricatus*	Recorded in recent times (1-10 yrs) along Frankston-Seaford Foreshore Reserve, the Pines FFR, and Studio Park. Likely to be largely landlocked within the foreshore reserves but movements may occur between the Pines FFR and former DARA lands (ID#375) with the provision of crossing structures under the Peninsula Link freeway. Movements between Studio Park and nearby suitable habitats along Boggy Creek are also likely.	0.50	est A
GDR	White-lipped Snake *Drysdalia coronoides*	Populations recorded in Seaford Wetlands, Studio Park, Robinsons Park, Bunarong Park, and Baxter Park. There is poor existing connectivity among populations and they are likely to be isolated from one another. The species may be more widely distributed and further surveys are required. Movement may be occurring from Studio Park into connecting suitable habitat west of the Rocla Quarry and into preferred wetter habitats along Boggy Creek. Movements may also occur between Seaford Wetlands and the Melbourne Water Eastern Treatment Plants and associated wet habitat via Eel Race Drain. Movement through the node (ID#322) adjacent to Seaford wetlands is possible although the poor quality of groundstorey habitat makes this less likely. Rare dispersal events are also possibly occurring south-west of Baxter Park along drains. The Bunarong Park population is potentially landlocked by residential development although very rare dispersal events to suitable habitat may be present along the railway reserve. Movement north along an existing drainage line to Ballam Park and suitable habitat to the west is considered very unlikely considering that intervening land supports little to no groundstorey habitat.	3.30	est A (Webb and Shine 1997: *Pseudonaja textilis*)
SEMAQ	Common Froglet *Crinia signifera*	Greatest density of records associated with the RBGC and Langwarrin FFR with scattered records throughout Frankston. Core populations associated with habitats in the RBGC and Langwarrin FFR but also Mount Eliza Regional Park and Seaford Wetlands. Priority should be on enhancing connectivity along Boggy Creek and between the Seaford Wetlands and habitat within the south-east Melbourne Water treatment plant.	0.04	est. based on average movement squared
SemAQ	Eastern Long-necked Turtle *Chelodina longicollis*	Searches of existing databases revealed only one record (2008) of the species within Frankston, located in the south-west corner of the municipality within Kackeraboite Creek. However, casualty records for the species are extensive and numerous (n=177). Records are widely distributed across Frankston and are strongly associated with areas supporting remnant vegetation, water-bodies, and waterways. Localities include Kananook Creek, Seaford Wetlands, Boggy Creek, the Peninsula Golf Course, Sweetwater Creek, Frankston Reservoir, Tamarisk Creek, Langwarrin FFR, and wet habitats within the southern Langwarrin Woodland nodes (ID#424). The species is tolerant of modified landscapes and may move considerable distances overland between water-bodies and waterways. Casualty records may therefore be misleading in designating core areas for the species. Records would suggest movement along Kananook Creek, Sweetwater Creek, Boggy Creek, Eel Race Drain, and between the Greater Pines FFR and Boggy Creek node to the south-east across McClelland Drive. Also highly likely to be moving between core habitats in the Seaford Wetlands and Melbourne Water treatment (water-bodies and wetlands) plant via Eel Race Drain. Considering the very large discrepancies between database records for the species and records of casualties, further surveys are required to determine core habitat for the species and the location of resident populations.	8.35	Roe and George 2008
SEMAQ	Southern Brown Tree Frog *Litoria ewingii*	Broadly distributed across Frankston in areas supporting native vegetation and/or damp to wet habitats. Core populations/habitats associated with the RBGC based on a high frequency of records. Damp or wet habitats within the Pines FFR, Langwarrin FFR, Boggy Creek, Seaford Wetlands, and Mount Eliza Regional Park appear to be important strongholds for the species. Larger areas of suitable habitat include the Seaford Wetlands, Langwarrin FFR and Boggy Creek. Improved habitat quality and structural connectivity along Boggy Creek would improve dispersal opportunities for the species and link larger areas of suitable habitat.	0.25	Driscoll 2006: based on *Geocrinia alba* and *Geocrinia vitellina*
