


SOUTH WEST REGIONAL ECOLOGICAL LINKAGES

Technical Report

Produced by the

Western Australian Local Government Association's
South West Biodiversity Project

and the
Department of Environment and Conservation's
Swan Bioplan

September 2009

WALGA




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Technical Report

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and
Department of Environment and Conservation

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Foreword

The maintenance and restoration of a network of regional ecological linkages throughout the fragmented landscapes of the South West of Western Australia is a key strategic issue for environmental and planning consideration in this region.

Ecological linkages are likely to become an increasingly important component of efforts to reduce the loss on biological diversity over time, particularly given the expected impact of climate change.

As the South West Botanical Province is Australia's only globally significant biodiversity hotspot, we all have a significant responsibility through our planning and decision-making to do what we can to retain this natural treasure.

Ecological linkages are not a new environmental consideration. The importance of ecological linkages is recognised in existing environmental and planning policy documents, but to date with relatively few exceptions linkage issues have not been given the consideration that is appropriate.

The South West Regional Ecological Linkages (SWREL) project has sought to identify a network of regional scale ecological linkages throughout the south west, and develop mechanisms to support their early consideration in environmental and planning decision-making, as one of the key biodiversity factors.

We hope these guidelines will significantly help local governments, consultants and other decision-makers to consider and take measures to retain and where possible enhance the functioning of ecological linkages in the south west of Western Australia.

Dr Paul Vogel
Chairman
Environmental Protection Authority

Mr Gary Prattley
Chairman
Western Australian Planning Commission

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Acknowledgements

The South West Regional Ecological Linkages project is a joint project initiative of the Western Australian Local Government Association's South West Biodiversity Project team and the Department of Environment and Conservation's Terrestrial Ecosystems Branch. The publication of this Technical Report has also involved working closely with the Department of Planning, particularly the South West Region and the Peel Region offices.

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DEC's Terrestrial Ecosystems Branch:

Gary Whisson, Shaun Molloy, Bronwyn Keighery, John Dell, and Bridget Hyder.

The project partners would like to acknowledge and thank the following for their contribution in developing the South West Regional Ecological Linkages Technical Report:

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- **Planning sub-committee**

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Figure 1: South West Regional Ecological Linkages project area

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Part A – Preface

Preface

SWREL Project Objective

The South West Regional Ecological Linkages project is a partnership initiative of the Western Australian Local Government Association's South West Biodiversity Project and the Department of Environment and Conservation's Terrestrial Ecosystem's Branch ("the SWREL project").

The SWREL project provides a response to the issues of fragmentation and climate change through the identification of regional scale ecological linkages.

The objective is to support more effective recognition of ecological linkages in land use planning policy and procedures which will ultimately contribute to retention of native vegetation and fauna habitat and reduce the loss of biodiversity and key ecological functions across the South West project area.

The SWREL Technical Report:

- Explains the need for and rationale behind the identification of natural areas forming the regional ecological linkages for the Project Area, including the methodology used;
- Defines and identifies spatially, the natural areas included in regional ecological linkages in the SWREL project area ("the SWREL");
- Outlines policy recommendations that will support and facilitate the retention and strategic reconnection of ecological linkages and associated ecosystem functions across the landscape.

This Technical Report provides a sound and repeatable ecological framework which can better inform the statutory decision making process when identifying how a change in land use may impact on the viability and ecological linkage function of patches of remnant vegetation.

Project Initiation and Collaboration

In addition to an identified need to address the environmental issue of threats to biodiversity and to demonstrate a response to climate change, there were a number of external drivers for the development of the SWREL project. The Department of Environment and Conservation's Terrestrial Ecosystems Branch saw an opportunity to review ecological linkage theory and develop a suitable methodology to nominate effective, broad scale ecological linkages in the fragmented landscape of the Swan Coastal Plain. The Department of Planning which has long recognised a need for mapping of regionally-significant ecological linkages saw the opportunity to consider the SWREL project products when developing the SW Planning Framework and other regional planning initiatives. At the same time, some local government authority planners and environmental officers were calling for greater clarity regarding responsibilities and roles in considering ecological linkages in the land use planning system and environmental management plans.

The SWREL project was scoped in July 2008 and it was determined the outputs would, in broad terms, be delivered in three phases across three years, namely this Technical Report in Phase 1, the appropriate state and regional policy in Phase 2, and Phase 3 which involves training and awareness-raising to facilitate the implementation of policy in Local Government authorities.

It was proposed that a network of identified regional ecological linkages in the south west area, as depicted in Figure 1 (SWREL project area), would be recognised through a technically-informed, consultative process which involved the participation of stakeholders, including highly-skilled environmental professionals and community organisations as well as relevant local government Authorities and State Government agencies.

Consultation

A formal steering committee and a nominated technical working group were formed to guide and inform the development of this Technical Report. The members of these groups are named on page 4 and include representatives from the Australian Government (Biodiversity and Office of Climate Change),

State Agencies including the Department of Environment and Conservation, Department of Planning, Department of Water and Department of Agriculture and Food, Local Government, the community and the private sector.

In addition significant consultation has been undertaken with local experts in planning and ecology in Local Government, Landcare groups, private consultants and the community. In particular, these people were consulted during the process of identifying ecological assets and planning constraints to be taken into consideration when determining the location of the regional linkage axis line. Briefing sessions were conducted or offered to the indigenous groups of the Wagyl Kaip, the South West Boojarah and the Gnaala Karla Booja. Briefings were also made to the EPA Board, the State NRM Council, the South West DEC regional office, the South West Regional Planning Committee and the South West Country Zone of WALGA.

Methodology

Part B explains the need for and rationale behind the identification of natural areas forming the SWREL for the project area, including the methodology used and supporting appendices.

The SWREL project recognises that:

Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.

The beginning of the methodology process is based around selection of native vegetation patches of key conservation significance using the best available information; then the Proximity Analysis Tool has been applied to define linkage networks; and finally these linkages have been refined through considering input from other experts and local knowledge.

The Proximity Analysis Tool is a new mechanism for providing clarity to the existing policy expectation that ecological linkages will be considered during environmental impact and planning approval processes.

The Proximity Analysis Users Guide (Appendix 4) provides practical instructions on how to use this software application to identify levels of proximity, either from the SWREL axis line, from a particular patch or from a point.

Maps showing the SWREL linkage access lines, patches of remnant vegetation within the SWREL project area and their assigned proximity values can be found in Part D of this report and within the attached supplementary CD. This CD also contains GIS shape files of these patches of remnant vegetation (and their proximity values) and the SWREL linkage axis lines, along with the proximity analysis tool and relevant supporting data. These items have been supplied for land use planners and environmental decision makers to allow a greater understanding of ecological linkages and to facilitate the incorporation of the SWREL project's products and methodology into land use planning processes.

Recommendations for policy

The objective of Part C is to outline changes in land use and environmental policy and procedures that will contribute to the retention of high value native vegetation forming the SWREL and associated ecosystem functions across the South West landscape.

It is acknowledged that during the strategic and statutory planning decision making process, the connectivity value of a patch of native vegetation is just one consideration within a suite of environmental factors to be considered and weighed up along with other land use issues such as sustainability in terms of location, existing and future infrastructure requirements, employment potential and social impact.

Recognition of the SWREL in planning policy and procedures will facilitate State and Local Governments in preparing strategic plans and will assist in the assessment of development proposals to produce more ecologically-effective planning outcomes in regard to both strategic and management objectives for the South West region.

Key Recommendations

Environment Policy
The EPA prepare an Environmental Bulletin that recognises the importance of conserving regional ecological linkages and making reference to the SWREL and the Proximity Analysis Tool assessment process.
Land Use Planning Policy
The WAPC consider releasing a Statement concurrently with the proposed EPA Bulletin on ecological linkages outlining: • the regard to which the WAPC will give recognition to the importance of regional ecological linkages and the contribution that patches of native vegetation make to ecosystem function in the landscape; • particular reference to the SWREL; and • how the Proximity Analysis Tool can be used in the planning process when assessing all matters of planning consideration including other social, economic and environmental factors.
Local Governments incorporate a proximity analysis assessment as part of the application checklist for development applications, subdivision/development guide plans, structure plans or rezoning applications submitted to Local Government Authorities.

Future considerations

It should be noted that strategic and statutory recognition of the environmental value of regional ecological linkages is considered an important step in implementing Phase 2 of the SWREL project.

It will also be important to raise awareness in Local Government authorities and other land use decision making authorities of the implications of the SWREL being recognised in such policy directions.

Whilst the SWREL maps can be used as an independent resource to support planning decision making, the use of the Proximity Analysis Tool to measure impact on ecological function involves a level of understanding of the purpose of the software as a decision support tool. How to correctly use the software is outlined in the Users Guide and how to make a considered and informed analysis is outlined in the Methodology and Flow Charts 1 & 2, however upskilling of officers involved in the land use planning decision making process within State Agencies and Local Government authorities is strongly recommended.

It is further recommended that a review be undertaken in 5 years time with a view to measure the contribution of the project to retaining native habitat and reducing loss of biodiversity and impact on key ecological functions across the South West project area. Ecological linkages are potentially subject to impacts from ongoing clearing and this is an evolving area of policy. As such a review of the SWREL and the effectiveness of the methodology and its application in land use processes should be undertaken at intervals no greater than 5 years.

Key success evaluation questions may include:

- degree of changes made in landuse planning procedures and processes;
- where the project methodology and tools have been used in other projects; and
- the number of recommendations which have been achieved or partially implemented.

Further research in the area of ecological linkages will also better inform the review. Issues may include:

- climate change impact on species spatial patterning to determine preference for linkage direction;
- offsets program implications;
- linkage enhancement guidelines; and
- permeability assessment.

Measure of Success/Project Outcomes

Standard adaptive management procedures require that future reviews of the SWREL methodology, and the products and tools from which it was developed, should commence with three very important questions:

- To what extent have the project's aspirational outcomes been met?
- If not to a high extent, why not?

And, having answered the first two questions;

- How can the project's products and implementation be improved?

Therefore, to facilitate any future reviews of the SWREL project it has been deemed appropriate to look beyond the project's current objectives to nominate those outcomes which are intended to be achieved within the initial review period (6 months to 5 years post publication). In so doing, the degree to which these outcomes have eventuated, along with any unforeseen consequences of the project's implementation, can be used as a measure of success of the SWREL project.

The ecological linkages, tools, and methodology developed by the SWREL project, have been developed with the intent of achieving the following aspirational outcomes:

- The products and principles of the SWREL project will be used to increase the awareness of the value of connectivity, and proximity between patches of remnant vegetation, in land use planning and management within the greater community.
- The products and principles of the SWREL project will be used to support the principles outlined in EPA Guidance Statements 10 and 33, **not** to replace them.
- The products and principles developed through the SWREL project will be incorporated in standard practices within the existing land use planning framework.
- Local Government Authorities, statutory authorities and relevant stakeholders will apply the products and principles developed by the SWREL project in evaluating development applications and planning schemes.
- There are indications that the application of products and principles of the SWREL project has maintained and/or facilitated the movement of organisms and genetic material within and beyond the context of the project landscape.
- The SWREL methodology, data bases and tools will be applied to enhance and facilitate the development of more effective linkage projects at all scales within and beyond the SWREL project area.
- The products and principles of the SWREL project will be trialled for species and community specific biodiversity conservation planning.

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Part B
Methodology
Support Paper

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PART B – METHODOLOGY SUPPORT PAPER

A METHODOLOGY FOR THE SOUTH WEST REGIONAL ECOLOGICAL LINKAGES PROJECT

Technical Support Paper

Shaun Molloy
September 2009

An application of the Local Government Biodiversity Planning Guidelines, Addendum for the South West Biodiversity Project Area (Molloy *et al.* 2007)

Acknowledgments

The author would like to acknowledge the contributions of all who participated in the numerous workshops and meetings. It was their suggestions and advice that made this project possible. In particular the author would like to acknowledge and thank the SWREL project Steering Committee and the SWREL project Technical Working Group for their contribution in developing the South West Regional Ecological Linkages and the supporting methodology.

The author would also like to acknowledge the contributions of Jodie Wood, Sue Wallrodt, John Dell, Gary Whisson, Geoff Barrett, Simon Hall and Teik Oh.

Executive Summary

Purpose

The Western Australian Local Government Association's (WALGA) South West Biodiversity Project (SWBP) in collaboration with the Department of Environment and Conservation's (DEC) Swan Bioplan Project and relevant State Agencies propose to recognise a series of regionally significant ecological linkages across the South West region to be known as the South West Regional Ecological Linkages (SWREL).

Note: Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.

Objectives

The SWREL project intends to deliver the following objectives:

- To explain the need for, and rationale behind, the development of the linkages in a Technical Report which describes the methodology used to identify them;
- To define and identify, spatially, the areas proposed for inclusion in the Ecological Linkages;
- To facilitate the implementation of Ecological Linkages into State and Local Government policy directions in the SWREL project area and to raise awareness of these linkages in regional planning processes.

Background

The south-western corner of Australia is recognised internationally as a "biodiversity hotspot", not only for the biological richness and uniqueness of species but also for the level of threat. It is the only international hotspot in Australia recognised by the International Union for the Conservation of Nature. Currently, increasing residential and rural-residential subdivisions, inappropriate fires and ongoing demands for expanded infrastructure contribute to an ongoing decline in the extent of native vegetation throughout the region.

Since European settlement in south-western Western Australia both the condition and extent of native vegetation have continued to decline. Approximately 22% of the pre-European extent of native vegetation remains on the southern Swan Coastal Plain and much of that remnant vegetation is to some extent degraded.

Landscape fragmentation

A fragmented landscape is one where clearing has occurred to the extent that once-continuous native vegetation has been reduced to small, insular patches of remnant vegetation, thereby reducing habitat and isolating populations of native species. Therefore, the ability of a patch to persist as a functional ecological assemblage is largely influenced by its size, proximity to other patches and the quality of the linkage between them.

Climate change

The current extent and condition of native vegetation in south-western Western Australia has resulted in a landscape which is fragmented to such an extent that a substantial loss of native species is currently occurring. It is expected that climate change, particularly the dramatic reduction in rainfall and increased mean temperature predicted in the state's South West, will exacerbate these impacts.

What is an Ecological Linkage?

For the purposes of this project an ecological linkage will be defined as: *A series of (both contiguous and non-contiguous) patches which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape.*

The Purpose of Ecological Linkages

The purpose of an ecological linkage is to recognise a patch's additional value to biodiversity conservation as a result of its close proximity to other patches. This recognition of the value of connectivity allows biodiversity managers and planners to achieve more (ecologically) effective planning outcomes in regard to both strategic and management objectives.

Regional Ecological Linkages

Link protected patches of regional significance by retaining the best (condition) patches available as stepping stones for flora and fauna between regionally significant areas. This increases the long-term viability of all the constituent areas. Regional linkages also need to facilitate connectivity to patches of regional significance situated outside of the SWREL project area.

1. Introduction

Note: Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.

1.1 Purpose

The Western Australian Local Government Association's (WALGA) South West Biodiversity Project (SWBP) in collaboration with the Department of Environment and Conservation's (DEC) Swan Bioplan Project and relevant State Agencies propose to recognise a series of regionally-significant Ecological Linkages across the South West region of Western Australia to be known as the South West Regional Ecological Linkages (SWREL) project. To do this the project partners have produced this support paper to more fully explain and better demonstrate the principles behind their methodology.

In recognising ecological linkages the SWREL project does not detract from any existing ecological value assigned to any patch or biodiversity conservation asset; rather, its purpose is simply to recognise the value to ecological function that comes from close proximity between patches when planning and managing biodiversity at both the patch and landscape scales.

1.2 Objectives

The SWREL project intends to deliver the following objectives:

- To explain the need for and rationale behind the development of the Ecological Linkages in a technical report which describes the methodology used in identification;
- To define and identify spatially, the areas proposed for inclusion in the Ecological Linkages;
- To facilitate the implementation of Ecological Linkages into State and Local Government policy directions in the SWREL project area (Figure 1 of the Technical Report) and to raise awareness of these linkages in regional planning processes.

An overview of the South West Regional Ecological Linkages for the entire SWREL project area is shown in Figure 1 hereof. More detail can be seen in Part D of the Technical Report.

1.3 Background

The south-western corner of Western Australia is recognised internationally as a "biodiversity hotspot", not only for the biological richness of species and their uniqueness but also for the level of threat faced by that biodiversity (Myers *et al.* 2000). It is the only biodiversity hotspot in Australia recognised by the International Union for the Conservation of Nature.

Historically, the clearing of native vegetation for agriculture and residential purposes has resulted in losses of large areas of bushland. Since European settlement in south western Western Australia both the condition and the extent of native vegetation continues to decline. Currently, approximately 22% of the pre European extent of native vegetation remains on the southern Swan Coastal Plain and much of that remnant vegetation is to some extent degraded (Molloy *et al.* 2007).

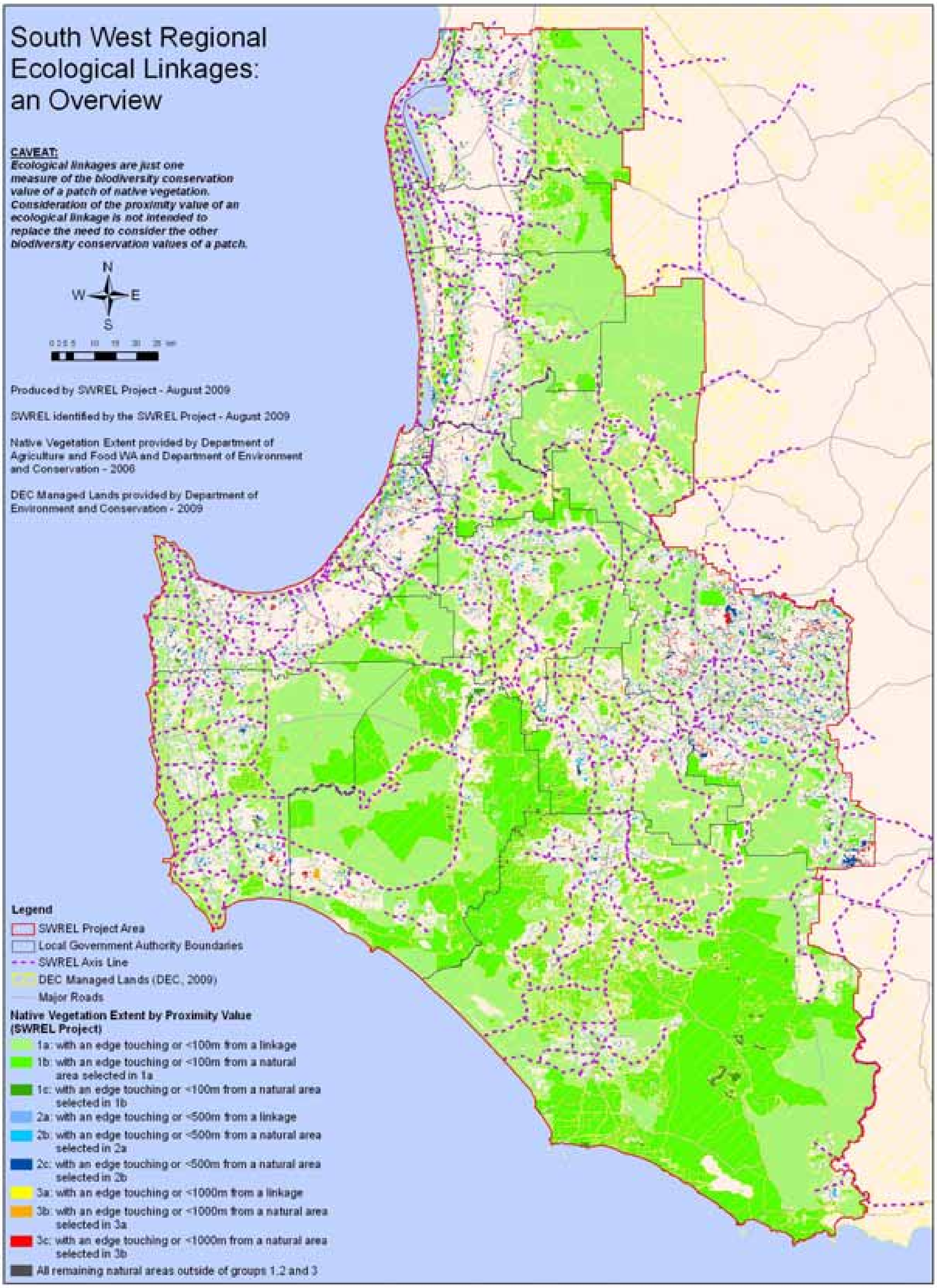

Figure 1: An overview of the South West Regional Ecological Linkages.