SEMAQ	Southern Bullfrog *Limnodynastes dumerilii*	A common species widely distributed across Frankston. Records largely associated with watercourses, dams, damp native vegetation habitat, and wetlands. Clusters of records associated with the RBGC, Seaford Wetlands, and Mount Eliza Regional Park, although the species distribution is likely under-represented based on current records. Priority connectivity provision is linking core RGBC population with suitable habitat along Boggy Creek (corridors C1 and C2), and within the Pines FFR and Seaford Wetlands.	0.04	Rowley and Alford 2007: est *L. lesueuri*
SEMAQ	Southern Toadlet *Pseudophryne semimarmorata*	Isolated and restricted occurrences to Sweetwater Creek Reserve, Mount Eliza Regional Park, the RBGC, Langwarrin FFR, Studio Park, the Greater Pines FFR, Little Boggy Creek Reserve and south of Robinsons Rd within the Langwarrin Woodlands node ID#424. Populations also potentially occurring at Lexton Reserve and Lloyd Park (north) although these require verification (SMEC 2011). The highest densities of records are associated with Langwarrin FFR suggesting this is core habitat for the species. Large areas of suitable habitat within the Pines FFR also suggest this may be core habitat for the species. Movements between distant remnants and populations are likely to be rare considering large distances between disjunct populations and low level of habitat connectivity (i.e. fragmented) between occupied habitat patches. Rare movements along Boggy Creek between the former DARA lands and Little Boggy Creek Reserve, between the Pines FFR and Burdett's Quarry, and between Studio Parp and Studio Park may be feasible under current conditions.	<0.01	Yoni Tiljak (unpublished observations): breeding ranges
WB	Crested Shrike-tit *Falcunculus frontatus*	Scattered records for the species occur across Frankston with recent records made within the Langwarrin Woodlands (nodes ID#308 and 342), Langwarrin FFR, Studio Park, Little Boggy Creek Reserve, and the RBGC. Based on numbers of records, core populations are likely to be within the RBGC and Mount Eliza Regional Park although other populations may occur within Langwarrin FFR and the Langwarrin Woodland nodes. Some rare movements may occur along creeklines such as Boggy Creek and where canopy density is higher such as the Langwarrin Woodland nodes and intervening land. Records within the last decade are few, suggesting the species may have declined within Frankston in recent times, potentially due to poor connectivity and declining habitat quality. Mostly associated with dry eucalypt forests and woodlands and more abundant in forested gullies and riparian vegetation. Adversely affected by urban development, altered fire regimes and loss of habitat. Movements are not well understood but thought to be resident or sedentary with some local seasonal movements recorded. Longest distance travelled recorded to be 10 km with most animals moving <10 km. Feeds on insects and occasionally fruits, seeds, and arils and forages over a large territory mostly in the canopy and subcanopy from under or off the bark of trees but also foliage and dead stems. Abundant loose and decorticating bark may be an important habitat resource for the species (Recher 2006). Likely to have relatively low fecundity based on documented clutch sizes and success.	20.00	est A
WB	Dusky Woodswallow *Artamus cyanopterus*	Core populations/habitat are associated with the RBGC and Langwarrin FFR. Implementation of both C1 and C2 would provide connectivity between significant habitat and populations in the RBGC and Langwarrin FFR. The species has been recently recorded in the Pines FFR, Mount Eliza Regional Park, Burdett's Quarry, and Seaford Wetlands with infrequent or older records elsewhere.	70.00	est A
WB	Eastern Yellow Robin *Eopsaltria australis*	Woodland habitats in the RBGC and Langwarrin FFR appear to be strongholds for the species. Frequent records have been made in the Langwarrin Woodlands nodes and in Heathy Woodland habitats in the Greater Pines FFR, Studio Park, and nodes in Skye. Other important habitat for the species in Frankston includes the Frankston Reservoir, woodlands in the east of Langwarrin (Link IDs: 320 and 321), Frankston and Seaford Foreshore, and Mount Eliza Regional Park. The species has been recorded making daily movements of over 1 km across an agricultural landscape supporting scattered trees between larger habitat patches. This suggests animals are likely to move between larger patches where the intervening landscape is largely agricultural land supporting scattered trees or where tree density is higher and some shrub cover is present. At least some movements (e.g. dispersal) are likely occurring	5.00	HANZAB

Group	Species	Fauna distribution and movement	Home Range (ha)	HR reference
		between larger habitat patches (node and core habitats) between Cranbourne-Frankston Rd and Ballarto Rd (up to Belvedere Reserve). Canopy habitat is sparse between the Pines FFR and Seaford Wetlands and the distance relatively great (2km) suggesting movements may be rare between these areas. Movement between Frankston-Seaford Foreshore, Kananook Creek Reserve, and the Seaford Wetlands and associated woodlands to the north are likely to be more common. Movements among the Langwarrin Woodland node patches and the Langwarrin FFR are also likely to be common. The Peninsula Freeway may be constituting a barrier to movement for populations east and west of the freeway. Dispersal movements are likely to occur among most habitat patches west of the Peninsula Link freeway including Frankston Reservoir, Sweetwater Creek Reserve, Paratea Reserve and Baxter Park, and Robinsons Reserve. Open pasture and roadside canopy habitat between Golf Links Rd and Baxter-Toordin Rd is likely important for continued dispersal between the Robinsons Reserve/Bayside Christian College nodes and Baxter Park and Paratea Reserve is possibly an important stepping stone between Frankston Reserve and Baxter Park. Vegetation along the railway easement may assist rare dispersal events southward from Frankston patches. Movements are also likely along Sweetwater Creek between Sweetwater Creek Reserve and Frankston Reservoir. Connectivity between populations and core habitat in the RBGC and Langwarrin FFR is of highest priority which requires implementation of both C1 and C2 corridors. The supplementary corridor S1 provides connectivity for a population associated with the Studio Park node to habitat in the Pines, along Boggy Creek and habitat connected by the implementation of corridor C2. The supplementary corridor S2 provides connectivity for populations associated with the Langwarrin Woodlands node in Langwarrin South.		
WB	Rufous Whistler *Pachycephala rufiventris*	The majority of records for the specie shave been made in the RBGC and Langwarrin FFR suggesting these are core populations and habitat refuges for the species within the study area. Infrequent records have been made elsewhere associated with higher quality native woodland habitats (e.g. Studio Park, Bunarong Park, Escarpment Bushland Reserve and Stotts Link node ID#364, Paratea Reserve ID#361, Monique Bushland Reserve, Frankston Reservoir, Baxter Park, and the northern and southern Langwarrin Woodland nodes ID#: 424, 342, 308, 320), while older records are associated with the Pines FFR, Lyppards Rd node (Skye). Several recent records are also associated with Mount Eliza Regional Park suggesting a resident population. Based on the wide distribution of recent (<10 years old) records, this species may be a good disperser and movement may be occurring among numerous patches supporting woodland habitats. Movement has likely been occurring between the Langwarrin Woodland nodes, Langwarrin FFR and nodes south-east of this core population such as through the Stott's Link node ID#364, Paratea Reserve, Baxter Park, and through to Frankston Reservoir. These nodes and other woodland patches south and south-east of Langwarrin may have functioned as stepping stones for movement of the species between Langwarrin FFR, Frankston Reservoir and Mount Eliza Regional Park.	70.20	Moise 2008
WB	Varied Sittella *Daphoenositta chrysoptera*	Most frequently recorded in Langwarrin FFR and RBGC in contemporary times (last 10 years). Historically recorded in the Greater Pines FFR, Frankston Reservoir, Sweetwater Creek (i.e. Lower Sweetwater Creek Reserve), north-eastern (ID#320-21) and southern (ID#342) Langwarrin Woodland nodes. Generally a sedentary species which is highly sociable, forming foraging and breeding groups. Based on the distribution of habitat and species records, some infrequent movements may occur between Langwarrin FFR and the RBGC through the Langwarrin Woodland nodes, and some between Langwarrin FFR (and adjoining remnants) and the Greater Pines FFR along narrow woodland remnants.	20.00	Noske 1998

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Table 13. General and specific habitat requirements and food resources of target fauna species

Group	Species	Specific Habitat Requirements	Habitat	Resources and Other