There are a number of factors which continue to threaten biodiversity in this region. Currently, increasing residential subdivision, inappropriate fire (in regard to changes in seasonality, frequency and intensity) and the ongoing demand for expanded infrastructure, make a significant contribution to the threatening processes which have brought about the ongoing decline in both the extent and quality of this region's remnant vegetation, and in those native species which rely on that vegetation for their survival (EPA 2007, How and Dell 1993 McKenzie *et al.* 2003, WAPC 2008).

1.4 Climate Change

The current extent and condition of native vegetation in south-western Western Australia has resulted in a landscape which is fragmented to such an extent that a substantial loss of native species is already occurring (EPA 2007, How and Dell 1994, How and Dell 1993, Kitchener and How 1982, Kitchener *et al.* 1982,). It is expected that climate change, particularly the reduction in rainfall and increases in mean temperature predicted in the state's South West, will exacerbate these impacts (CSIRO 2007, Dunlop and Brown 2008, EPA 2007). Therefore, in conjunction with careful conservation planning and management, the retention and restoration of well-planned and adequately managed ecological linkages will be important to the survival of remaining native species.

Note: Although ecological linkages as designed through the SWREL Project have been mindful of the impacts that climate change may have on the regional ecology, the future impacts of climate change on the spatial requirements of the region's biota are not, as yet, well understood. For this reason it is considered appropriate that any future reviews of this methodology, and/or any ecological linkages designed through its application, be undertaken in light of a current and well informed understanding of climate change and its impacts on the regional ecology.

2. Fragmentation

2.1 What is landscape fragmentation?

The ability of a patch of remnant vegetation to persist over a protracted period as a functional ecological assemblage is largely influenced by its size, proximity to other patches, the quality of the linkage between individual patches and the scale of threatening processes. Size, proximity and linkage quality largely influence the movement of organisms (and consequently the flow of genetic material) and the maintenance of ecological processes within, and between, patches. For the purposes of this document, a fragmented landscape is considered to be one where clearing has occurred to the extent that once continuous native vegetation has been reduced to small, insular patches of remnant vegetation, thereby reducing habitat and limiting interaction between populations of native species. (Hobbs and Yates 2003, Fischer and Lindenmayer 2007, Hobbs and Saunders 1993, Lambeck 1999, Coates *et al.* 2007).

2.2 Impacts from fragmentation

Figures 2 and 3 represent conceptual models of the pressures, processes and interactions through which fragmentation results in the loss of native species. Although both models have been designed to meet different purposes and applications, they both clearly demonstrate a complex interaction of cause and effect through which fragmentation results in an ongoing decline in, and subsequent loss of, populations and species. Both models also demonstrate that with each loss the capacity for persistence amongst remaining native species is, in general, diminished (Lindenmayer *et al.* 2008).

When species populations become depleted, the biotic interactions (competitive, mutualistic, contramensal and amensal) which are fundamental to maintaining ecosystem processes are impaired or lost (Dickman 2003). The loss of species from a patch also leaves an ecological vacuum which, in turn, encourages invasion from pest (usually exotic) plant and animal species (Cheal and Coman 2003). Further, this loss of species can result in changes to abiotic aspects within the ecosystem such as; exposure to light and wind, and changes to groundwater hydrology and soil structure (King and Hobbs 2006). Therefore, the loss of one or more species can have impacts on the viability of remaining species. In this way landscape fragmentation can facilitate extinction cascades (Fischer and Lindemayer 2007) which, in turn, can result in a system's eventual collapse, and/or the transformation of that system into another stable but significantly altered, and often, degraded state (Holling 1973).

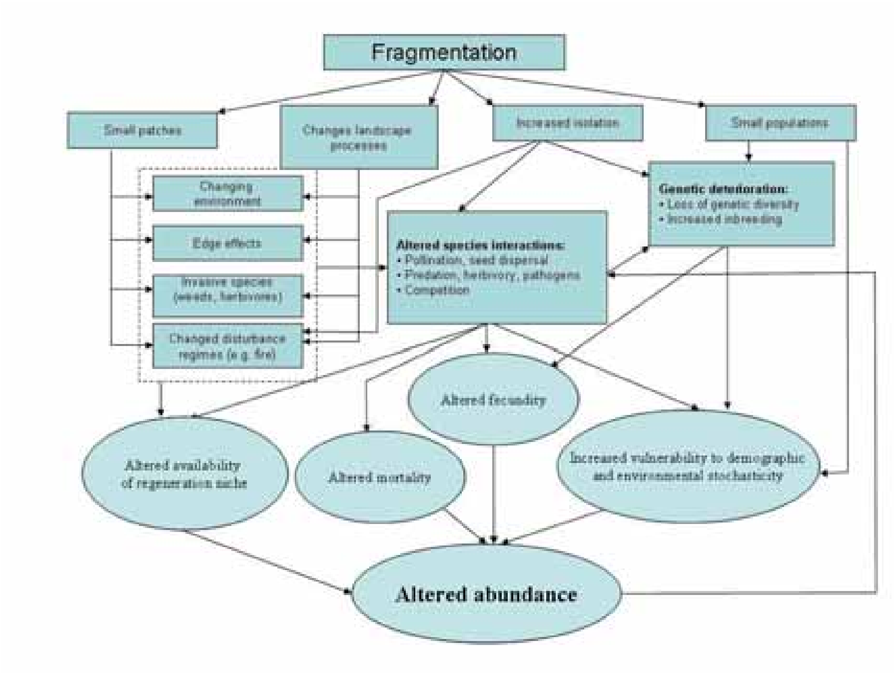

Figure 2: ***Conceptual framework of major factors influencing plant populations in fragmented landscapes (adapted from Hobbs and Yates 2003).***

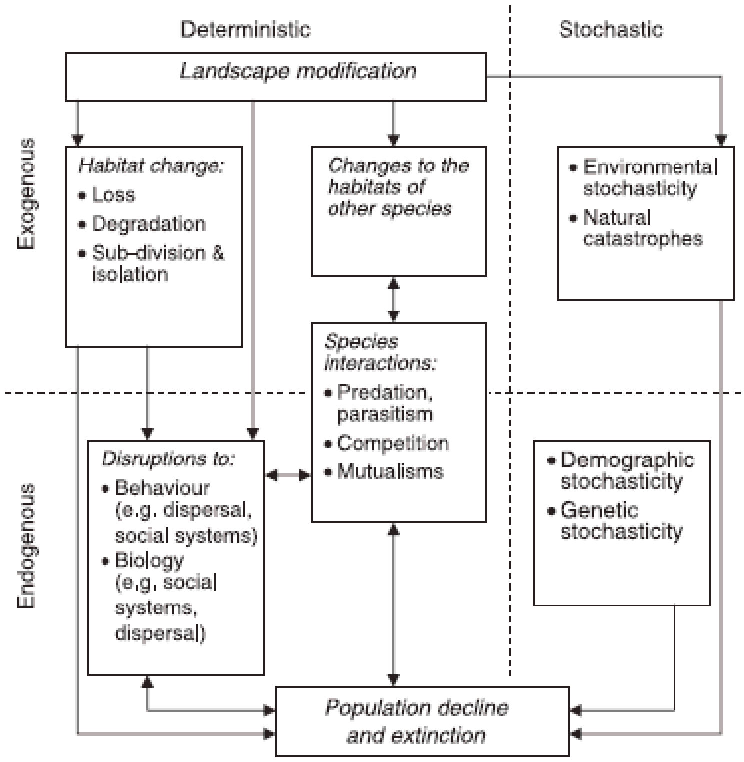

Figure 3: ***Threatening processes arising from landscape modification such as fragmentation can result in species and population declines (Fischer and Lindenmayer 2007). Threatening processes are broadly classified as deterministic versus stochastic and endogenous versus exogenous. This diagram demonstrates how predictable and random responses to internal and external disturbances tend to have a detrimental effect on native species. This results in the ongoing loss of native species from patches.***

Where remnant vegetation is degraded to the point where it is significantly reduced in structure (for example; to an open canopy of trees and large shrubs over weeds) only a reduced number of native species will use these areas for dispersal between more suitable patch or habitat purposes (Kitchener *et al.* 1992, How and Dell 1994, Tischendorf and Fahrig 2000). Further, significant degradation of vegetation structure may leave species exposed to a greater than normal risk from predators or consumers. In this way, degraded and poorly re-vegetated linkages can become an ecological sink having a significant negative impact on native species populations within a landscape (Catling *et al.* 2000, Bennett 2003, Saunders *et al.* 1991, Fischer and Lindenmayer 2007).

When a given habitat type approaches approximately 30% of its original extent there is generally a rapid decline in the number of species that can persist in that landscape. This degree of clearing usually results in a highly fragmented landscape within which there are declining resources and a corresponding break down in ecological processes and functions (Smith and Sivertsen 2001, Radford *et al.* 2005, Fahrig 2003, Smith *et al.* 2000, Fischer and Lindenmayer 2007, Possingham 2000, Andrén 1994). When habitat becomes fragmented to this level the potential for extinction cascades becomes greatly increased and the spatial arrangement of patches across the landscape becomes critically important for maintaining biodiversity (Fischer and Lindenmayer 2007, Bennett 2003, Saunders *et al.* 1991). For these reasons 30% of original extent of vegetation types is generally accepted as a threshold figure below which the clearing of native vegetation should not occur (EPA 2006).

2.3 Amelioration

In response to the threatening processes associated with landscape fragmentation, the capacity for the long term survival for a diverse and sustainable suite of species can be significantly improved by:

- Providing access to a greater home range and consequently a greater number and diversity of resources (Bennett 2003, Fahrig 2003, Lambeck 1999, Smith and Sivertsen 2001);
- Conserving larger and more viable populations (Levins 1969, Kitchener *et al.*1982);
- Enabling species dispersal and migration, thereby facilitating metapopulation movements (Levins 1970, Hanski 1990, Fischer and Lindenmayer 2007);
- Providing a more representative mosaic of habitat types and structures (Davis 2008, Fahrig 2003, Lambeck 1999, Saunders *et al.*1991, Fischer and Lindenmayer 2007, Kitchener *et al.* 1982);
- Facilitating greater genetic variation within species, attracting a diverse suite of pollinators (Coates *et al.* 2007, Hobbs and Yates 2007); and,
- Increasing the capacity of species and communities to persist through adapting to disturbances such as those anticipated as a result of climate change (Saunders *et al.* 1991, Slatkin 1985, Smith and Sivertsen 2001, Fischer and Lindenmayer 2007, Dunlop and Brown 2008).

Therefore, if all other factors are equal, the viability of a patch and its capacity to support a greater diversity of species is improved:

- Where the condition of a patch is good or better (Keighery 1994);
- The closer it is to another patch of good or better condition;
- The greater the number of patches within close proximity to each other; and
- Where a heterogeneous and representative (of the original landscape) suite of habitat types (in regard to factors such as structure, proportion and diversity) is maintained.

3. Ecological Linkages

3.1 Connectivity

Within the context of landscape fragmentation the definition of connectivity varies with perspective. Connectivity in landscape ecology relates to the maintenance of ecological function and process at both the patch and landscape scale, while connectivity in metapopulation ecology relates to maintaining the needs of individual populations and ecological assemblages (Hanski 1990, Tischendorf and Fahrig 2000).

An Ecological Linkage should therefore be designed for a specific purpose. The purpose of the SWREL project is to support the maintenance of biodiversity at the landscape scale through informed decision

making. For this reason the landscape ecology perspective has been chosen. Therefore the SWREL project is based on fundamental landscape ecology principles. As such, it complies with the simple premise that:

> *The ecological viability and biodiversity conservation value of the whole of a patch which <u>touches</u> or comes within <u>close proximity</u> to another patch or patches will probably be greater than that of a comparable patch which is isolated (Lindenmayer et al. 2008, Tischendorf and Fahrig 2000, Watson et al. 2001).*

3.2 What is an Ecological Linkage?

For the purposes of this project an Ecological Linkage will be defined as:

> *A series of (both contiguous and non-contiguous) patches which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape.*

Although most ecologists agree about the importance of various kinds of connectivity, disagreement arises when connectivity is simply equated with corridors or linear strips of a particular type of vegetation that link patches of (what is usually) a similar type of vegetation (Lindenmayer *et al.* 2008).

Note: Ecological Linkages are not to be confused with biodiversity, or wildlife, corridors. Biodiversity corridors are generally considered to be linear strips of remnant vegetation or revegetation which directly connect patches. Instead, Ecological Linkages, as determined by the SWREL project use axis lines which have been specifically designed to be used as a basis for recognising the ecological value of spatial relationships between patches of remnant vegetation when planning and managing biodiversity at both patch and landscape scales (Lindenmayer *et al.* 2008, Fischer and Lindenmayer 2007).

The following figures serve to provide an example of an ecological linkage as defined by the SWREL project:

Figure 4:* *Depicts patches remnant vegetation within a fragmented landscape with 2 major biodiversity conservation assets (DEC reserves) highlighted.

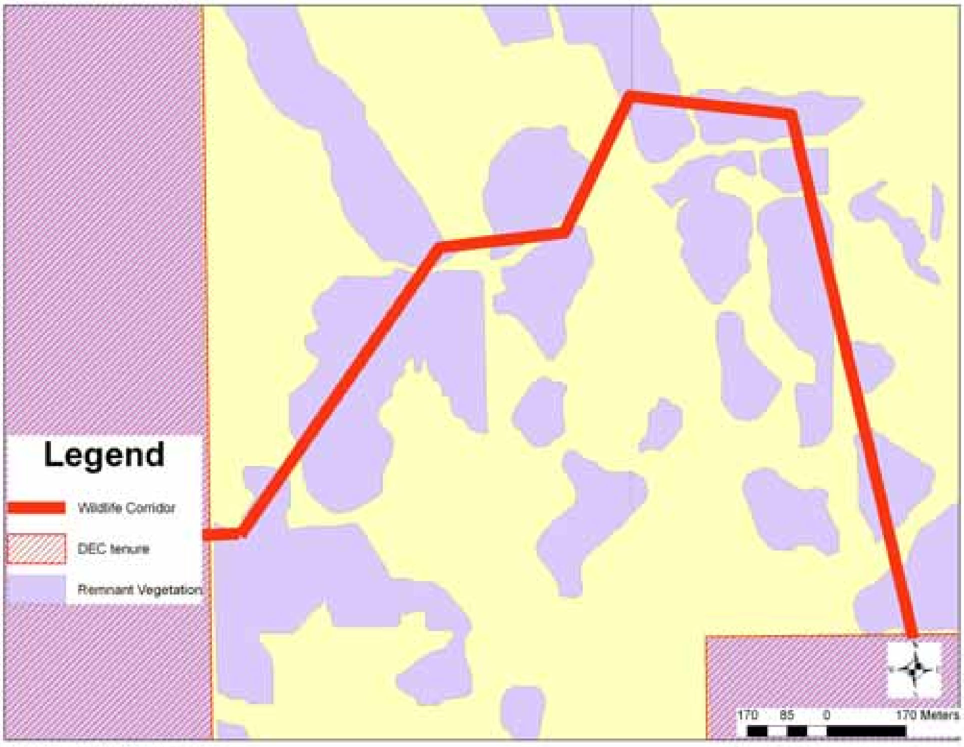

Figure 5: ***The same landscape depicted in Figure 4 but with a linkage marked. With biodiversity corridors, similar lines are often used to mark linear areas within which remnant vegetation protection and revegetation activities are undertaken.***

Figure 6: ***Ecological linkage axis lines are used to identify the whole of patches of remnant vegetation that have edges which touch or come within a nominated proximity of the linkage.***

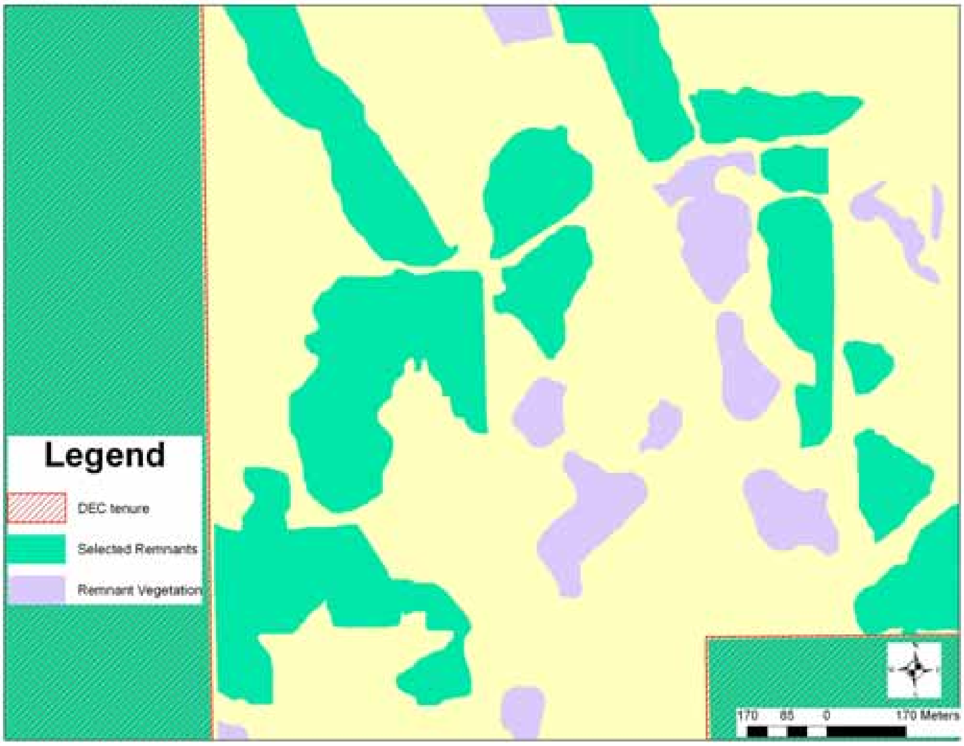

Figure 7: ***Having used the ecological linkage axis line (as demonstrated in figure 6) to identify patches of remnant vegetation with a high connectivity or linkage value, the emphasis for biodiversity planning and conservation becomes the protection and management of the patches identified using the linkage axis line, rather than within the area defined by the line itself, as is often the case with biodiversity corridors.***

3.3 The purpose of Ecological Linkages

The purpose of an Ecological Linkage is the recognition of a patch's additional value to biodiversity conservation that results from its close proximity to other patches. This recognition of the value of connectivity allows biodiversity managers and planners to achieve more (ecologically) effective planning outcomes in regard to both strategic and management planning objectives. For this reason the identification and management of Ecological Linkages should not be regarded in isolation of other biodiversity values, but rather in consideration of other regional and local biodiversity conservation values and initiatives.

Having recognised Ecological Linkages, patches of remnant vegetation with a high landscape connectivity value can be identified and assigned (in consideration of other conservation planning initiatives and values) an appropriate level of consideration in regard to management and retention options (Molloy *et al.* 2007). It is also intended that less viable patches with a high landscape connectivity value will be considered for appropriate management activities. It is intended that such activities will be undertaken to; improve their condition, increase their size, and to buffer them from threatening processes. This will enable these (previously) less viable patches to better function as stepping stones linking larger patches and/or regionally significant biodiversity conservation assets.

It should also be noted that revegetation projects undertaken to physically connect patches within the Ecological Linkage (through corridors) are generally considered to be of a lower priority than protecting and conducting landscape rehabilitation in existing patches (Del Marco *et al.* 2004, Dunlop and Brown 2008, Mackay *et al.* 2008, Molloy *et al.* 2007).

3.4 Regional Ecological Linkages

Designated Regional Ecological Linkages serve to link protected patches of regional significance (as defined in Molloy *et al.* 2007) by identifying the best condition patches available as stepping stones for flora and fauna between regionally significant areas. This increases the long-term viability of all the constituent areas. Regional linkages also need to connect regionally significant patches and biodiversity conservation assets which are situated outside the study area (Del Marco *et al.* 2004, Molloy *et al.* 2007).

3.5 Local Ecological Linkages

This methodology can be used to define a network of Local Ecological Linkages which aim to link protected locally-significant patches to; each other, regionally significant patches and Regional Ecological Linkages. Local Ecological Linkages are an important part of improving the viability of patches that may be; too small, of an unsuitable shape, or in a condition which would significantly lessen their ability to otherwise persist. The viability of patches will be improved by including as many viable patches within each link as possible and by maximising the number of connections to each area.

Note: The development of Local Ecological Linkages will not be a function of the SWREL project; however, it is intended that the methodology developed for this project along with the recognition of regional Ecological Linkages will assist Local Governments in the development of Local Ecological Linkages.

4. Identification of Ecological Linkages

4.1 Factors for consideration

There are potential advantages and disadvantages to be considered when establishing Ecological Linkages:

Advantages:

- More ecologically effective and environmentally sustainable planning and development (Brooker *et al.* 2008);
- Increased migration rates, leading to: maintaining (or increasing) species richness, increased population sizes, a mitigation of inbreeding depression, and facilitating recolonisation following local extinctions (Levins 1970, Hanski 1990, Fischer and Lindenmayer 2007);
- Increased foraging and home range areas (Lambeck 1999);
- Providing cover for escape from predators between patches (Catling *et al.* 2000, Pope *et al.* 2005);
- Providing a mix of habitats at different successional stages (Catling *et al.* 2000, Pope *et al.* 2005);
- Providing alternative refuge from major disturbances (Dunlop and Brown 2008, Pope *et al.* 2005, Diamond 1975, Fischer and Lindenmayer 2007); and
- Providing greenbelts to limit the effects of urbanisation on species and ecological communities (Mason *et al.* 2006, Brooker *et al.* 2008).

Potential disadvantages of poorly designed linkages:

- Increased migration can facilitate the spread of diseases, pests or weeds (Dunlop and Brown 2008, Diamond 1975, Panetta and Hopkins 1991);
- Increased migration can also lead to a decrease in the level of genetic variation between populations and subpopulations (Diamond 1975);
- Facilitating the spread of fire or other abiotic disturbances (Dunlop and Brown 2008);
- Increase exposure of fauna to anthropogenic impacts (Piper and Catterall 2006, Loney and Hobbs 1991); and
- The creation of predator based ecological sinks (Piper and Catterall 2006).

When evaluating the connectivity value of a patch, the needs of those species which are likely to use that patch either as habitat, or as part of a linkage, must be considered (Lambeck 1999, Lindenmayer *et al.* 2008). Species needs which should be considered include; access to an appropriate suite of resources, threats, species mobility, availability of pollen and/or seed vectors, life history [for example; quenda, *Isoodon obesulus*, might disperse as juveniles across a gap in vegetation that an adult would never cross (Stoddard and Braithwaite 1979, Claridge and Barry 2000, Catling *et al.* 2000)] and required frequency of genetic exchange (some species require broad scale mixing of the population's gene pool every few generations while other species may require continuous mixing (Slatkin 1985)).

Effective ecological linkages should incorporate a regionally representative array of ecological assemblages and habitats. This will facilitate the persistence of a diverse and regionally representative suite of native flora and fauna species (Bennett 2003). For example, using only waterways as Regional Ecological Linkages will limit the movement of flora and fauna to those species that can use aquatic or riparian habitat. Conversely, a dramatic change in habitat type within a linkage may prove to be a barrier to the movement of biota; it may even function as an ecological sink. For example, an abrupt change from tall closed woodland to a low shrubland may prevent the movement of arboreal fauna by forming a physical or behavioural barrier, and may expose species to hazards such as an increased risk of predation (Jones *et al.* 2004, Mason *et al.* 2006, and Pope *et al.* 2005).

Generally, most species have their own well defined habitat requirements. This means that each species relies on a limited set of ecological assemblages within the greater context of a heterogeneous landscape for its resources (Lindemayer *et al.* 2008). Consequently, although linkages should be structurally heterogeneous they should facilitate movement between areas which are similar in structure and species composition (Bennett 2003, Hobbs and Saunders 1993, Environmental Protection Authority 2007, and Lambeck 1999).

In summary; an effective Ecological Linkage connects a suite of patches of remnant vegetation which are representative (in regard to factors such as structure, species composition and proportion of assemblage type) of those found in the natural landscape. They should be designed to minimise barriers and threats to native flora and fauna species, and they should facilitate movement of intended species and genetic material.

Note: ***"The importance of looking at the region's natural areas as an integrated ecological system is recognised, and the maintenance or establishment of linkages is given a high priority. Areas adjacent to, or contiguous with, different communities may provide a necessary combination of habitats for particular fauna species".*** **EPA Guidance Statement 10 (EPA 2006).**

4.2 Guiding principles

The following aspirational principles have been proposed for the identification of Ecological Linkages:

- The greater a patch's area the greater its capacity to maintain a larger and more viable suite of species (Menges and Dolan 1998, Coates *et al.* 2007); therefore where available, patches should be at least 10ha in size and of good (Keighery 1994) or better condition (Freudenberger 1999 and 2001, Lindenmayer *et al.* 2008).
- Continuous stands of native vegetation with a preferred width of >500 m (where these are available) should be chosen where appropriate (Davis 2008, Saunders *et al.* 1991, Major *et al.* 1999);
- Thin remnants (<100m wide) should be avoided where practical (Mason *et al.* 2006, Major *et al.* 1999);
- Heterogeneity in patch structure should be sought (Fischer and Lindenmayer 2007, Lindenmayer *et al.* 2008, Hanski 1990);
- The widest possible diversity of habitat types should be sought within a linkage (Claridge and Barry 2000, Catling *et al.* 2000) with similar habitats (preferably) less than 1000m apart (see section 5 of this document);
- Open canopies over a highly disturbed understorey may be of little value except for highly mobile species (Claridge and Barry 2000, Catling *et al.* 2000, Lindenmayer *et al.* 2008);
- Where continuous stands of native vegetation are not available, linkages made up of patches which form stepping stones between larger intact patches should be selected (Lindenmayer *et al.* 2008, Lambeck 1999, Brooker *et al.* 2008, Fischer and Lindenmayer 2007);
- The target maximum between patches is less than 1000 m (Claridge and Barry 2000, Catling *et al.* 2000). Although closer proximities between patches are preferred distances more than1000m will be considered in highly fragmented landscapes (Brooker *et al.* 2008) (see section 5 of this document);
- The number of linkages connecting to any given patch should be maximised as this improves overall connectivity across the landscape and long-term viability of individual patches (Lindenmayer *et al.* 2008);

- Patches should be chosen whose shapes minimise edge effects (Lindenmayer *et al.* 2008); and
- The potential effects of stochastic and deterministic abiotic processes (such as the impacts of wind and water movements and their potential for secondary affects such as dryland salinity, erosion and acidification) within a landscape should be considered (Fischer and Lindenmayer 2007).

The following areas have been given high priority for inclusion in the linkage:

- Patches forming the most direct links with regionally significant patches or other identified Ecological Linkage;
- Ecological Linkages should be selected whose directions facilitate normal migration, and aid in the adaptation of species and assemblages to climate change (Molloy *et al.* 2007, Mackey *et al.*2008, Dunlop and Brown 2008);
- DEC Conservation Estate (as identified through the relevant DEC GIS layer (see Table 1)) and patches which contribute to the maintenance, function and viability of; DEC Managed Estate, System 6 areas, other areas of regional biodiversity conservation value and locally significant patches greater than 10 ha. This will buffer generally large, viable, already protected patches and areas of recognised high conservation value, thereby enhancing their viability;
- Riparian vegetation along waterways including an appropriate buffer of non-riparian vegetation (it should be noted that the use of riparian vegetation should be considered in light of the need to maintain structural heterogeneity within the landscape);
- Patches that enhance the viability of significant biodiversity conservation assets and initiatives through conserving both species and structural heterogeneity and therefore habitat values (Kitchener *et al.* 1982, How and Dell 1994, and How and Dell 1993); and
- Patches at high points in the landscape that are in the line of sight of other patches. Line of sight is important for species dispersal and home range utilisation (Hehl-Lange 2001, Alderman and Hinsley 2007).

Note: These principles are aspirational in nature and, given the extent of fragmentation across much of the SWREL project area, may not be practical in all landscapes. For example; some landscapes may not have sufficient patches with an area of >10ha or a width of >100m available to form a linkage or suitable patches may be >1000m apart. In such instances decisions will be made by technical specialists on a case by case basis.

4.3 The Identification of Ecological Linkages: a methodology.

Having identified factors for consideration and guiding principles, the following methodology for determining the South West Regional Ecological Linkages was used.

1. The identification and prioritisation of suitable patches in accordance with the SWREL project's guiding principles and factors for consideration.

2. The listing of high-priority biodiversity conservation assets. This includes, but is not limited to;

- all known sites for threatened and priority flora, fauna and communities,
- conservation category, resource enhancement and conservation treaty/agreement wetlands,
- appropriate water courses,
- DEC Conservation Estate (as identified through the relevant DEC GIS layer (see Table 1)),
- other formal and informal reserves including private and local government vested,
- areas recognised as being of a high conservation value through other biodiversity conservation initiatives.

(See list of GIS data sets used, Table 1)

3. The information gathered in steps 2 and 3 was produced in map format and used for the identification of potential Ecological Linkages by applying the factors for consideration and guiding principles listed above.

4. Potential ecological linkages were then evaluated using the proximity analysis method (Box 1, Appendix 1) and a Marxan Analysis (Appendix 3) to assess their effectiveness.

5. A draft set of regional ecological linkages was prepared for stakeholder consultation.

6. Ecological linkages were assessed and evaluated by the SWREL project's Technical Working Group (TWG) and recognised stakeholders, and alterations made as required (see Table 2).

7. A second proximity analysis was conducted.

8. Agreement was sought from members of the TWG under guidance from the project's Steering Committee.

9. Nomination of regionally-scaled ecological linkages.

List of GIS Data Sets Used in SWREL

Theme	Title	Custodian	Meta Data Date
Imagery	Orthophotography – Image Tiles (1:50,000 double format sheets)	Department of Land Information WA (DLI)	1991 to 2006
	Google Earth	Google	Ongoing
Remnant vegetation Mapping	Swan Bioplan Mapping Remnant vegetation mapping (No meta data yet available)	Environment and Conservation WA (DEC) Swan Bioplan Project.	N/A
	Remnant Vegetation	DEC/Department of Agriculture and Food WA	September 2007
Biodiversity conservation on private lands	National Trust of Australia (WA) Nature Conservation Covenant Sites	National Trust of Australia WA	August 2008
	DEC Covenant Sites	DEC	October 2008
	Land for Wildlife Site Polygons	DEC	November 2008
Threatened Species and Communities	Declared and Endangered Flora	DEC	August 2006
	Threatened and Priority Fauna Database	DEC	September 2007
	Threatened Ecological Community Boundaries	DEC	Jan 2009
Vegetation Complex Mapping	Native Vegetation Extent by Vegetation Complex	Western Australian Local Government Association's (WALGA) South Western Biodiversity Project (SWBP)	2007
Linkage Planning	Greater Bunbury Region Draft Regionally Significant Ecological Linkages	DEC	December 2003
	Regional Ecological Linkages for the Perth Metropolitan Region	WALGA	September 2003
Reserve and DEC vested lands	Existing DEC Managed Lands and Waters	DEC	June 2008
	Other Crown Reserves	Landgate	June 2008
	Fauna Habitat Zones	DEC	Dec 2007
Proposed Reserves	EPA Proposed Conservation Reserves (Red Book, Systems 1-12)	DEC	July 2006
Wetlands	CALM Operational Graphics (COG) Hydrography Digital Acquisition Program (DAP)	DEC	October 2008
	Important Wetlands In Australia	DEC	February 2001
	Geomorphic Wetlands of the Swan Coastal Plain	DEC	October 2008
	RAMSAR sites in WA	DEC	August 2007
	(Geodata) Drainage Lines	Geoscience Australia	October 2003

List of GIS Data Sets Used in SWREL			
Theme	**Title**	**Custodian**	**Meta Data Date**
Vegetation Extent	Tuart Woodlands	DEC	August 2005
	Wandoo Occurrence	DEC	August 2008
	DEC Flora survey's (Gibson *et al.*, EEEA and Whicher)	DEC	Not available
	Old Growth Forest	DEC	December 2003
Topography	(Geodata) Contours 5-10m	Geoscience Austalia	Septmber 2004
Geology	1:500,000 Regolith Map of Western Australia	Geological Survey of Western Australia	June 2003
Infrastructure	WA Townsites (Polygon and Point)	Department of Land Information	September 2008
	Geodata Pipelines	Geoscience Australia	December 2005
	Geodata Railway Lines	Geoscience Australia	December 2005
	Geodata Road Lines	Geoscience Australia	December 2005
Climate	Average Annual Rainfall of Western Australia	Bureau of Meteorology	December 1994
Regional Forest Agreement	Forest Management Plan 2004-2013 Proposed Tenure	DEC	August 2005
Cultural	Cultural Heritage Sites	Heritage Commission of WA	August 2005
	Aboriginal Site Register System	Department of Indigenous Affairs	December 2008

Table 1: GIS data sets used in determining the SWREL

4.4 The Technical Working Group and Stakeholder Engagement

The SWREL project Technical Working Group (TWG) included representatives from the Australian Government (Biodiversity and Office of Climate Change), State Agencies including the Department of Environment and Conservation, Department of Planning, Department of Water and Department of Agriculture and Food, Local Government, the community and the private sector. The TWG has provided valuable input into the process of developing the methodology, identifying the linkages and mapping.

Information gathered through the TWG has been enhanced by an extensive process of consultation with recognised stakeholders.

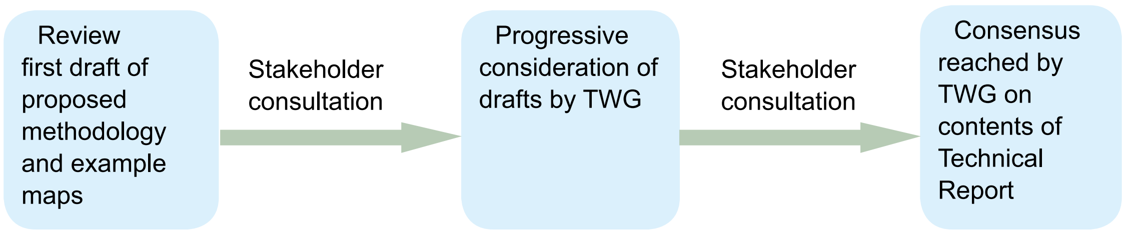

Figure 8: Role of the Technical Working Group

To take the mapping process beyond a desktop exercise significant stakeholder consultation was undertaken to include input from local experts with on ground experience and first-hand knowledge of the project area. The Technical Report has incorporated specialist knowledge from relevant professionals throughout (and beyond) the project area.

The consultation process has taken the form of 37 meetings and briefings (in the period June 08 until publication) with participation from more than 150 individuals. The information gained through these meetings has also been supplemented by feedback gained from innumerable private information sessions and a significant amount of feedback provided by individuals through other means. Although not all feedback has been able to be incorporated in the final Technical Report, comments and opinions have been accommodated wherever possible and practical to do so. The information provided through this consultative process has contributed greatly to the value of the SWREL project and its products.

Ecological Linkage Mapping and Proximity Analysis

Map 1: Patches and other biodiversity conservation assets of regional significance.

Map 2: Patches and other biodiversity conservation assets of regional significance (Map 1) with Regional Ecological Linkages axis line overlaid

Map 3: Proximity analysis Level 1

The whole of all patches with a proximity to a Regional Ecological Linkage of the following scales:

a) With an edge touching or <100m from a Regional Ecological Linkage;

b) All other patches with an edge touching or <100m from a patch selected in a); and,

c) All other patches with an edge touching or <100m from a patch selected in b)

Map 4: Proximity analysis Level 2

The whole of all patches and Regionally Significant Assets with a proximity to a Regional Ecological Linkage of the following scales:

a) With an edge touching or <500m from a Regional Ecological Linkage;

b) All other patches with an edge touching or <500m from a patch selected in a); and,

c) All other patches with an edge touching or <500m from a patch selected in b)

Map 5: Proximity analysis Level 3

The whole of all patches and Regionally Significant Assets with a proximity to a Regional Ecological Linkage of the following scales:

a) With an edge touching or <1000m from a Regional Ecological Linkage;

b) All other patches with an edge touching or <1000m from a patch selected in a); and,

c) All other patches with an edge touching or <1000m from a patch selected in b)

Map 6: An overlay highlighting all patches identified in maps 3, 4 and 5 (analysis Level 1, 2 and 3). The linkage value of each patch will be given in accordance with the proximity analysis level and function by which they were first identified; i.e. assigned values will be given as 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, and 3c. Patches not identified through this process will not be assigned a value.

Note: This process is used to provide a specific series of predetermined measurements which reflect connectivity (proximity) values given to patches of remnant vegetation in reference to a SWREL axis line. This process was not designed, or intended, to explore the full gamut of spatial relationships between patches which may be present in any given landscape.

Box 1: Method for Ecological Linkage Mapping and Proximity Analysis

5. Scales of proximity analysis

5.1 Discussion

The south western region of Western Australia contains over 7380 native vascular plant taxa of which 49% are endemic (Hopper and Gioia 2004). These plant species form over 300 types of recognised vegetation complexes (Molloy *et al.* 2007), which are home to approximately 220 bird species, 33 species of native terrestrial mammal, in excess of 120 reptile species and 26 species of frog (Western Australian Museum 2008). Although the number of fungi and invertebrate species within the region is still unknown, it is estimated that up to 90% of Western Australia's invertebrate and fungi species (Abbott 1999) and as much as 10-15% of our plant species have not yet been scientifically described and catalogued (Hopper and Gioia 2004). As a consequence of the extent of the region's biodiversity, there is a significant knowledge gap in regard to the movement and dispersal requirements of many species. This represents a significant limitation to connectivity planning.

Defining species movement is problematic as species exist within the context of different domains (or levels) of movement. This is demonstrated in Figure 9. The habitat domain refers to the scale at which a species exploits resources and reproduces. Within a landscape context this is usually considered to be within the home range, or patch, scale. The landscape domain includes the scales at which landscape heterogeneity may be perceived by a species and therefore is a factor influencing source-sink and metapopulation dynamics. Both natal dispersal and relocation of the home range occur within this domain. The geographic domain refers to the extent and distribution of a species. Migration, infrequent long range dispersal, regional persistence and evolutionary factors are considered at this scale (Bestelmeyer *et al.* 2003).

Determining home ranges for many species can also become a gender specific issue. With many species, males and females can have very different home ranges. For example, the home ranges of 30 adult male honey possums, *Tarsipes rostratus*, averaged 1277 m2 (range 150–3494 m2), significantly larger than the mean of 701 m2 (range 112–2212 m2) for 20 adult females (Garavanta *et al.* 2000).

The effectiveness of near patch proximity is also linked to patch size (Miller and Cale 2000). In general, the larger a patch is the greater its ability to maintain a diverse suite of species and ecological processes. Conversely, smaller patches have a diminished capacity for population persistence. Therefore, populations resident in smaller patches are more likely to require resources from other patches to persist (Fischer and Lindenmayer 2007, Piper and Catterall 2006, Brooker *et al.* 2008, Lindenmayer *et al.* 2008, Watson *et al.* 2001). Consequently, the capacity for a population to persist in a small patch is more likely to be enhanced by that patch being in close proximity to other patches than a similar population resident in a large patch with a diverse suite of persisting species in residence (Freudenberger 1999, Freudenberger 2001, Watson *et al.* 2001, Lambeck 1999).