AQUA	Eastern Long-necked Turtle *Chelodina longicollis*	Several ephemeral or permanent freshwater waterbodies/wetlands within home range. More shallow, slow-moving waterbodies and waterways connected by vegetated terrestrial corridors and surrounded by some terrestrial habitats (>130m buffer).	Wide variety of terrestrial and freshwater aquatic habitats but preferences for freshwater bodies including oxbow lakes, billabongs, anabranches, and pools but also swamps and slow-moving rivers. Prefers lower water depths, low flowing, and more ephemeral waterbodies (Chessman 1988; Cogger). Requires terrestrial habitats adjacent/connected to waterways or waterbodies where it will remain inactive during periods of drought and drying of temporary waterbodies. Can survive in small, remote and ephemeral pools. Resists desiccation and spends considerable time within terrestrial habitats after wetland/waterbody drying events. May spend an average of 64 days away from a wetland in adjacent forests over the course of a year, burying itself under detritus and sand (Roe and George 2007).	Generally carnivorous, feeding on a wide variety of organisms including molluscs, yabbies, shrimps, crustaceans, zooplankton, tadpoles and small fish (Chessman 1988; Cogger). Using temporary wetlands, the species can exploit abundant prey with the absence of competitors resulting in faster growth rates and much higher reproductive outputs (Roe and George 2007)
ARB	Common Ringtail Possum *Pseudocheirus peregrinus*	Large, hollow-bearing trees (e.g. large old trees), understorey trees and shrubs (e.g. *Acacia* spp. *Leptospermum* spp.)	Use hollows in eucalypts and other trees as regular den sites across a wide variety of rainforests, forests, woodlands and scrub habitats. Unlike other large possums they don't necessarily require a tree hollow as a den site and can construct a nest in thickets or scrub called a drey (Menkhorst 1996) Individuals	Diet consists of mainly leaves but will include flowers, fruits and buds from a wide variety of trees and shrubs (Menkhorst 1996). Lives in family groups and individuals will often use multiple hollows and/or dreys within their home range.
ARB	Feathertail Glider *Acrobates pygmaeus*	Forests or woodlands with hollow-bearing trees (cavities with small entrance), high diversity of understorey shrubs, dense tall and medium shrub cover, and numerous vertical stems (dead or alive)	The world's smallest gliding mammal which inhabits a wide range of tall forests and woodlands throughout most of Victoria. More common in wet and mature forest than dry or regenerating forests. Requires a high diversity of shrubs to provide a year-round supply of nectar and vegetation with dense cover, numerous vertical and horizontal stems for climbing (Menkhorst 1996). Forages across a range of levels within the forest strata including shrubs, canopy and ground-storey. Will utlise a large variety of enclosed spaces for dens including tree hollows, bird boxes, old bird nests and possum dreys. Requires den sites (e.g. hollows) with small openings to avoid competition with other fauna. Also can make dreys (spherical nests of leaves, bark, and other plant fibres).	This possum feeds on insects, nectar, pollen, honeydew and manna. The species is highly social forming groups between 7-20 with one record of 40 animals utilising a single tree hollow.
ARB	Koala *Phascolarctos cinereus*	Eucalypt tree canopy cover of preferred species in local area (likely Manna Gum *Eucalyptus viminalis* but also Swamp Gum *E. ovata* and Narrow-leaved Peppermint *E. radiata*) on more fertile soils	Wide variety of vegetation types where preferred eucalypts species are present. An agile climber, this species is largely arboreal but descends to the ground when necessary. Prefers larger trees and particular preference for Manna Gum *Eucalyptus viminalis* but also Swamp Gum *E. ovata* during summer (Hindell et al 1985, Hindell and Lee 1987) in Port Phillip Region. The eucalypt species *E. globulus,* Narrow-leaved Peppermint *E. radiata*, and *E. macrorhyncha* are also consumed.	Mostly solitary and diet consists almost entirely of eucalypt leaves. Preferentially feed on the leaves of a small number of eucalypt species within a local area, travelling between feeding trees.
ARB	Sugar Glider *Petaurus breviceps*	Forest or woodlands with tree hollows, high density and diversity of medium and tall shrubs	Wide variety of native forests and woodlands with tree hollows. Preferences for habitat with high stem density, high plant food species and a dense mid and upper canopy cover and potentially higher abundance of wattles such as black wattle Acacia mearnsii (Suckling 1984, Jackson 2000). Den sites are located in tree hollows and fissures and preferrably have smaller sized entrances to avoid competition with	Opportunistic omnivores with a diet consisting of invertebrates, acacia gum, eucalypt sap, nectar and pollen, manna, fungi and honeydew. Live in family groups

Group	Species	Specific Habitat Requirements	Habitat	Resources and Other
			parrots, possum species, and other hollow-using fauna.	