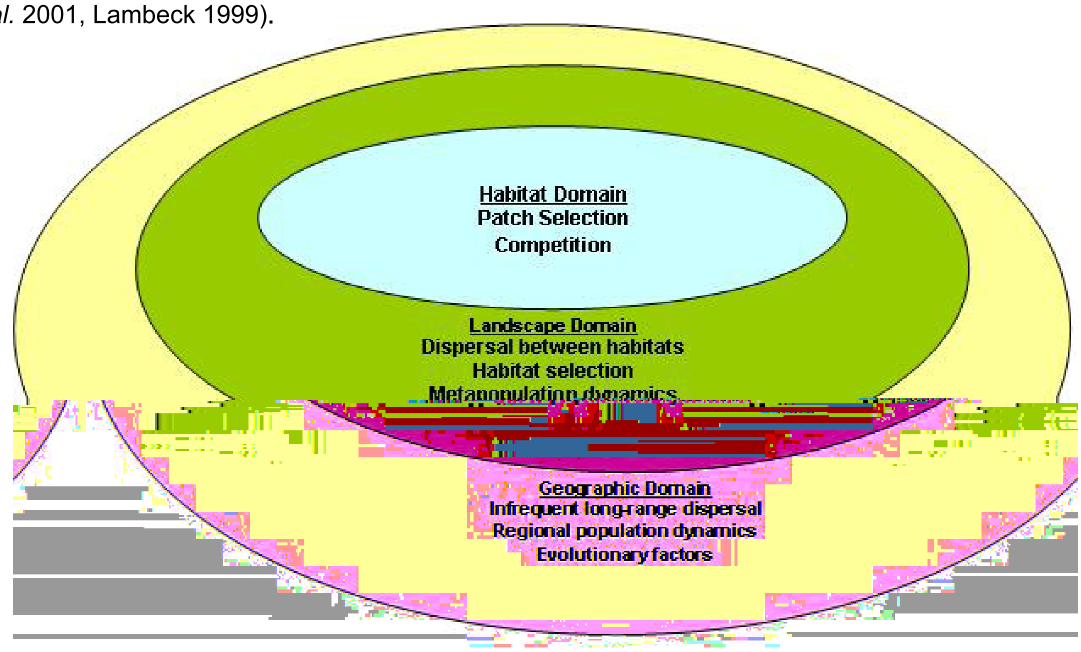

Figure 9: Three ranges of domain or levels of movement adapted from Bestelmeyer et al. (2003)

Animal species may have the physical ability to disperse long distances, but lack the behavioural repertoire to traverse the matrix surrounding their patch (Saunders *et al.* 1991). Any gap in the continuity of native vegetation exposes fauna that venture into that gap to an increased risk from predation. Cleared areas are also free of the habitat requirements and resources which motivate fauna species to move beyond their immediate patch. Because cleared and agricultural areas present an increased risk and lack of enticement, they generally act as barriers to the movement of native fauna species that are dependent on native vegetation or habitat. Fauna species are largely responsible for maintaining plant species through such activities as the dispersal of pollen and seed (Coates *et al.* 2007). Therefore the movement and consequent persistence of fauna species is integral to the persistence of native vegetation.

Although it is well accepted that close proximity generally increases the viability of patches of remnant vegetation (Lindenmayer *et al.* 2008, Tischendorf and Fahrig 2000, Watson *et al.* 2001, Hanski 1990); the number of species within the region, the complexity of determining the spatial domains for each of those species, the affects of patch size on the spatial requirements of individual species, and significant gaps in the understanding of the region's biota, makes the development of proximity parameters which meet the requirements of every species highly impractical if not impossible. This is why it has been necessary to set arbitrary parameters for proximity analysis. Although these parameters of relative proximity have been arbitrarily set at 100m, 500m, and 1000m respectively, they have been determined through an extensive process of consultation and literature review. The findings of this process are explained as follows:

5.2 Gaps of less than 100m

Small forest and woodland mammals such as; native rodents, possums, bandicoots, boodies, bettongs, potoroos and smaller dasyurids are particularly sensitive to fragmentation. Cleared and agricultural areas can act as ecological sinks for many of these species (Garavanta *et al.* 2000, Fahrig 2003). Although these species generally avoid cleared areas as part of their habitat domain, they will cross small gaps in vegetation cover (<100m) when dispersing (Catling *et al.* 2000, Jones *et al.* 2004, Downes *et al.* 1997, Claridge and Barry 2000, Pope *et al.* 2005). Even somewhat larger marsupials such as the quokka, *Setonix brachyurus*, which may forage over a 200m radius during a day, will rarely venture more than 100m from cover (Nicholls 1971).

Castellon and Sieving (2006) found that a sedentary insectivorous bird would cross open gaps of 20m but few would cross a gap greater than 80m. Saunders and de Rebeira (1991) found that a gap of 100m presented a complete habitat barrier to many small insectivorous passerines. This complies with the findings of Allen and Saunders (2002), Watson *et al.* (2001), Fortin and Arnold (1997), and Mason *et al.* (2006) whose findings show that small insectivorous birds are generally sedentary in nature and are unlikely to move beyond their habitat patch. Freudenberger (1999 and 2001) also demonstrated that, in regard to small patches (<10ha), the distribution of small insectivorous passerines was demonstrably linked to highly connected landscapes. Both of Freudenberger's studies (1999 and 2001) demonstrated that the presence of these bird species was demonstrably higher where patches were contiguous or in very close proximity to each other (<100m) (Figures 11 and 12).

Studies within the Western Australian Wheatbelt (Abensperg-Traun *et al.* 1996, Smith *et al.* 1996, Kitchener and How 1982) show that both terrestrial arthropods and small lizards are generally sedentary in nature. Woodland and forest dwelling species from both of these groups are unlikely to move significantly beyond the patch under normal circumstances. Both of these studies demonstrate that very small, isolated patches contain a significantly diminished suite of resident species from both groups. The fact that the abundance of species present in small patches did not markedly improve where patches were in relatively close proximity indicates that, even in modestly cleared areas, agricultural clearing presents a significant barrier to movement of small lizards and arthropods.

The movement of frogs is highly variable depending largely on species size and climatic conditions. Although some species of frog are capable of dispersing several kilometres under the right conditions many smaller species such as *Geocrinia spp*. only have a home range of several square meters and have not been able to disperse beyond 150m in experiments (Driscoll 1997).

Byrne *et al.* (2008) demonstrates that while dissemination of pollen in eucalypts can take place over a distance of several kilometers nearly all imported pollen comes from within a distance of approximately 800m and most is sourced from within a distance of 100m. This is supported by Tscharntke *et al.* (2005) who found that few stenotopic arthropods dispersed beyond the patch canopy and that few disperser

species ventured far beyond the immediate patch. This can be linked to insect movement as insects are perceived to be a major pollinator of eucalypts in south-western Western Australia (Coates *et al.* 2007). This supports Mader (1984) who states that a distance of 100m over agricultural fields may be a complete barrier to dispersal for many small invertebrates.

The above information strongly indicates that; while gaps in vegetation will, to some degree, compromise the capacity of flora and fauna species to persist, where the cleared gap between patches is <100m those impacts will be limited in that such a gap does not bring about a significant barrier to the dispersal of many fauna species, seed and other genetic material. Further, a gap of <100m provides an excellent opportunity to connect patches through revegetation and management activities, thereby improving overall landscape viability.

5.3 Gaps of less than 500m

The capacity for fauna species to move is largely determined by size, i.e. the larger the animal the (generally) greater its ability to cover a large area (Saunders *et al.* 1991, Allen and Saunders 2002, Driscoll 1997, Davis 2008, Fisher and Owens 2000). For this reason the species which can traverse a <500m gap between patches are generally larger than those which can traverse a <100m gap.

The foraging range of a chuditch, *Dasyurus geoffroii*, is known to extend to approximately 500m beyond cover, although its dispersal may be considerably greater (Sonderquist and Serena 2000). The western brush wallaby, *Macrpus irma*, and the black footed rock wallaby, *Petrogale lateralis*, that regularly graze in the open near patches of remnant vegetation have the capacity to disperse across a 500m gap (Eldridge *et al.* 2004). Wilkinson *et al.* (1998) and Augee *et al.* (1975) find that 500m is the maximum distance that an echidna, *Tachyglossus aculeatus*, will travel from its sheltering sites. Lumsden (2004) found that although insectivorous bats may forage many kilometres from their roosting sites within contiguous woodlands, they are reticent to forage more than 500m into cleared areas. Lumsden hypothesises that this is linked to the distribution of prey (arthropod) species. Arnold *et al.* (1989 and 1994) found that western grey kangaroos, *Macropus fuliginosus*, and euros, *Macropus robustus*, rarely venturing further than 400m into cleared areas while browsing (although these species have a capacity to disperse across much greater gaps). For these reasons a gap of 500m can be seen as a threshold relevant to the movement of many mammals. It should also be noted that many of the mammals significantly influenced by a 500m gap in vegetation cover also fall within the critical weight range of 35g to 5.5kg mean adult body weight and are of a very high priority to biodiversity conservation (CALM 2003).

Fortin and Arnold (1997) found that a gap of 500m between small remnants led to a significant drop in the richness, turnover and changes in the presence of small passerine birds in the WA Wheatbelt (Figure 10). Freudenberger (1999 and 2001) found that many bird species, and in particular, medium-sized birds are significantly more abundant within 500m of a patch (Figures 11 and 12). This is supported by the Victorian Department of Natural Resources and Environment (DRNE 2000) who nominated 500m as a preferred threshold gap between patches of remnant vegetation after reviewing a series of studies on bird movement and dispersal.

Green and King (1978) show that a gap of 500m is pertinent to the home range of larger lizards and Driscoll (1997) notes that 500m is the dispersal limit for some frog species. This is comparable with the findings of Pearson *et al.* (2005) who demonstrate that it is unlikely that large snakes such as a carpet python, *Morelia spilota imbricata*, would disperse through a 500m gap in vegetation.

Although some species of beetle residing in fragmented landscapes in New Zealand ventured over 1km beyond their patch, many species of beetle would not venture further than 500m (Ewers 2004). Nason and Hamrick (1997) found that in fragmented woodlands the frequency of heterozygotes among the progeny of insect pollinated trees indicated that approximately 26% of effective mating was with trees located at least 500m away. This demonstrates that the exchange of pollen had dropped by over 70% across a 500m gap in vegetation indicating a significant drop in the movements of vector species of this distance. This is supported by Byrne *et al.* (2008) and Yates *et al.* (2007) who found that gaps of 500m between small patches of remnant vegetation in south-western Western Australia result in a significant drop in the frequency of insect pollination. This corroborates the findings of Tscharntke *et al.* (2005) who found that a gap between patches greater than 500m presents a significant barrier to stenotopic, ecotone and disperser arthropods.

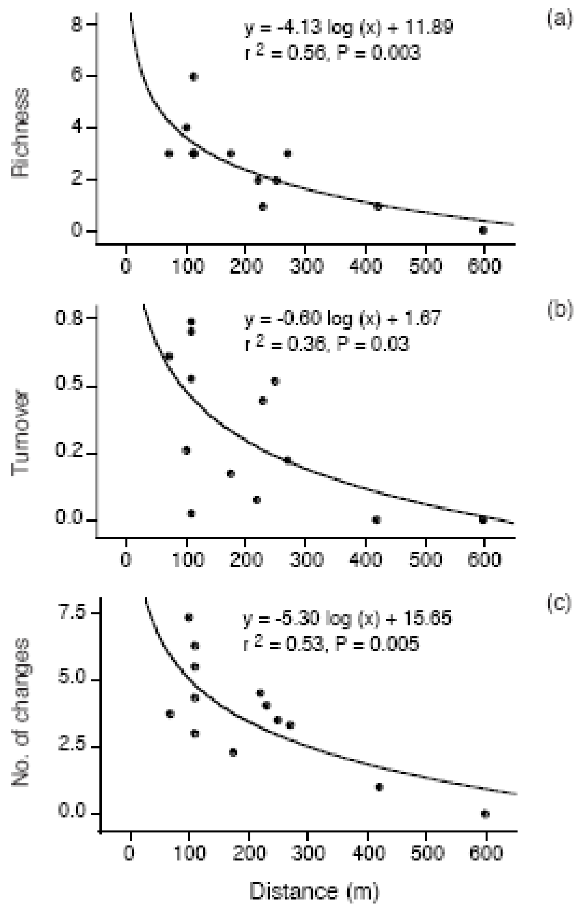

Figure 10: ***Impact of the distance of road verges on birds in relation to; (a) species richness, (b) average species turnover and (c) number of changes in the number of individuals between consecutive censuses of the 10 small passerines species recorded in 13 small remnants of native vegetation in the WA Wheatbelt (from Fortin and Arnold 1997).***

The above information indicates that a comparatively moderate gap of 500m between patches of remnant vegetation provides a significant barrier to the movement of many fauna species. Consequently less species visit and reside in small patches (<10ha) which are isolated by a 500m gap leading to a diminished transfer of pollen, seed and genetic material. In this way a gap of 500m can inhibit the long term viability of flora as well as fauna populations. While it is acknowledged that biotic interaction between patches is still reasonably robust over a gap of 500m, it should be noted that a gap of this distance represents a threshold past which there is a notable decline in biotic interaction. This decline may have moderate to profound negative impacts on some (particularly small) patches of remnant vegetation. Further, a gap of <500m provides a very good opportunity to connect patches through revegetation and management activities, thereby improving overall landscape viability.

5.4 Gaps of less than 1000m

As previously stated, the capacity for fauna species to move is largely determined by size, that is, the larger the animal the (generally) greater its ability to cover a large area (Saunders *et al.* 1991, Allen and Saunders 2002, Driscoll 1997, Davis 2008, Fisher and Owens 2000). For this reason species which can traverse a gap of <500m between patches are generally larger-sized than those which can traverse a 500m gap.

Although 1000m is well within the dispersal range of western grey kangaroos, *Macropus fuliginosus*, and

euros, *Macropus robustus*, females and juveniles of either species rarely venture further than 400m into cleared areas (Arnold *et al.* 1989 and 1994). Although few smaller mammals would cross a gap of 1000m for habitat purposes, some species will disperse across this range in spite of a greatly increased risk of predation (Sonderquist and Serena 2000). Wilkinson *et al.* (1998) and Augee *et al.* (1975) both give approximately 1000m as the average home range diameter of an echidna, *Tachyglossus aculeatus*.

Freudenberger (1999 and 2001) and Fortin and Arnold (1997) found that although many larger bird species will travel several kilometres from a patch into cleared areas, these species are much more abundant within 1000m of a patch (Figures 10, 11 and 12). Freudenberger then goes on to suggest 1000m as the preferred maximum gap for connectivity in the Vegetation Investment Project (Freudenberger 1999). This is supported by Collard (1999) and the Victorian Department of Natural Resources and Environment (DRNE 2000) who both nominated 1000m as the maximum acceptable gap between patches of remnant vegetation when designing effective ecological linkages. Byrne *et al.* (2008) and Yates *et al.* (2007) also found that pollination of plant species by birds is diminished but still relatively effective at 1000m.

Green and King (1978) show that a gap of 1000m is about the maximum home range distance of larger lizards and Driscoll (1997) also notes that 1000m is the dispersal limit for a few larger frog species given the right conditions. Experiments also indicate that some larger skinks may be able to disperse over a 1000m gap (Freak 2001). However a gap of 1000m is likely to be impassable for most small lizard and snake species (Smith *et al.* 2000).

Ewers (2004) shows that some beetle species can disperse over a gap in vegetation cover of over 1000m, while Tscharntke *et al.* (2005) shows that only ubiquist and cultural arthropods species are likely to venture 1000m beyond the patch. This is supported by Nason and Hamrick (1997) Byrne *et al.* (2008) and Yates *et al.* (2007) who demonstrate that insect dispersal of pollen over a 1000m gap in vegetation cover is minimal.

The above information indicates that a significant gap of 1000m between patches of remnant vegetation provides a major barrier to the movement of many fauna species. Consequently there is a very significant reduction in insect vectored pollen to plants while bird pollination of plants remains diminished but effective. This may not only inhibit the long term viability of some plant populations, it may affect species heterogeneity within patches. The movement of terrestrial fauna across a 1000m gap in vegetation cover is mainly limited to larger species, while smaller species are far less inclined to cover such a gap and those smaller species which do attempt this distance are greatly endangered by doing so. Therefore, while it is acknowledged that biotic interaction between patches is still a factor over a gap of 1000m, it should also be acknowledged that a gap of this distance represents a threshold past which there is a major decline in biotic interaction. This decline will probably have a profound negative impact on some (particularly small) patches of remnant vegetation. It should also be noted that revegetation and management activities have a moderate to good potential for ameliorating some of these impacts where the gap between patches is <1000m.

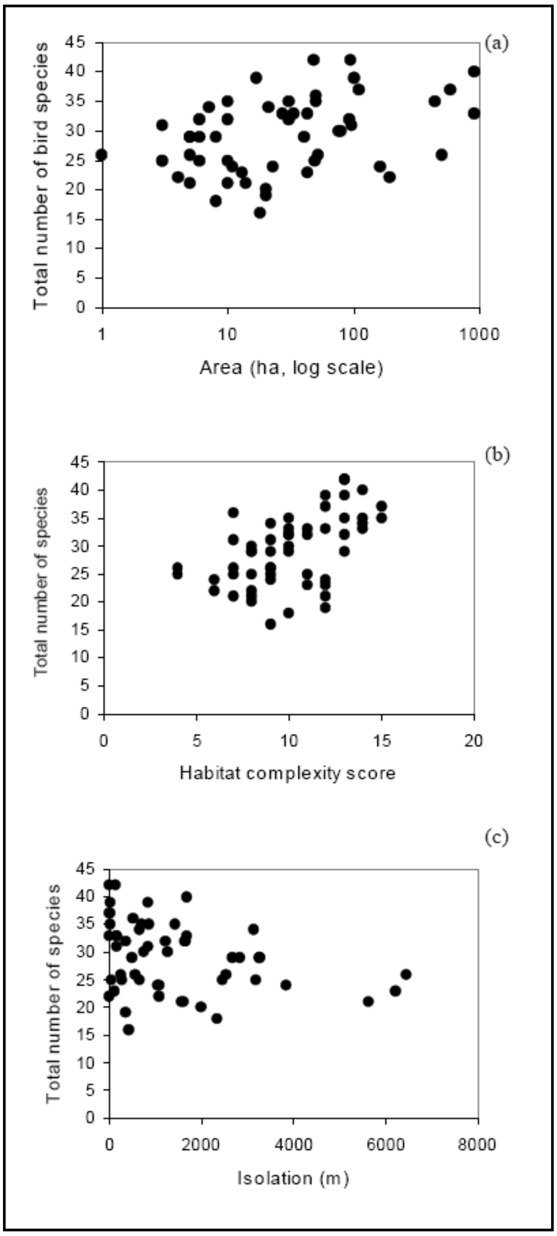

Figure 11: ***Graphs from Freudenberger (2001) showing the total occurrence of bird species in surveyed patches in relation to patch area, complexity and isolation. This study of 35 patches in the Boorowa River catchment indicates that a greater diversity of bird species is likely where; patches are larger (>10ha), where patches have greater structural diversity and where patches are less isolated (<1000m).***

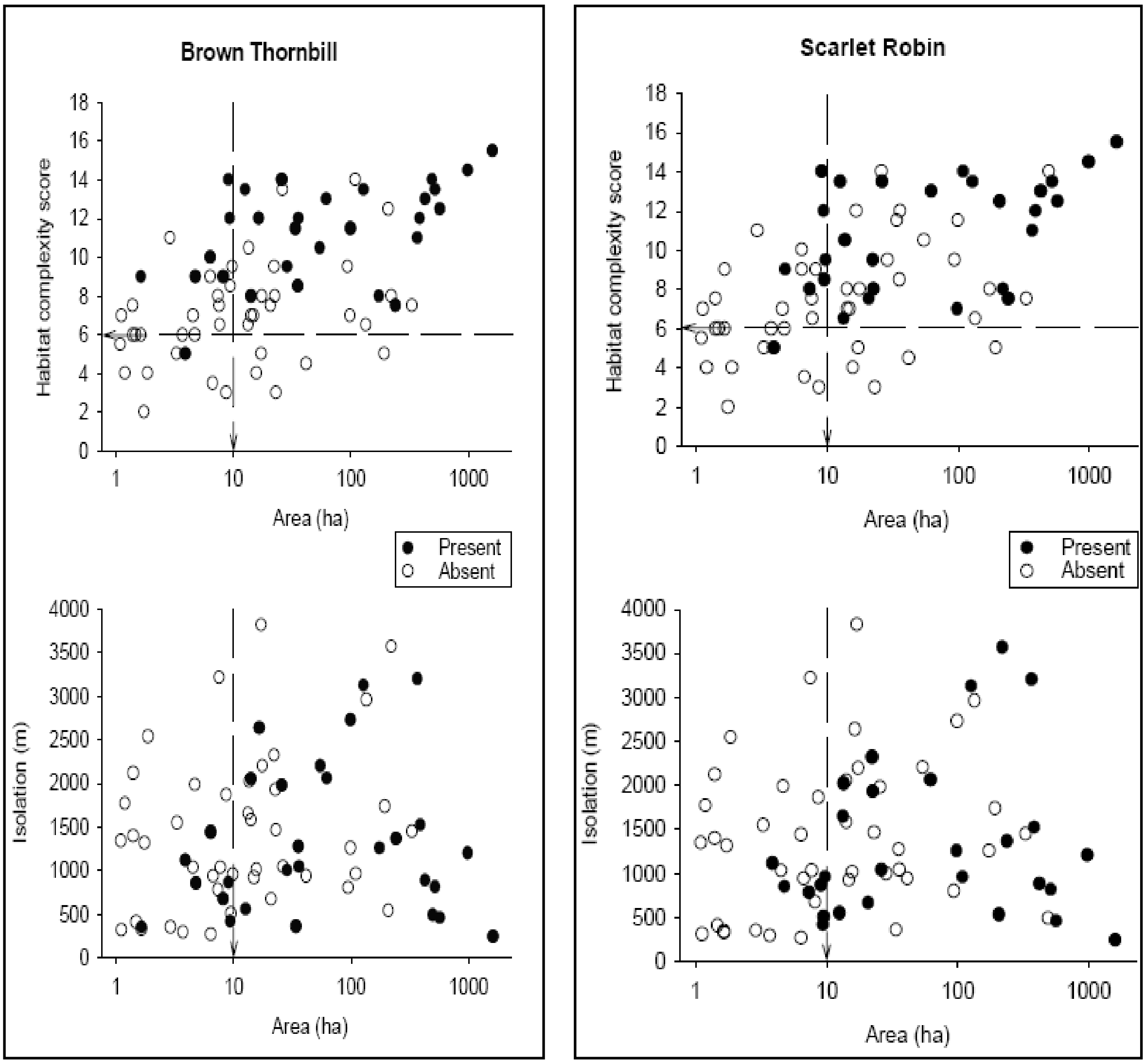

Figure 12: ***Graphs of the occurrence of 2 individual bird species in relation to the area, habitat complexity and isolation of surveyed patches, from Freudenberger (1999). During this study Freudenberger collected similar data on the occurrence of 37 species across 200 patches in the ACT and SE NSW and concluded that patches should be >10ha in size and <1000m isolated to maximise biodiversity conservation outcomes in a fragmented agricultural landscape.***

6. Caveats

In presenting this methodology the SWREL project acknowledges the following caveats:

- For the purposes of this project an Ecological Linkage will be defined as:
  "A series of (both contiguous and non-contiguous) patches which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape."

- Linkages identified through the SWREL project are not intended for use as Biodiversity Corridors.

- Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.

- The SWREL project does not detract from any existing ecological value assigned to any patch or biodiversity conservation asset.

- This methodology is based on the simple premise that:
  The ecological viability and biodiversity conservation value of the whole of a patch which touches or comes within close proximity to another patch (or patches) will probably be greater than that of a comparable patch which is isolated. This is a generalisation and is not applicable to all species or situations.

- This methodology is based on general biodiversity conservation management principles and is therefore arbitrary in nature. As such, this methodology does not recognise the specific requirements of all regional taxa and can not be seen as a substitute for focused species or community management planning.

- This methodology is intended to provide a decision support tool. The Ecological Linkages and biodiversity conservation assets identified using this methodology are intended to support more extensive management and planning processes. They are not intended to be the sole basis for decision making. Consequently, the value of a patch or biodiversity conservation asset is in no way diminished by not being identified as part of an Ecological Linkage.

- Within this methodology each scale of proximity is only removed to the third level from the linkage. There are two reasons for doing this. Firstly, the number of degrees of proximity is kept down to 10 (from 1a to Not Identified). This is an appropriate number of options for a project of this type. Secondly, a link beyond a third level has become tenuous and can be justifiably compared with the value of the next scale of proximity.

- In applying proximity analysis to land use planning it must be understood that 1b and 1c, second and third level patches are not part of the core linkage (1a level patches), therefore their value in maintaining a linkage's ecological function will (generally) not be as great.

- In all trials conducted (to date) significant patches removed to the fourth level from the Ecological Linkage have been picked up at the next scale of proximity. However, it must be acknowledged that this may not always be the case. This potential to omit significant patches and biodiversity conservation assets is a limitation of this methodology. This limitation can be compensated for by appropriate linkage design which underlies the earlier assertion that the proximity analysis is designed to be a decision support tool and is not in any way intended to be the sole basis for the design of Ecological Linkages.

Glossary

Amensal: A relationship between species or organisms where there is a negative impact to one or more species and no species benefits, for example; the impacts of macropod grazing on some bird species which may result from disturbance to grassland nesting sites.

Competitive: A relationship between species or organisms where there are two or more species competing for the same resource resulting in a negative impact to all competing species.

Contramensal: A relationship between species or organisms where there is a positive benefit to one to one at the expense of a negative impact to another, for example; predation, parasitism or herbivory.

Contiguous: A landscape where there are no breaks in native vegetation.

Deterministic: The doctrine that all facts and events exemplify natural laws, and as such are predictable.

Disperser: Those species that normally reside in remnant vegetation but will disperse into surrounding croplands. Numbers of these species remain higher nearer to remnants (Tscharntke *et al.* 2005).

Ecology: The study of interactions between organisms and between organisms and their physical environment.

Ecological: Pertaining to ecology.

Ecological linkage: For the purposes of this document an ecological linkage will be described as "a series of (both contiguous and non-contiguous) patches which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape".

Ecological source/sink: Source-sink dynamics is a theoretical model formulated by Pulliam (1988) to describe how variation in habitat may affect populations. Source areas are those areas where a surplus of a species is produced and as such areas bases of dispersal. Sinks are those less densely populated areas that a species disperses into. As such an ecological sink subject to high predation (such as a poorly vegetated patch) diminish a population within the broader landscape context.

Ecotone species: Those species that specialise in interzones such as where cropland and native vegetation meet (Tscharntke *et al.* 2005). Numbers of these species are highest at the interzone and decrease with distance into both cropland and native vegetation.

Extinction cascades: A cascade or domino effect of multiple secondary and subsequent extinctions within an ecosystem triggered by the primary loss or total extinction of one or more key species or loss of habitat.

Heterozygote: An organism, seed or embryo possessing multiple forms of the same gene.

Heterogeneous: Possesses a high number of variants in shape, structure and species composition. Used in reference to the diversity of recognisable vegetation types found within a natural landscape.

Heterogeneity: The quality of being heterogeneous.

Local Significance: Locally significant patches are those that have been field assessed by a suitable expert and meet at least one local significance criteria as determined by a local government. Local significance criteria are ecological and social criteria determined by a local government to identify significance from the perspective of the local community.

Metapopulation: A metapopulation is generally considered to consist of several distinct populations together with areas of suitable habitat which are currently unoccupied. In classical metapopulation theory, each population cycles with some (often minor) interaction with other populations and eventually goes extinct as a consequence of demographic stochasticity (Levins 1969).

Mutualistic: A relationship between species or organisms where there are positive benefits to all participants, for example; symbiosis.

Patch: A defined area of remnant vegetation.

Regional Significance: An area (patch) of remnant vegetation this is part of an existing or proposed conservation system or meets, in part or in whole, a range of criteria for regional significance which is outlined in Appendix 3 of EPA Guidance Statement 10 (EPA 2006).

Stenotopic: Those species which do not penetrate into cropland (Tscharntke *et al.* 2005), often used in reference to canopy specialists in remnant vegetation.

Stochastic: Involves random elements. Therefore predictions involving stochasticity are probabilistic rather than deterministic.

Ubiquist Species: Refers to those species whose presence is not linked to any particular ecological assemblage. Tscharntke *et al.* (2005) uses this term to describe those species whose numbers remain relatively constant across both remnant vegetation and cropland.

Viability: For the purposes of this document, a patch is considered to be viable if it can persist into the foreseeable future in good or better condition if given an acceptable level of planning and management activity.

Wildlife Corridor: A strip of vegetation, usually joining 2 or more patches. Described by Lindenmayer *et al.* (2008) as linear strips of a particular type of vegetation that link patches of (what is usually) a similar type of vegetation.

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Appendix 1: Ecological Linkage Mapping and Proximity Analysis

A Trial at a Landscape Scale

By Shaun Molloy and Jodie Wood

Introduction

The purpose of this appendix is to demonstrate the method of proximity analysis which has been adopted for decision support by the South West Regional Ecological Linkages (SWREL) project. Although this form of proximity analysis has been designed for use at a regional rather than a local government scale, for the purposes of this demonstration it was felt that this scale provided a suitable level of resolution for demonstrating the project's proximity analysis process in A3 or A4 publications.

This area was chosen for this demonstration on the basis of its physical attributes, which could demonstrate the effectiveness of the proximity analysis at multiple levels of remnant vegetation fragmentation.

Proximity Analysis

The proximity analysis method being used by the SWREL project relies on a series of staged activities. In this demonstration these activities are represented in a series of maps. Contents of these maps are as follows:

Map 1: Patches and other biodiversity conservation assets of regional significance;

Map 2: Patches and other biodiversity conservation assets of regional significance (map 1) with Regional Ecological Linkages overlaid;

Map 3: Proximity analysis group1

The whole of all patches with a proximity to a Regional Ecological Linkage of the following scales:

a) with an edge touching or <100m from a Regional Ecological Linkage;

b) all other patches with an edge touching or <100m from a patch selected in a); and

c) all other patches with an edge touching or <100m from a patch selected in b).

Map 4: Proximity analysis group 2

The whole of all patches and regionally significant assets with a proximity to a Regional Ecological Linkage of the following scales:

a) with an edge touching or <500m from a Regional Ecological Linkage;

b) all other patches with an edge touching or <500m from a patch selected in a); and

c) all other patches with an edge touching or <500m from a patch selected in b).

Map 5: Proximity analysis group 3

The whole of all patches and regionally significant assets with a proximity to a Regional Ecological Linkage of the following scales:

a) with an edge touching or <1000m from a Regional Ecological Linkage;

b) all other patches with an edge touching or <1000m from a patch selected in a); and

c) all other patches with an edge touching or <1000m from a patch selected in b).

Map 6: An overlay highlighting all patches identified in maps 3, 4 and 5 (analysis group 1, 2 and 3).

Map 7: As per map 6 with biodiversity conservation assets outside of shire boundaries added. This has been included to enable a better indication of effectiveness.

Assigning Proximity Values

The linkage value of each patch will be given in accordance with the proximity analysis group where it was first identified, for example, a patch may meet criteria for 1c, 2b, and 3a in the analysis. In that case the patch is assigned the linkage value 1c. Patches not identified through this process will not be assigned a linkage value. In this way all patches of remnant vegetation within a landscape one of 10 values, these being, 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 3c and value of 0 or no recognised linkage value.

Maps 6 and 7 have only been produced to show proximity analysis groups 1, 2 and 3 as the authors felt that a full presentation would have been inappropriate at this scale; and, as sub groups can be readily determined using maps 3, 4, and 5.

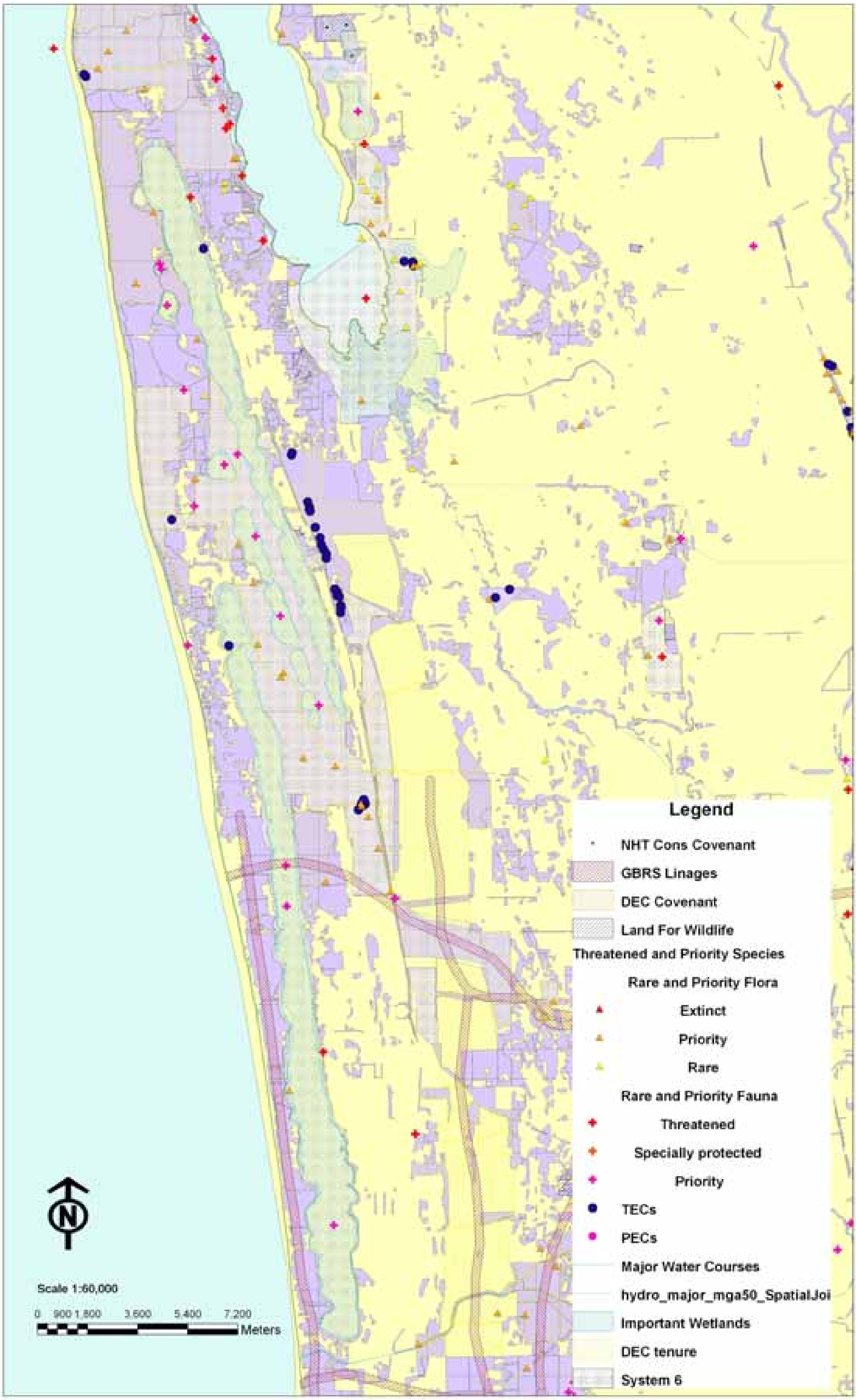
Conclusion

When examining Maps 6 and 7, the lack of connectivity in the highly fragmented landscape of the eastern part of the trial area becomes highly evident when compared to the connectivity demonstrated in the relatively intact landscape to the west. In this way, the proximity analysis tool demonstrates a sound indication of the effectiveness of the proposed ecological linkages in respect to proximity and connectivity. In this way proximity analysis undertaken using this methodology can reflect the spatial impacts of varying degrees of landscape fragmentation in a quantifiable and repeatable manner.

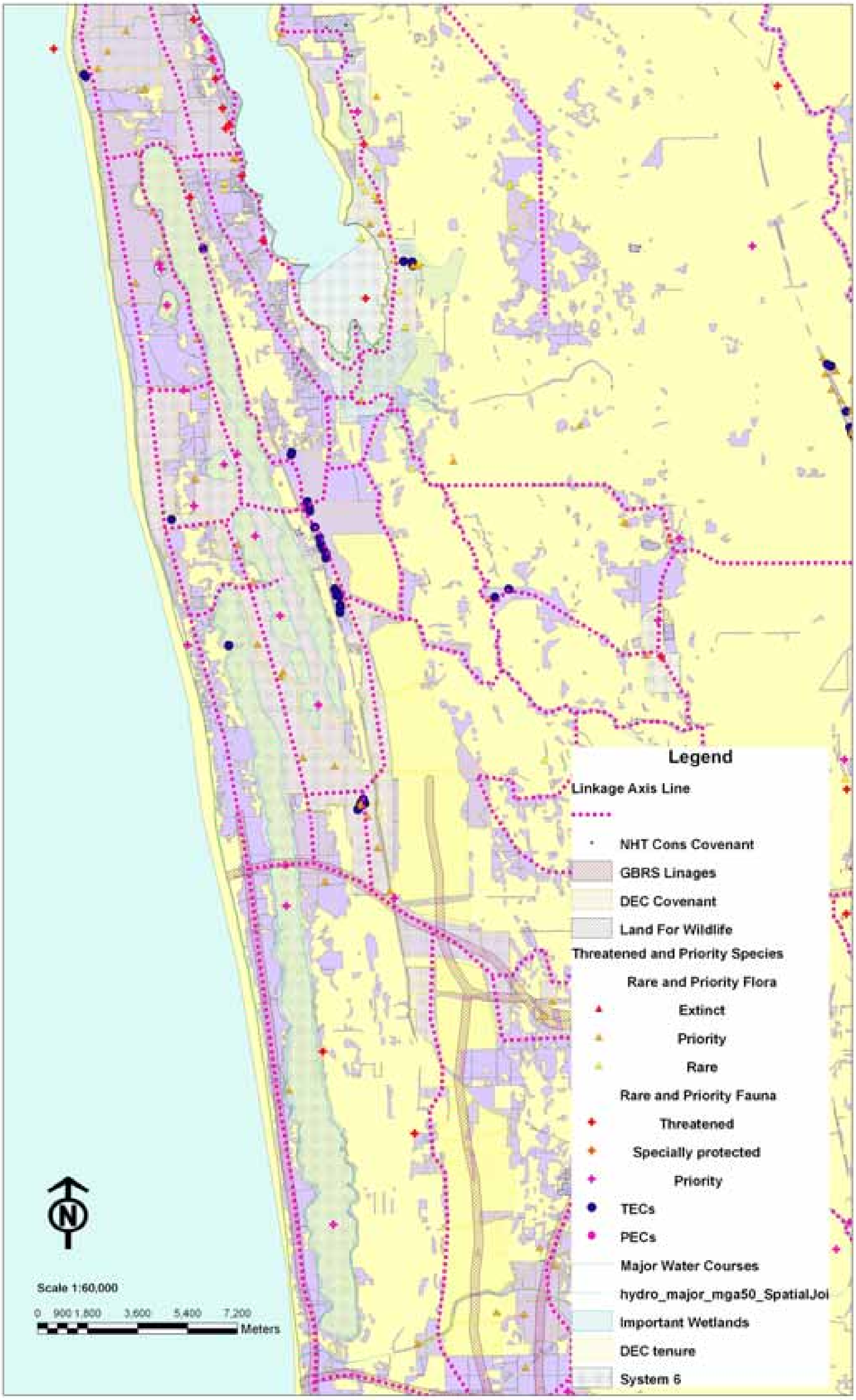
This demonstration is given to support the assertion that, by applying the SWREL methodology through proximity analysis, biodiversity conservation planners and managers are provided with a means by which they are able to undertake a better informed landscape planning process. This demonstrates that proximity analysis, undertaken as per the methodology, has the capacity to serve as a valid and valuable decision support tool which can help to deliver improved outcomes within the context of these processes. Importantly the tool also serves to highlight areas where strategic reconstruction of ecological linkage is a significant priority.