FISH	Common Galaxias *Galaxias maculatus*	Slow-flowing waters with abundant insect and copepod prey and connectivity to estuaries.	Coastal rivers, estuaries, and creeks extending into foothills but also in swamps, lakes, and less frequently, landlocked waterbodies. Generally upper reaches of creeks but within the Port Phillip region, more common in degraded metropolitan streams, potentially due to lower competition/predation from the exotic trout in upper reaches of waterways (Danger and Walsh 2008). Can tolerate higher water temperatures than other galaxiids.	Juveniles feed on copepods and other small zooplankton while adults feed on aquatic and terrestrial insects. (Danger and Walsh 2008).
FISH	Dwarf Galaxias *Galaxiella pusilla*	Slow-flowing or still water with cooler water temperatures (i.e. canopy cover over waterways), well-vegetated margins, abundant insect and copepod prey, and protection from introduced predators (i.e. trout).	Slow-flowing or still freshwater creeks, drains, roadside ditches, and swamps with well-vegetated margins but also shallow wetlands. Can occupy both ephemeral and permanent waterbody habitats. Impacted by stormwater run-off although can still persist in such situations (i.e. Little Boggy Creek). Prefers lower water temperatures.	Generalist feeder of aquatic insects including insect larvae and crustaceans but also aquatic plants and algae. The Dwarf Galaxias is a small short-lived fish (<2 yrs), reaching maturity in the first year of life and dies shortly after spawning.
FISH	Southern Pigmy Perch *Nannoperca australis*	Slow-flowing water with higher water quality, stands of macrophytes, and healthy populations of prey items	Prefers slow-flowing (often weedy) or still swampy coastal creeks and drains but also still waters such as lakes, billabongs, farm dams, drains, rivers and streams with stands of macrophytes (i.e. aquatic vegetation) where it can shelter from predators and hunt for food. Prefers higher water quality (i.e. impacted by stormwater runoff)	Carnivorous and feeds upon small crustaceans, insects and their larvae.
FISH	Tupong *Pseudaphritis urvillii*	Brackish estuaries or slow-flowing water (creeks and stream), good sediment quality, and bottom substrate with submerged logs, leaf litter, and macrophytes. Connectivity to estuaries.	Occupies brackish estuaries and also slow-flowing freshwater creeks and streams. A bottom-dwelling fish usually found in, or around logs and aquatic plants where it buries itself in the substrate to ambush passing prey. Most abundant in slow-moving water among leaf litter and benthic debris such as under logs, aquatic plants, overhanging/undercut banks or buried in sand. Likely sensitive to poor sediment quality due to being a bottom dwelling species.	large (up to 20cm) long-lived fish species (females may take up to 5 yrs to reach maturity) and is usually carnivorous, feeding upon insects, crustaceans, molluscs, worms and fish.
FROG	Common Froglet *Crinia signifera*	Still shallow water-bodies, wetlands, and waterways with fringing high groundcover (grasses, sedges, logs, and litter) and emergent, submergent, or floating macrophytes (aquatic vegetation). Rocks, logs, leaf litter and thick vegetation surrounding aquatic habitats	Occupies a wide variety of mostly damp habitats but breeds in slow-moving creeks, farm dams, wetlands, ponds, and waterholes. Prefers waterbodies with still water and damp areas such as ponds and streams with high cover (logs and litter). Largely a terrestrial species, spending much of its time amongst leaf litter and sheltering during dry periods in microhabitats where moisture is retained such as under rocks, logs, damp depressions, and thick vegetation. Prefers ephemeral waterbodies but will occupy more shallow areas of deeper permanent wetlands or waterbodies (including wet roadside dicthes and even wheel ruts) during breeding. Will call from the water surface, floating or semi-submerged vegetation or shallows (Cogger 2000).	Adults insectivorous foraging amongst leaf litter. Tadpoles consume aquatic insects (including mosquito larvae) and also graze on vegetation Calls from shallow water or vegetation (Cogger) and can tolerate high levels of disturbance and elevated nutrient levels.