This exercise provides an accurate indication of the effectiveness of the proposed SWREL axis lines provided. It does this by demonstrating how the proposed linkages can affect remnant connectivity, and hence ecological function, within the project area. The proposed linkages demonstrated have been devised using the principles and guidelines explained in SWREL Project Methodology, recognising that in highly fragmented environments these are aspirational in places.

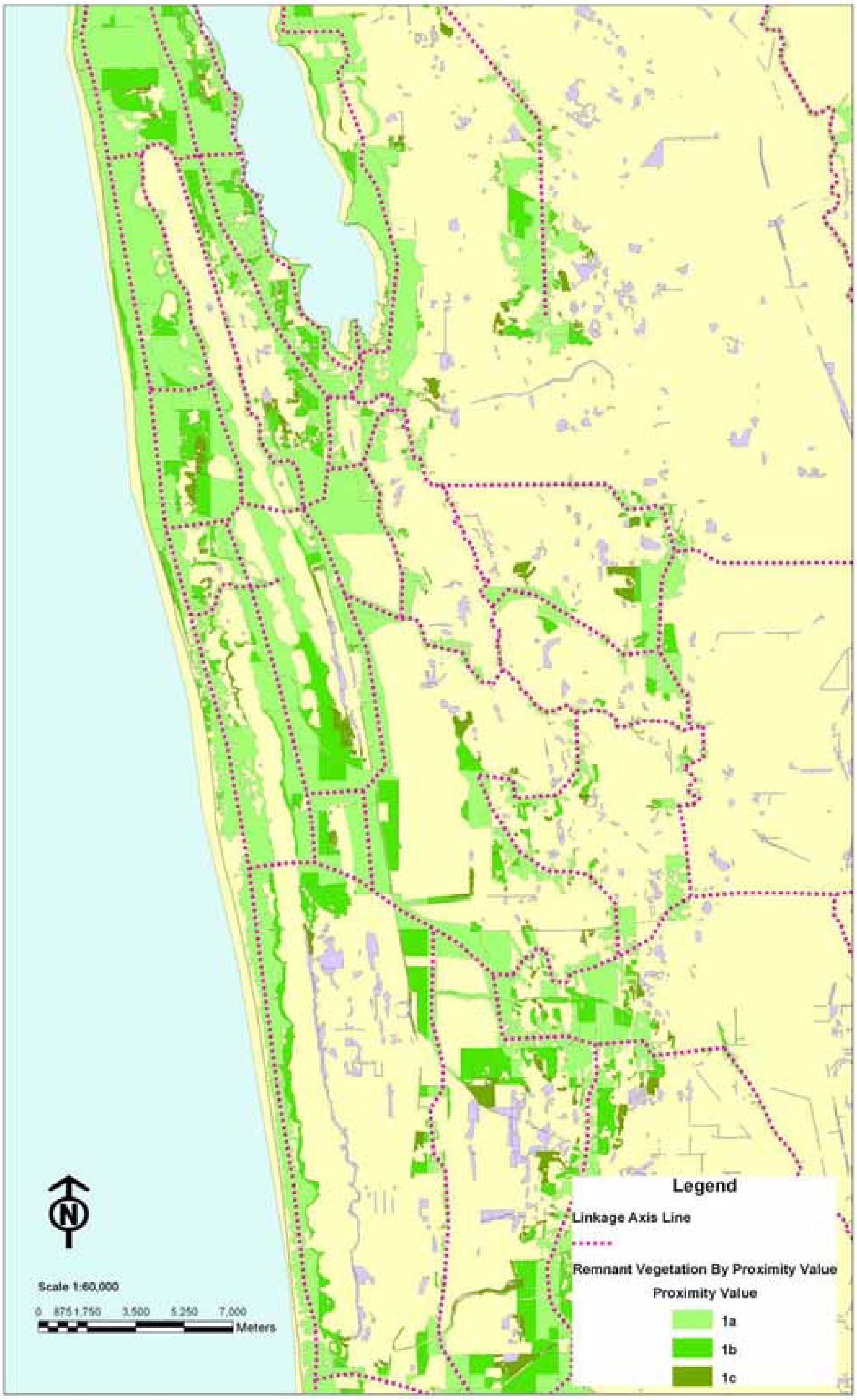
Note: **It must always be remembered that this proximity analysis tool has been developed to support an informed and consultative review process, which, by necessity, must be done in consideration of many other pertinent facts and values.**



Map 1: ***Patches and other biodiversity conservation assets of regional significance.***



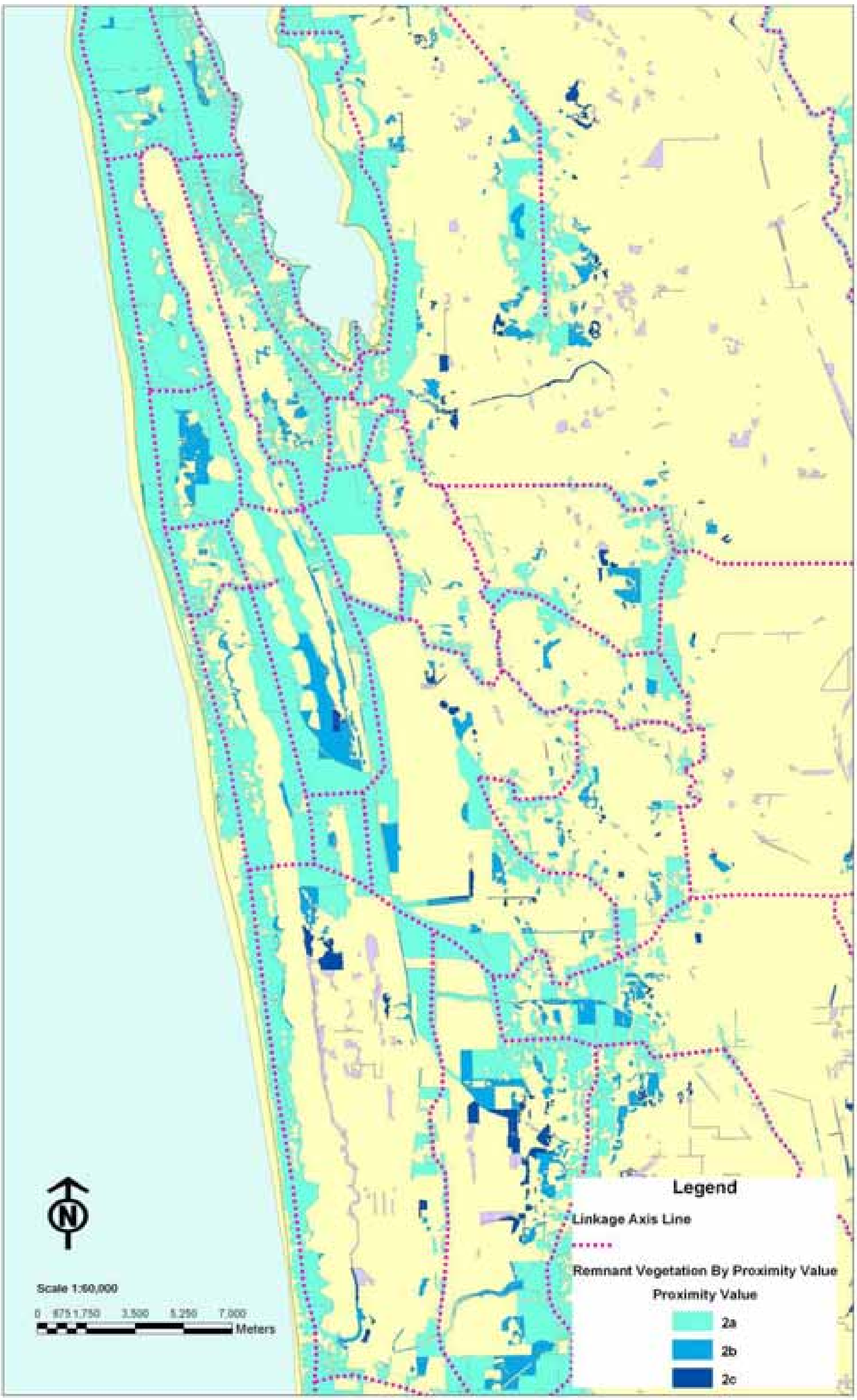
Map 2: ***Patches and other biodiversity conservation assets of regional significance (Map 1) with SWREL axis line overlaid***



Map 3: Proximity analysis Level 1

The whole of all patches with a proximity to a Regional Ecological Linkage of the following scales:

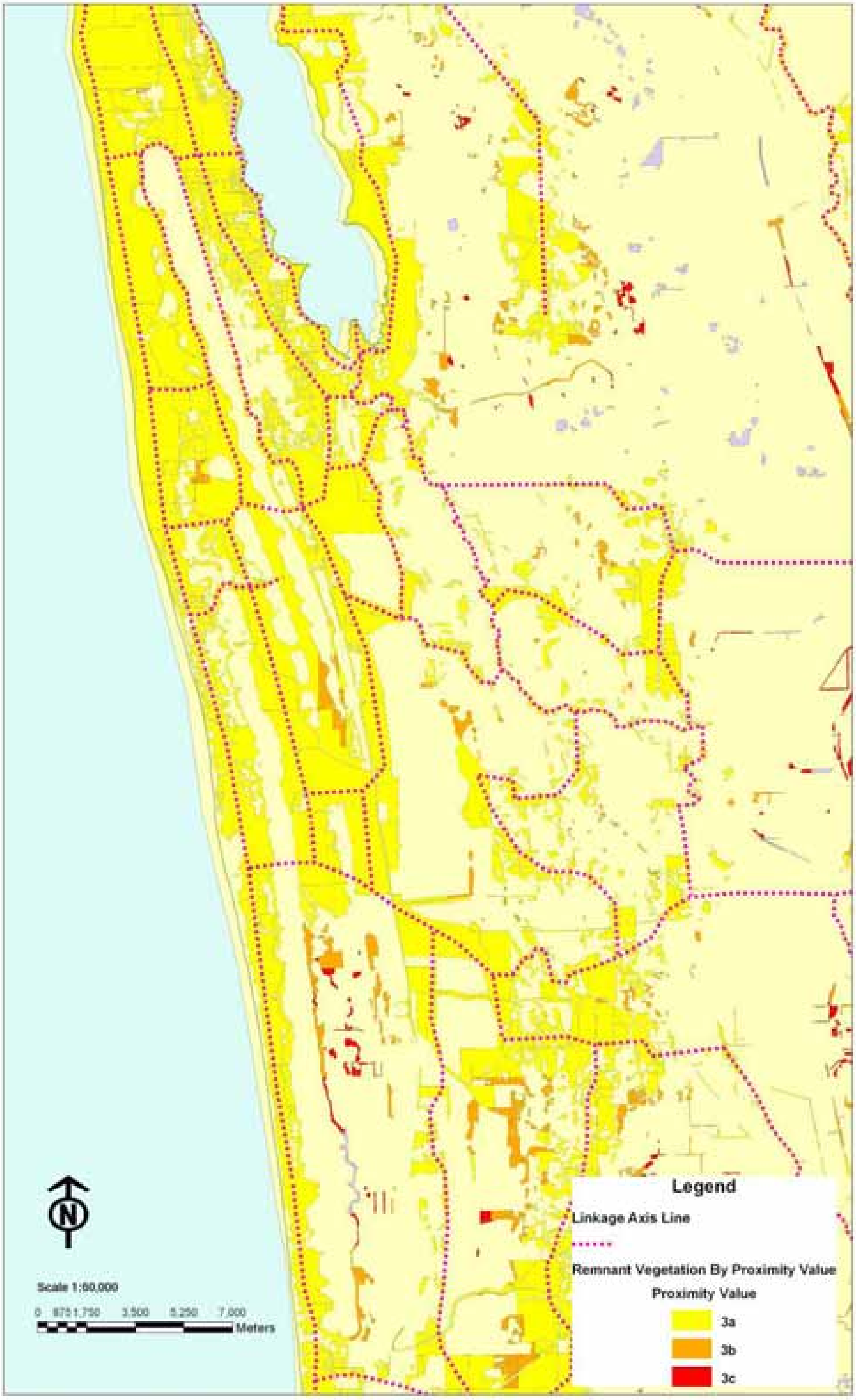
- With an edge touching or <100m from a Regional Ecological Linkage;
- All other patches with an edge touching or <100m from a patch selected in a); and,
- All other patches with an edge touching or <100m from a patch selected in b)



Map 4: ***Proximity analysis Level 2***

The whole of all patches and regionally significant assets with a proximity to a Regional Ecological Linkage of the following scales:

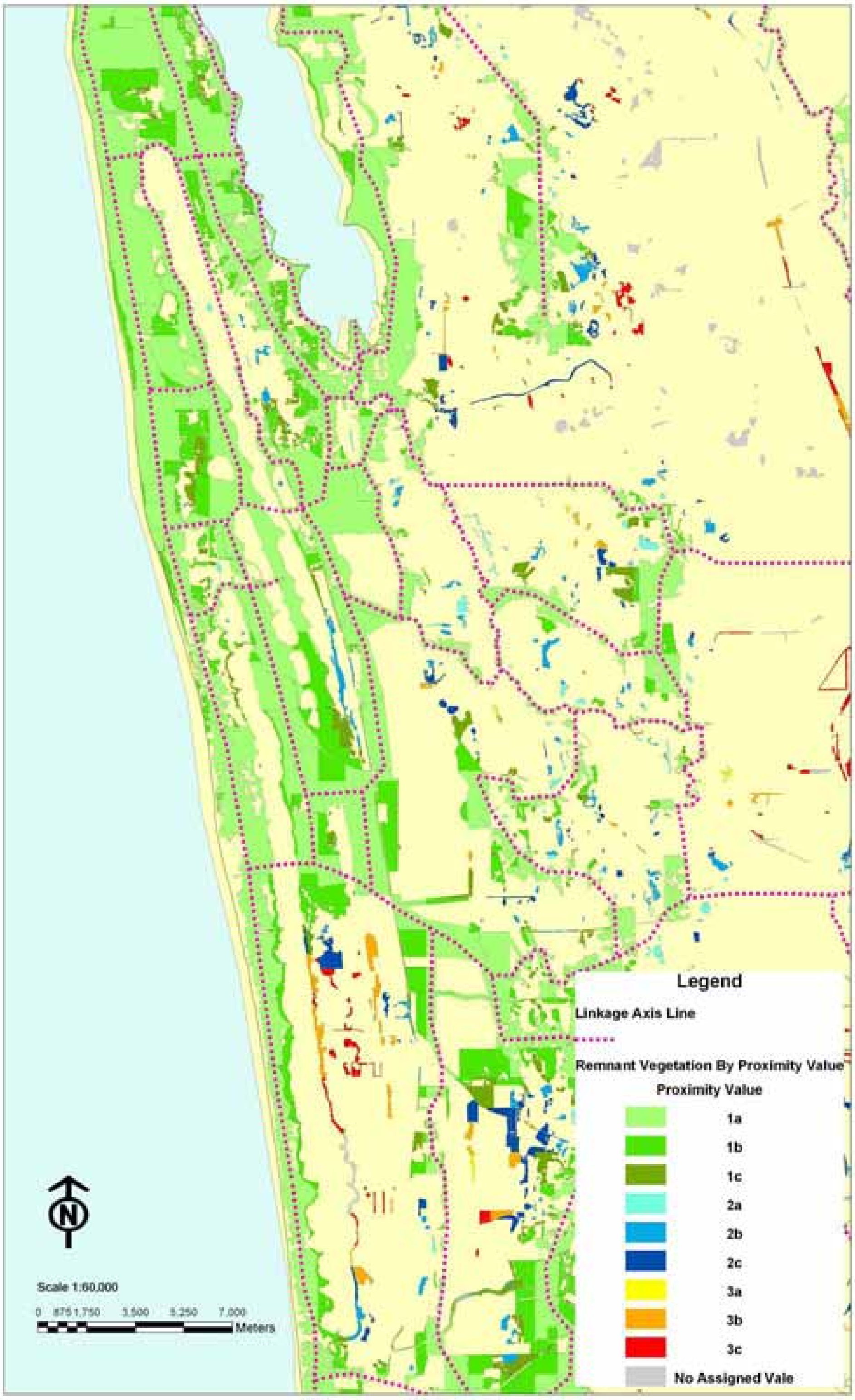
- With an edge touching or <500m from a Regional Ecological Linkage;
- All other patches with an edge touching or <500m from a patch selected in a); and,
- All other patches with an edge touching or <500m from a patch selected in b)



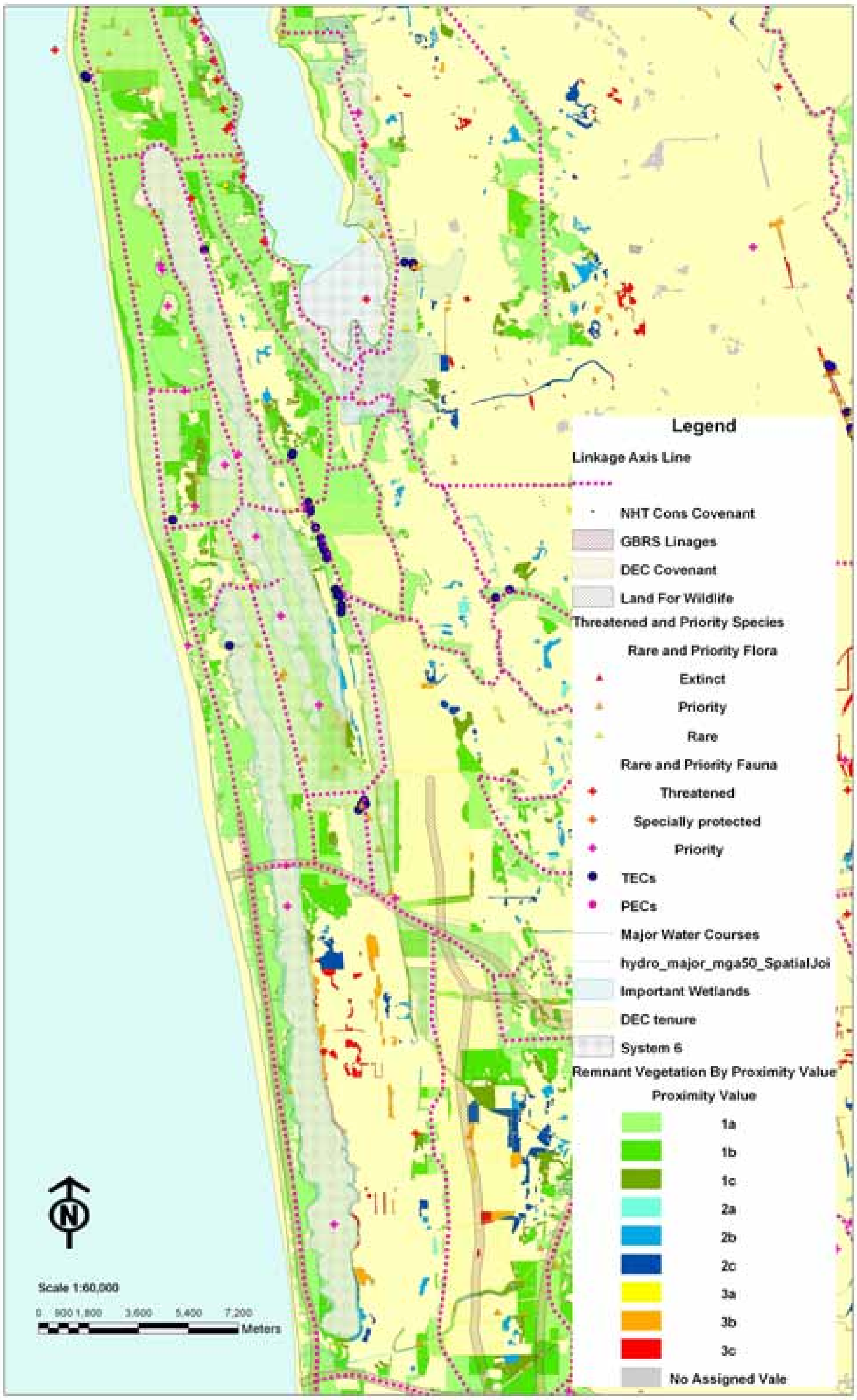
Map 5: Proximity analysis Level 3

The whole of all patches and regionally significant assets with a proximity to a Regional Ecological Linkage of the following scales:

- With an edge touching or <1000m from a Regional Ecological Linkage;
- All other patches with an edge touching or <1000m from a patch selected in a); and,
- All other patches with an edge touching or <1000m from a patch selected in b)



Map 6: An overlay highlighting all patches identified in Maps 3, 4 and 5 (analysis Levels 1, 2 and 3).