FROG	Southern Brown Tree Frog *Litoria ewingii*	Deeper waterbodies with shallow sections and fringing or emergent tall sedges, reeds, or trees (paperbarks or eucalypts)	Occurs in a wide range of freshwater waterbodies, lakes, ponds, swamps, dams, and low damp vegetation. Prefer deeper waterbodies (semi-permanent or permanent) for breeding but will lay eggs on submerged vegetation in shallow waters. An arboreal species that shelters in the crown of sedges and reeds or small hollows in paperbark and eucalypts. Males call from grass stems or small branches overhanging deep water.	Adults insectivorous, feeding on aquatic and terrestrial invertebrates by active hunting. Tadpoles suspected of grazing on benthic algae attached to aquatic macrophytes (aquatic vegetation), submerged leaf litter or rocks.

Group	Species	Specific Habitat Requirements	Habitat	Resources and Other
FROG	Southern Bullfrog *Limnodynastes dumerilii*	Moist or wet habitats with riparian/fringing vegetation and some semi-submerged vegetation. Larger and deeper waterbodies preferred	Found in a variety of heaths and forest and associated with well-vegetated (ephemeral or permanent) freshwater water-bodies, wetlands, swamps, streams, and dams. Considered to prefer larger and deeper (>60cm) permanent waterbodies (ponds or damns) or streams and wetlands with intact riparian vegetation for breeding. Males call from secluded sites within dense vegetation or overhangs along the waterbody edge but prefer semi-submerged (<30cm) large emergent grass tussocks. During periods of inactivity, this species burrows into the ground.	Insectivorous adult diet of small invertebrates. Tadpoles graze benthic algae and vegetable matter. Threatened by the introduced *Gumbusia holbrooki* through reducing tadpole survival and also predation of adults by foxes and cats
FROG	Southern Toadlet *Pseudophryne semimarmorata*	Remnant vegetation habitats (i.e. heaths, woodland etc) with (or nearby) ephemeral shallow soaks, periodically inundated (e.g. flooded) low-lying areas, or moist to wet habitats (e.g. ponds, wetlands etc)	The Southern Toadlet can be found in dry forest, woodland, shrubland, grassland and heaths. It shelters under leaf litter and other debris in moist soaks and depressions. Their eggs are spawned in shallow burrows under organic litter in low areas close to water (Hero et al. 1991) or wet soaks. Dry swampy sites which are inundated in winter. Within the region, commonly occurs in swampy habitats or woodland (commonly heathy) remnants supporting ephemeral shallow soaks.	Insectivorous, feeding on small invertebrates.
GDM	Agile Antechinus *Antechinus agilis*	native vegetation with fallen timber and large logs, tree hollows, and structurally complex habitat (i.e. groundstorey vegetation, small, medium, and large shrubs, and canopy trees)	Occurs in moist forest types, heaths, scrubs, and woodlands where abundant leaf litter, fallen logs, and tree hollows are present. Generally requires large patches of bushland (edge sensitive) with intact understorey and shrub layer. The species builds nests of eucalypt leaves in hollows of large trees either at ground level (infrequently) or several metres above the ground (commonly). Can also utlise fallen timber (e.g. hollow logs) for nest sites.	Diet consists mostly of invertebrates (large beetles, spiders and cockroaches) but occasionally also berries, small lizards, bird eggs and nestlings. Spends some time foraging at ground level but is considered a scansorial species adapted for climbing and foraging above the ground in shrubs and trees.
GDM	Black Wallaby *Wallabia bicolor*	dense understorey vegetation (0.0-1.0m strata) with diversity of plant (particularly shrubs) and fungi food items	Wide range of habitats including dry and wet slcerophyll forests and woodlands, heaths, and scrubs. Generally requires some areas with dense thickets/shrubs/tall ferns which provide shelter. Di Stefano et al (2009) found lateral vegegation cover (at 60 cm height) to be an important predictor of wallaby habitat preference while Lunney and O'Connell (1988) found projective shrub cover to an important factor. Both these habitat features characterise understorey density. Will utislise adjacent more open areas in circumstances.	Generally a browsing macropod feeding of a wide variety of shrubs, ferns, sedges, and grasses but also significant mycophagous habits (i.e. fungi).
GDM	Short-beaked Echidna *Tachyglossus aculeatus*	native vegetation habitats with fallen timber, leaf litter, areas of dense groundstorey cover (grasses, sedges, small shrubs), hollow logs, and higher insect prey (i.e. ants or termites)	Inhabits a wide range of habitats including woodlands, forest, scrubs, heaths, and pasture. Favours forest, heath, and scrub habitats with intact understorey and fallen logs with hollows. This species shelters in hollow logs, crevices, burrows ,and leaf litter (Menkhorst 1996). Will also use rabbit burrows to shelter and thick patches of undergrowth, hollow tree stumps, and large tussock grasses.	Insectivorous feeding largely on ants, termites and small invertebrates.