Map 7: ***A comparison of linkage axis lines and proximity values are examined in relation to recognised biodiversity conservation assets to assess their effectiveness.***

Appendix 2 : Applications for Proximity Analysis in Project Evaluation

By Shaun Molloy

Note: This method of evaluating ecological linkages as part of clearing permit applications can be considered under Schedules 5 and 51O of the Environmental Protection Act 1986 being the principles of clearing native vegetation and planning instruments and other matters. Clearing of native vegetation is an offence as specified under s51C of the EP Act unless the clearing is done in accordance with a clearing permit or is of a kind set out in Schedule 6 or is of a kind prescribed under the Environmental Protection (Clearing of Native Vegetation) Regulations 2004.

Introduction

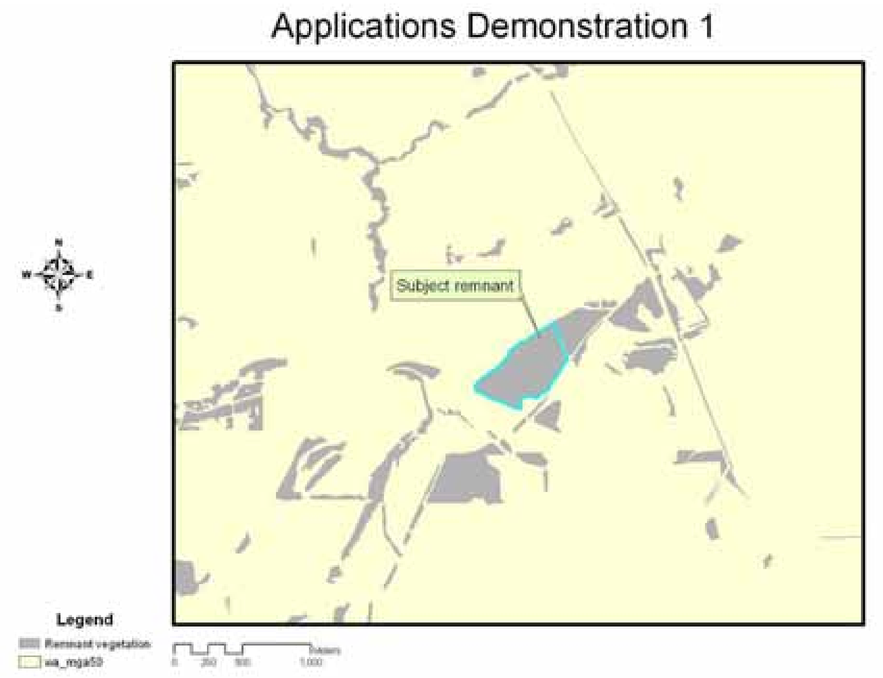
As demonstrated in Appendix 1, the South West Regional Ecological Linkages (SWREL) project has developed a form of proximity analysis to provide decision support data for the development of its Ecological Linkages. To undertake this analysis in a simple and efficient manner, the project has developed a proximity analysis tool for use with nominated GIS programs. This tool not only enables proximity analysis to be undertaken in relation to a line on a map (the usual way of marking linkages) it also enables proximity analysis to be undertaken in relation to any point or polygon within a landscape which can be represented in a GIS shape file. This, in turn, enables biodiversity conservation planners and managers to be able to assess the impacts to connectivity and ecological function within a landscape that may arise from the removal of a patch of remnant vegetation from a landscape through the use of different perspectives. Conversely, adding an object to an input shape file and running a proximity analysis from that object, this proximity analysis tool also has the capacity to demonstrate the impacts on connectivity and ecological function that may arise through the establishment or landscape rehabilitation of habitat areas.

Proximity Analysis from Different Perspectives

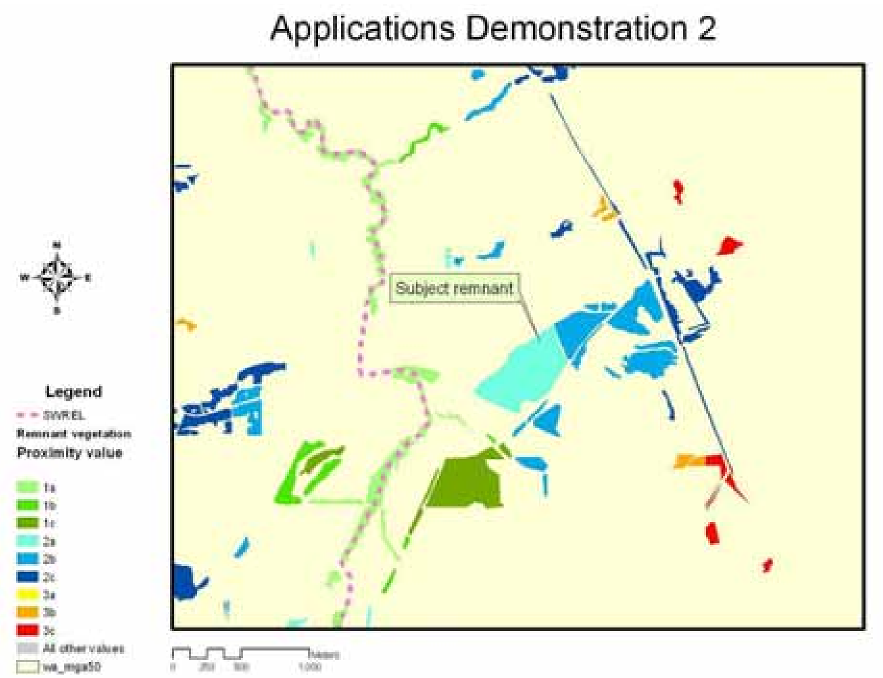
Proximity analysis relies on the measurement of a set of predetermined compound distances relevant to any nominated point or feature represented on a map. Therefore, any proximity analysis relative to any given asset or patch of remnant vegetation is pertinent only in regard to the nominated point or feature from which proximity is measured. Consequently, by changing that point or feature we are able to view proximity analysis in regard to the same asset from different perspectives, or viewpoints each of which will provide a different set of results when subjected to proximity analysis. The ability to view the same situation from different perspectives allows biodiversity planners and managers better insight into the potential consequences which may occur within a nominated landscape following the removal of a nominated patch of remnant vegetation.

To demonstrate the manner in which different perspectives can alter proximity analysis, a fictitious case study has been provided in which it is proposed that a patch of remnant vegetation in a fragmented landscape has been nominated for clearing. The purpose of this exercise is to identify the effects of connectivity within the immediate landscape using proximity analysis from three different perspectives:

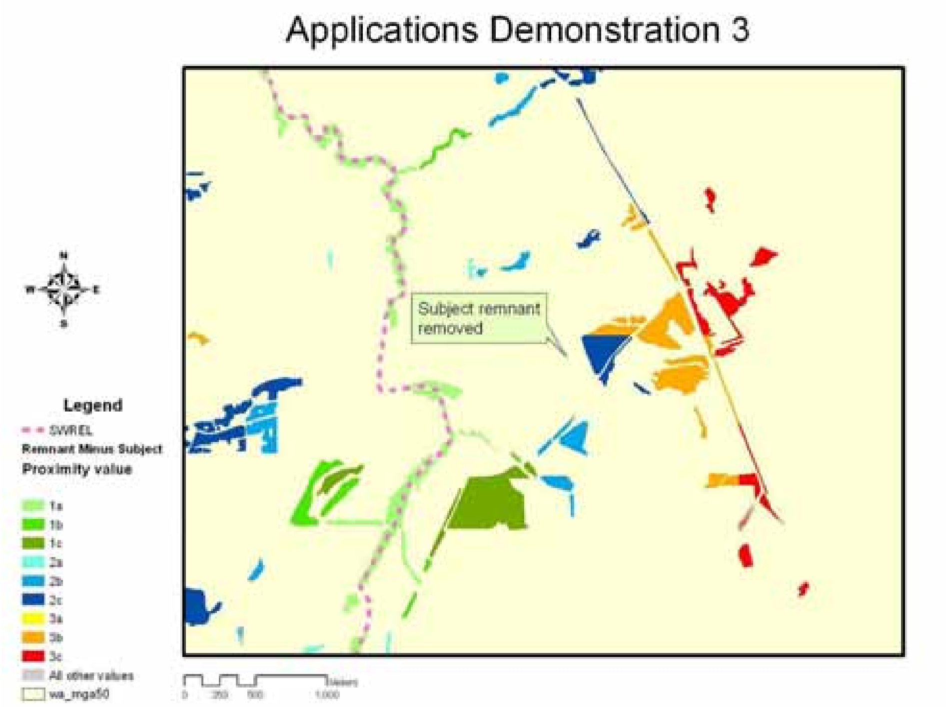
Perspective 1: Changes in proximity analysis in relation to SWREL axis line. This example indicates that in regard to ecological linkages the removal of the subject remnant will have a minor impact on only a few smaller surrounding remnants.



Map 1: ***Patches of remnant vegetation within a nominated landscape with a remnant subject to an evaluation in response to a clearing application (highlighted).***

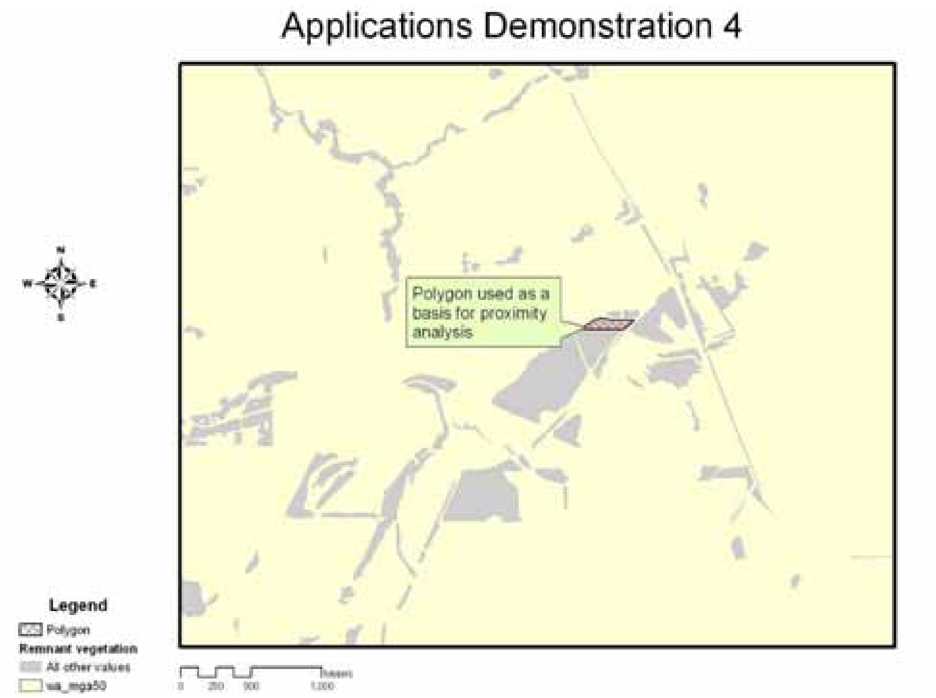


Map 2: ***Proximity analysis as described in the methodology of landscape in relation to the SWREL axis line.*** This demonstrates the degree of connectivity within that landscape in relation to the effectiveness of the nominated linkages.

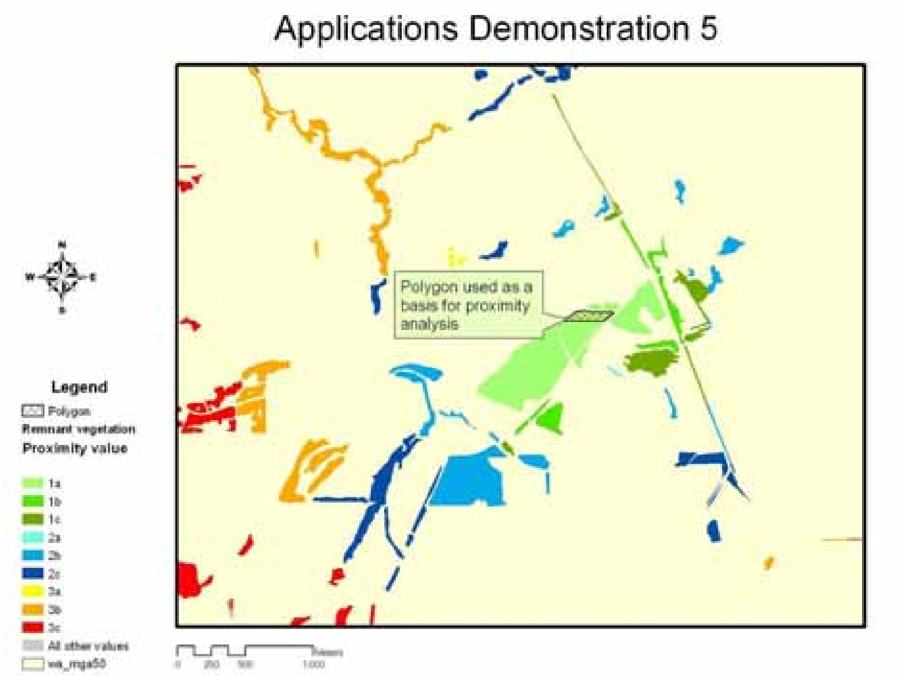


Map 3: ***Proximity analysis of landscape in relation to SWREL axis line with subject remnant removed.*** Removing the subject remnant from the remnant vegetation input and repeating the proximity analysis enables a demonstration of how connectivity within that landscape will change in relation to these linkages. In this instance changes to proximity of remaining remnants in relation to linkages is minor and is largely confined to remnants to the east of the subject remnant

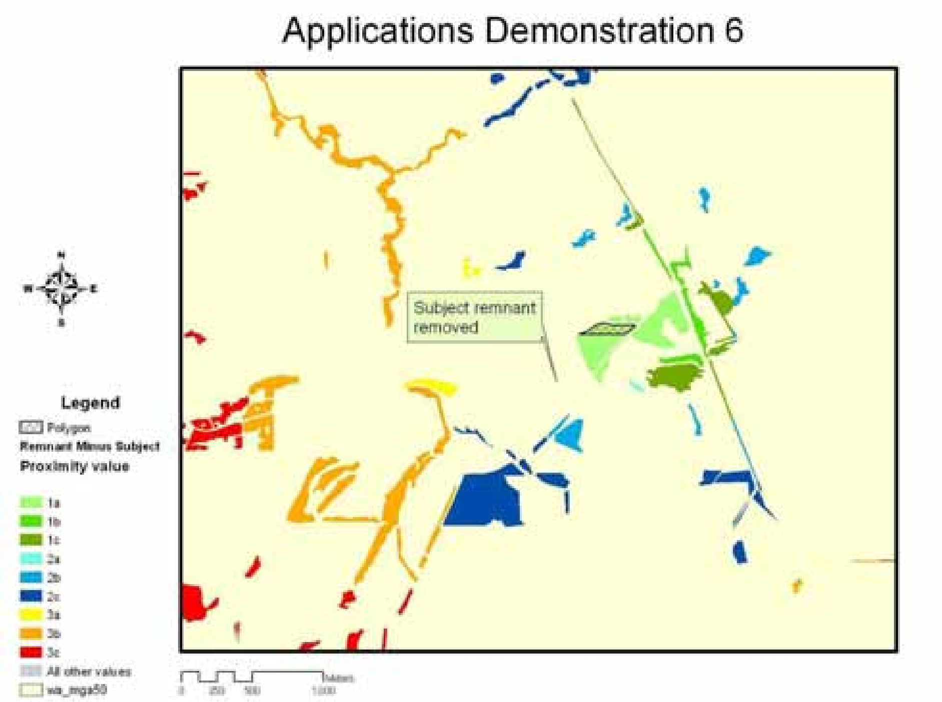
Perspective 2: Changes in proximity analysis in relation to a nominated polygon. This example shows that from the perspective of a nearby patch of remnant vegetation (which may represent a high-value asset such as a reserve or the habitat of a rare species or community) the removal of the subject patch makes a significant difference in regard to total area of closely limited habitat and linkage to nearby remnants, particularly those situated to the north of the subject remnant. In this example if the species or community resident in the nominated polygon was reliant or interactive with remnants to the north and/or their inhabitants, further study and possible re-evaluation may be warranted.



Map 4: ***Patches within a nominated landscape with a nominated polygon highlighted.*** Within the same landscape it is possible to nominate a reserve, ecological community or asset (which can be represented by a polygon) and judge the connectivity impacts on that asset that will arise with the removal of the remnant (as per Map 1) from that landscape.

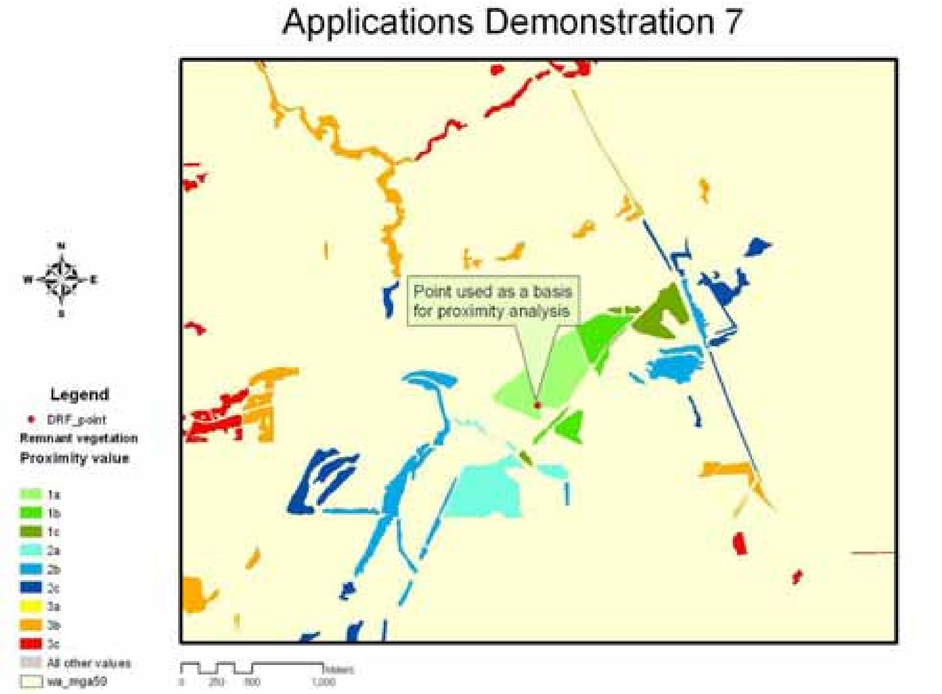


Map 5: ***Proximity analysis of a landscape undertaken in relation to the polygon nominated in Map 4.***

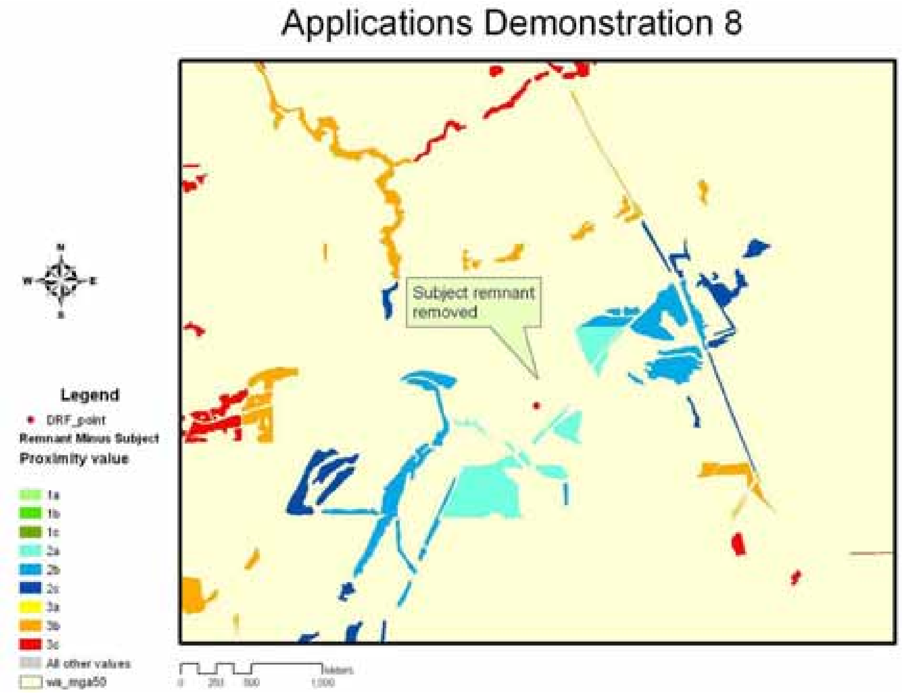


Map 6: ***Proximity analysis of a landscape undertaken in relation to the highlighted polygon with subject remnant removed.*** In this example we can see that changes in proximity, particularly to the west of our polygon, have been dramatically affected compared to the changes in proximity evident in Example 1 even though the only change in the landscape has been the removal of the same subject remnant.