GDM	Southern Brown Bandicoot *Isoodon obesulus obesulus*	native or exotic vegetation forming a dense groundcover (0.2-1.0m height range)	It is found in forest, heath and shrub communities but historically also likely to have occurred in more grassy woodland habitats (Bilney et al 2010). Largely continuous areas of dense vegetation (0.2-1.0m height range) are an important habitat feature. It shelters in a nest of vegetation beneath dense cover but has also been observed using rabbit warrens (SA) and artificial substrates such as tin sheets and farm equipment (Menkhorst and Knight 2001; Paull 2008).	Mostly insectivorous but can also include fungi and tubers within diet (Menkhorst and Knight 2001; Paull 2008). The Southern Brown Bandicoot is both active during the day and night.
GDM	Swamp Rat *Rattus lutreolus*	Dense groundcover (grasses, sedges or low heaths) and close proximity to water or swampy areas (i.e. streams, drains,	Most habitats with dense grassy or sedgy understorey, particularly margins of wetlands or swamps with tall grasses or sedges, along the banks of streams/creeks/rivers or well-vegetated drains, peaty ridges, and wet/damp heaths	Herbivorous diet of stems and seeds but also fungi and insects

Group	Species	Specific Habitat Requirements	Habitat	Resources and Other
		swamps, peats, moist heaths)	(Fox and Monamy 2007).	
REP	Blotched Blue-tongue Lizard *Tiliqua nigrolutea*	dense vegetation composed of sedges or grasses and hollow-bearing logs	Wide variety of habitats including wet and dry sclerophyll forests, woodlands, and heaths. Prefers microhabitats with sedgy and/or grassy understorey with hollow logs. Prefers dense vegetation to move between shelter sites (Koenig et al 2001). Shelters at night under or in logs, ground debris (including wood piles), and also artificial material such as tiles, tin sheets or other building materials.	Omnivorous diet of plant material (leaves, fruits, flowers) insects, carrion, and snails.
REP	Garden Skink *Lampropholis guichenoti*	leaf litter (CWD), grassy areas and rocks or logs	A common species found in the understorey of a wide range of habitats. Forages amongst leaf litter, grass and rock piles in dry and wet sclerophyll forest, moister woodlands, heaths, and also gardens and other modified environments. Prefers rocks or logs for basking.	Insectivorous diet including ants and other small insects. Diurnal lizard.
REP	Glossy Grass Skink *Pseudemoia rawlinsoni*	dense vegetation and moist habitats with nearby lakes, swamps, bogs, or wetlands	The Glossy Grass Skink is found in dense vegetation around the margins of lakes and in swamps and bogs. Is also found around creeks and in salt marsh (Wilson and Swan 2008). Slightly elevated veg around wetland edges humid microhabitats within swampy areas, where it occupies moist habitat underneath the vegetation. (Jenkins and Bartell 1980).	Insectivorous, feeding largely on arthropods. Diurnal habits and live-bearing, with females producing four to eight live young (Jenkins and Bartell 1980).
REP	Lowland Copperhead *Austrelaps superbus*	low vegetation near wet or moist habitats and more abundant prey	Low vegetation near edges of wetlands, marshes, swamps, creeks (i.e. riparian areas) and intact woodland and forests. Usually found close to water (45-188m; Shine 1979) and dependent on abundance of prey populations.	Carnivorous predator active both at day and night even at lower temperatures where other reptiles are inactive. Preys on rodents, frogs, snakes, and smaller skinks.
REP	Swamp Skink *Egernia coventryi*	wetlands or swampy heaths with low dense groundstorey of tussock grasses, logs, rocks, possibly decapods borrows	Occupies cool temperate, low-lying wetlands including swamp margins, swampy heaths, tea-tree thickets and tidal salt-marshes. This species is secretive, and often found in dense low vegetation. In wet habitats, the species shelters in the burrows of decapods crustaceans (Wilson and Swan 2008). It is active by day inhabiting densely-vegetated wetlands, including both freshwater and saltmarsh habitats. Shelters under logs, rocks, thick groundstorey vegetation or in burrows of it's own construction or burrows of decapods (i.e. yabbies, crayfish, crabs)(Clemann 1997). Preference for swampy habitats highlighted the preference of Swamp Skinks for habitats containing tussock life-forms which are typically swampy (Clemann 1997; Robertson 2004).	Opportunistic omnivorous with adults having a diet of fruits, seeds, plant material and juveniles adapting a more carnivorous diet (spiders, beetles, insects and crustaceans).
REP	Tree Dragon *Amphibolurus muricatus*	dry sclerophyll forest, woodlands, and heaths with low dense groundstorey vegetation, small shrubs, and logs preferably with hollows.	Dry sclerophyll forest or woodlands, rocky ridges and coastal heathlands on drier soils and supporting low dense vegetation and fallen timber with hollows. A semi-arboreal lizard species that utilises low shrubs and fallen timber to forage, hibernate and sun-bask. (R. Jenkins& R. Bartell 1980). Will also use areas with dense cover of introduced grasses (Hitchen et al 2011).	Insectivorous, preying on insects and spiders. Lays eggs in shallow burrows or under/within fallen decaying timber (Jenkins and Bartell 1980)
REP	White-lipped Snake *Drysdalia coronoides*	dense groundstorey vegetation of grasses and/or sedges, hollow logs, and abundant prey items (skinks)	Occupies moist habitats and shelters in cracks in the ground, under grass tussocks, fallen timber and scraps of tin. Prefers areas with dense vegetation (sedgy & grassy understorey) and fallen hollow logs.	Carnivorous predator feeding on small lizards (usually skinks) which comprise 86% of its diet. May be more active on warm days but capable of surviving in much cooler environments than

Group	Species	Specific Habitat Requirements	Habitat	Resources and Other
				other snake species.
WB	Crested Shrike-tit *Falcunculus frontatus*	mixture of understorey and overstorey trees, shrubby understorey, loose bark (i.e. stringybarks or ribbon gums), and high insect diversity and abundance.	Mostly associated with dry eucalypt forests and woodlands and more abundant in forested gullies and riparian vegetation. Forages in bark for insects.	Usually breed cooperatively and feeds on insects
WB	Dusky Woodswallow *Artamus cyanopterus*	sparse understorey with high structural complexity, CWD and logs	Dry sclerophyll forests, woodland, and shrublands dominated by eucalypts with open or sparse understorey of eucalypt saplings, acacias and other shrubs (including heath) and ground-cover of grass or sedges or course woody debris (i.e. leaves, dead stems, logs). May also be found in clearings or at edges of forests or woodlands.	Feeds mainly on insects and forages mainly in the air or at flowers of trees and shrubs in small to large flocks of up to 10 birds.
WB	Eastern Yellow Robin *Eopsaltria australis*	larger patches with tall shrub layer, high habitat complexity, numerous vertical stems, and areas with sparse ground cover (or areas of open ground)	Diversity of habitat types with tall shrub layer, sparse ground cover and numerous vertical stems. Prefers higher habitat complexity.	Mostly forage on ground for insects, searching for prey in areas with low vegetation ground cover (open areas) from low stems. In small remnant patches of woodland breeding animals have less food available than those in large continuous patches adversely affecting breeding success. Often killed by cats.
WB	Rufous Whistler *Pachycephala rufiventris*	larger patches with eucalypt (particularly stringybarks) or acacia overstorey, shrubby understorey, and logs	Dry sclerophyll forests, woodland, and shrublands dominated by eucalypts or acacias with an understorey of shrubs. Higher likelihood of occurrence in restoration projects with increasing area of planted native vegetation (habitat patches >20 ha in size had a >60% probability of detection in one study), and increasing number of logs.	Food mostly insects foraging in the foliage of trees, especially eucalypts, at higher levels and rarely ventures to the ground
WB	Varied Sittella *Daphoenositta chrysoptera*	large mature living and dead trees (particularly rough-bark eucalypt trees) at higher densities	Dry eucalypt forests and woodland, usually with rough-barked eucalypt species (e.g. stringybarks or ironbarks) and mature trees with hollows or dead branches. Prefers higher tree densities.	Feeds on arthropods, mainly insects, foraging in the crown of trees on large branches and trunks of live or dead trees but rarely on ground. Usually breeds cooperatively although sometimes in pairs