Perspective 3: Changes in proximity analysis in relation to a nominated point. In biodiversity planning and management, spatial data is often given in point form. Points may indicate species or survey sites or provide the central or base point for a landscape that has been defined through some form of spatial or cluster analysis. In this example the removal of the subject remnant from the landscape will have a major impact on the connectivity between the nominated point and the surrounding remnants and on their inhabitants.



Map 7: ***Proximity analysis of landscape in relation to a fixed point within a landscape.*** This represents any situation where a proximity analysis is conducted on single point input data (although multiple points can be utilised) such as that which is used to map species, survey or trap sites or where landscapes are defined in relation to a given point within a landscape; for example, where a landscape is defined through a spatial or cluster analysis.



Map 8: ***Proximity analysis of landscape in relation to a fixed point within a landscape with subject remnant removed.*** In this map the subject remnant has been removed from the data set and a new proximity analysis has been conducted. By comparing Maps 7 and 8 it is possible to observe a dramatic change (compared to examples 1 and 2) in landscape connectivity relative to a specific test point.

Discussion

In this case study three different spatial analyses were conducted within a nominated landscape from three different perspectives i.e. relative to a nominated set of lines, a polygon and a point. Spatial analyses were conducted within the context of complete landscapes and then repeated with the subject remnant removed. Within each perspective comparisons were made between analyses conducted with and without the subject remnant. The comparisons show that each perspective indicated different impacts on landscape connectivity would result from the removal of the subject patch of remnant vegetation. This indicates that an adequate understanding of the potential impacts to connectivity within a landscape that may arise from the removal of a patch of remnant vegetation may require proximity analysis from multiple perspectives.

This case study supports the SWREL project's position that the effective assessment of impacts to landscape connectivity and ecological function arising from the removal of remnant vegetation requires the capacity to analyse proximity from variable perspectives.

Appendix 3 : Computer Modelling in Support of the Development of the SWREL:

An Application of Marxan.

By Jodie Wood and Shaun Molloy

Note: Marxan has been used by the SWREL project to produce data which will inform, and thereby support the decision making process. The Marxan software has been used to provide a landscape solution that will demonstrate conservation requirements outlined in EPA policy (EPA 2006 and 2008). Data produced in this manner has been used in conjunction with many other data sets to inform, and thereby support, decision makers in applying the project's factors for consideration and guiding principles.

Introduction

The Western Australian Local Government Association's (WALGA) South West Biodiversity Project (SWBP) in collaboration with the Department of Environment and Conservation's (DEC) Swan Bioplan Project and State Agencies propose to recognise a series of regionally-significant ecological linkages across the south west region to be known as the South West Regional Ecological Linkages (SWREL) Project.

The SWREL project's methodology for the nomination of ecological linkages is largely reliant on nominating series of priorities and guiding principles which are used to draft linkages within the project area. These principles and priorities have been adapted from previous work produced by the SWBP (Molloy *et al.* 2007). The draft linkages are then reviewed by the project's technical working group (TWG) and regional stakeholders. All stages of this process are subject to a proximity analysis which is used to demonstrate the effectiveness of the nominated linkages in respect to landscape connectivity through all stages of the planning process (Molloy 2009). Furthermore, project staff have continued to assess the capacity of additional decision support tools to enhance the credibility of this planning process. In so doing it has been found that with the use of appropriate targets and parameters. Marxan 2 has the capacity to provide consistent and highly-effective decision support in design linkages.

What is Marxan?

Marxan (Ball and Possingham 2000) is a software package that is designed to deliver decision support for reserve system planning. It does this by selecting a series of areas (planning units) for retention and/or acquisition that best meet the outcomes required by the user. The user's requirements are expressed through input targets and parameters that enable Marxan to select a group of planning units with retention that will best reflect the user's reserve planning priorities and constraints.

It should be noted that Marxan is not designed to designate areas with priority for ecological linkages. Marxan is primarily intended to solve a particular class of reserve design problems known as the 'minimum set problem', where the goal is to achieve some minimum representation of biodiversity features for the smallest possible cost. In minimum set problems the elements of biodiversity that you wish to conserve are entered as constraints to solutions of the problem (Possingham *et al.* 2000). Given reasonably comprehensive data on species, habitats and/or other relevant biodiversity features, it aims to identify the reserve system (a combination of planning units) that will meet user-defined biodiversity targets for the minimum cost (Game and Grantham 2008).

Although Marxan can be used for a variety of purposes at a variety of stages in the systematic conservation planning process, it was designed primarily to help inform the selection of new conservation areas for minimal "cost" and facilitate the exploration of trade-offs between conservation and socio-economic objectives. Marxan can help set priorities for conservation action by highlighting places that are likely to be

important inclusions in an efficient reserve network. Marxan can also be employed as a tool for evaluating the representation and comprehensiveness of existing reserve networks (Game and Grantham 2008).

Note: It is important to understand that the appropriate role of Marxan, as with other decision support software, is to support decision making. Marxan solutions can form the basis of discussions towards a final plan that incorporates additional political, socio-economic and pragmatic factors (Game and Grantham 2008).

Why incorporate Marxan into the SWREL project?

Marxan was one of several tools considered by the SWREL project to assess its suitability to support decisions in the application of the SWREL methodology. In a trial using the southern section (south of the Perth Metropolitan Area) of Western Australia's Swan Costal Plain as a test landscape, a strong continuity was found between units selected by Marxan (with target parameters designed to reflect the values outlined in the Environmental Protection Authority's Guidance Statement 10 and 33 (EPA 2006 and 2008)) and landscapes selected through the SWREL project methodology (which had also been designed to comply with the values outlined in the same Guidance Statements). This strong similarity between the results of two very different processes indicated that Marxan may be a useful decision support tool to be incorporated into the SWREL methodology.

On examination it was found that similarities between the planning units selected through these two independent processes was estimated at approximately 95%. This degree of conformity was such that attention was immediately drawn to those comparatively few planning units where these processes appeared to conflict. Consequently, the planning units were subjected to examination and review by project staff to determine the reasons for their conflicting selections. The review found that in every case the reason for the apparent conflict was related to either; shortfalls in the GIS data used in the Marxan analysis (e.g. a lack of information about remnant vegetation condition or incorrectly mapped polygons), the specialist knowledge of those drafting the linkages (e.g. in regard to factors such as hidden assets values and tenure limitations), and where value judgements reflecting the application of the guiding principles (Molloy 2009) were required (e.g. where principles had to be prioritised in response to landscape requirements).

The result of this examination and review process was that Marxan allowed us to see that draft linkages determined through the application of guiding principles and proximity analysis soundly reflected the guiding principles outlined in Guidance Statements 10 and 33 (EPA 2006 and 2008). It also brought attention to conflicts and ambiguities between the two processes which needed to be addressed. In these cases explanations were found for the conflicting findings and in some cases processes were refined and draft linkages altered.

Having substantiated valid decisions and brought attention to ambiguities it was felt the Marxan appication added further dimensions of substance and rigour to the SWREL project. Consequently SWREL project staff have incorporated Marxan analyses into the project's methodology.

Setting up the Marxan analysis

Marxan requires a number of files to be created in order for it to run analyses. The use of Marxan in the SWREL project required the creation of the following files:

- a planning unit layer
- a species layer
- a planning unit versus species matrix layer; and
- a boundary file.

Planning Unit

The planning unit layer was created over the southern portion of the Swan Coastal Plain (the project area) as a square grid of 500m by 500m in size. Planning units within this grid can be 'locked in' or 'locked out' as required. In this analysis, planning units that were greater than 50% within DEC Estate (as identified through the relevant DEC GIS layer (see Table 1)) were 'locked in' to the analysis. That is, these units would be included in all Marxan solutions. The 50% threshold is arbitrary and can be changed.

The possibility of 'locking out' planning units based on regional zoning or tenure has been discussed.

Species Layer

The species layer lists the conservation features/species and the target amount to be included in the solution. The SWREL project area was analysed in three parts: the southern Swan Coastal Plain, the Warren Region and the Jarrah Forest Region. Map 1 shows these boundaries. The conservation features/species used in each of the analyses and the target amounts set are listed in Tables 2–5 (below).

A species penalty factor can be set for each conservation feature or can be generic. Marxan calculates whether the target for each conservation feature is met and includes a cost for any target that has not been met as specified by the species penalty factor.

Planning Unit vs. Species Matrix

This layer determines how much of each conservation feature occurs in each planning unit.

Boundary File

This layer determines the boundaries between each of the planning units. That is, the total amount of edge that the planning units share with unprotected units (scattered, unconnected planning units will have a large cost). The cost is quantified as the length of edge or dollars. Marxan then multiplies this value by the Boundary Length Modifier (BLM). Increasing the BLM increases the cost of having a fragmented set of conservation areas.

In the analyses the BLM was set at 0, 0.1, 0.01 and 0.001. Use of a 0.001 BLM resulted in the best solution for the problem posed in all three analyses.

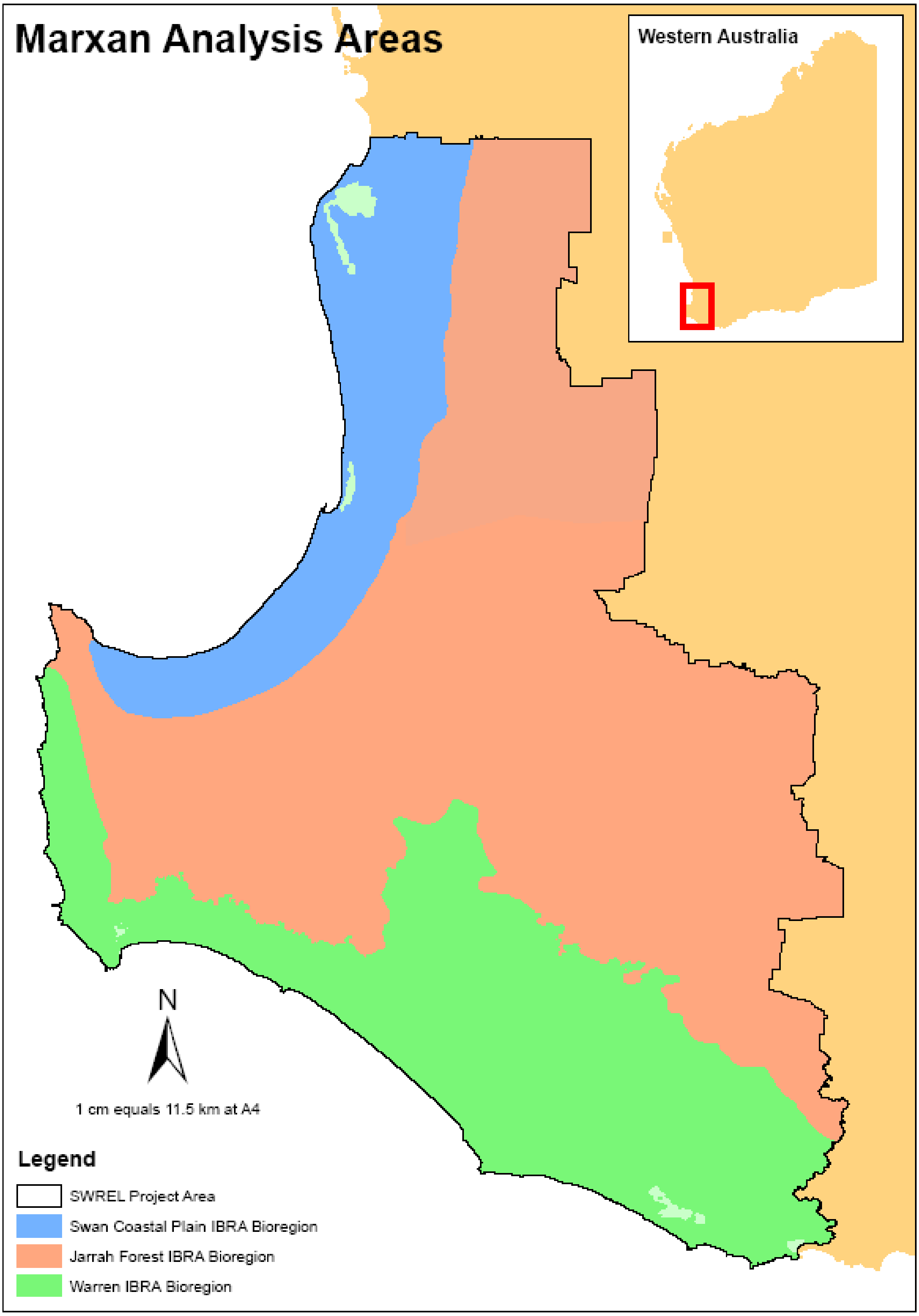


Figure 1: Map of Analysis Area Boundaries

Table 1: Conservation features/species used in the analysis and the target amounts set on the Southern Swan Coastal Plain.

Conservation Feature	% target	species penalty factor
Conservation Category Wetland	100	1
Resource Enhancement Wetland	80	1
Crown Reserves	100	1
DEC Covenants	100	1
Priority Fauna	50	1
Declared Threatened Fauna	100	1
Other Specially Protected Fauna	50	1
Rare Flora	100	1
Priority Flora	50	1
LFW Covenants	100	1
NHTWA Covenants	100	1
SCP FCT Sites	100	1
System 6 Sites	80	1
TEC Boundaries	100	1
Tuart Occurrence	50	1
Wandoo Occurrence	100	1
Whicher Scarp Plots	100	1
Vegetation Complexes		
Vasse Complex	80	1
Quindalup Complex	80	1
Yoongarillup Complex	50	1
Swan Complex	95	1
Karrakatta Complex-Central & South Complex	50	1
Southern River Complex	80	1
Guildford Complex	95	1
Yelverton Complex	80	1
Abba Complex	95	1
Ludlow Complex	80	1
Cartis Complex	80	1
Whicher Scarp	50	1
Preston Complex	80	1
Rosa Complex	50	1
Kingia Complex	80	1
Jalbaragup Complex	50	1
Darling Scarp Complex	80	1
Lowdon Complex	50	1
Dwellingup Complex	50	1
Yarragil 1 Complex	50	1
Bassendean Complex-Central & South Complex	80	1
Cannington Complex	95	1
Serpentine River Complex	95	1
Dardanup Complex	95	1
Forrestfield Complex	95	1
Cottesloe Complex-Central & South Complex	50	1
Helena 1 Complex	50	1
Murray 1 Complex	50	1
Herdsman Complex	80	1
Bidella Complex	50	1

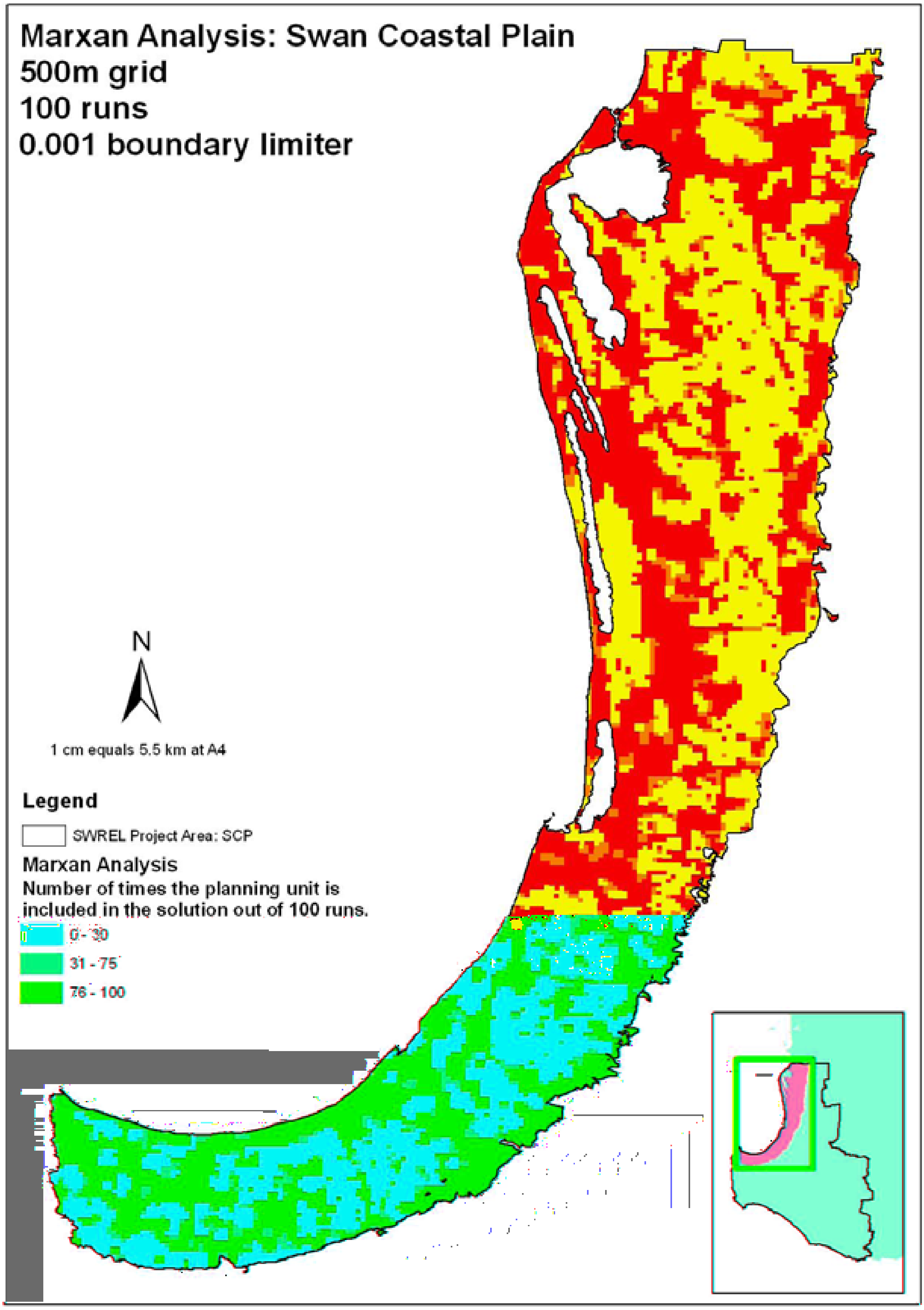


Figure 2: Number of Times the Planning Unit is Included in Solution for Swan Coastal Plain

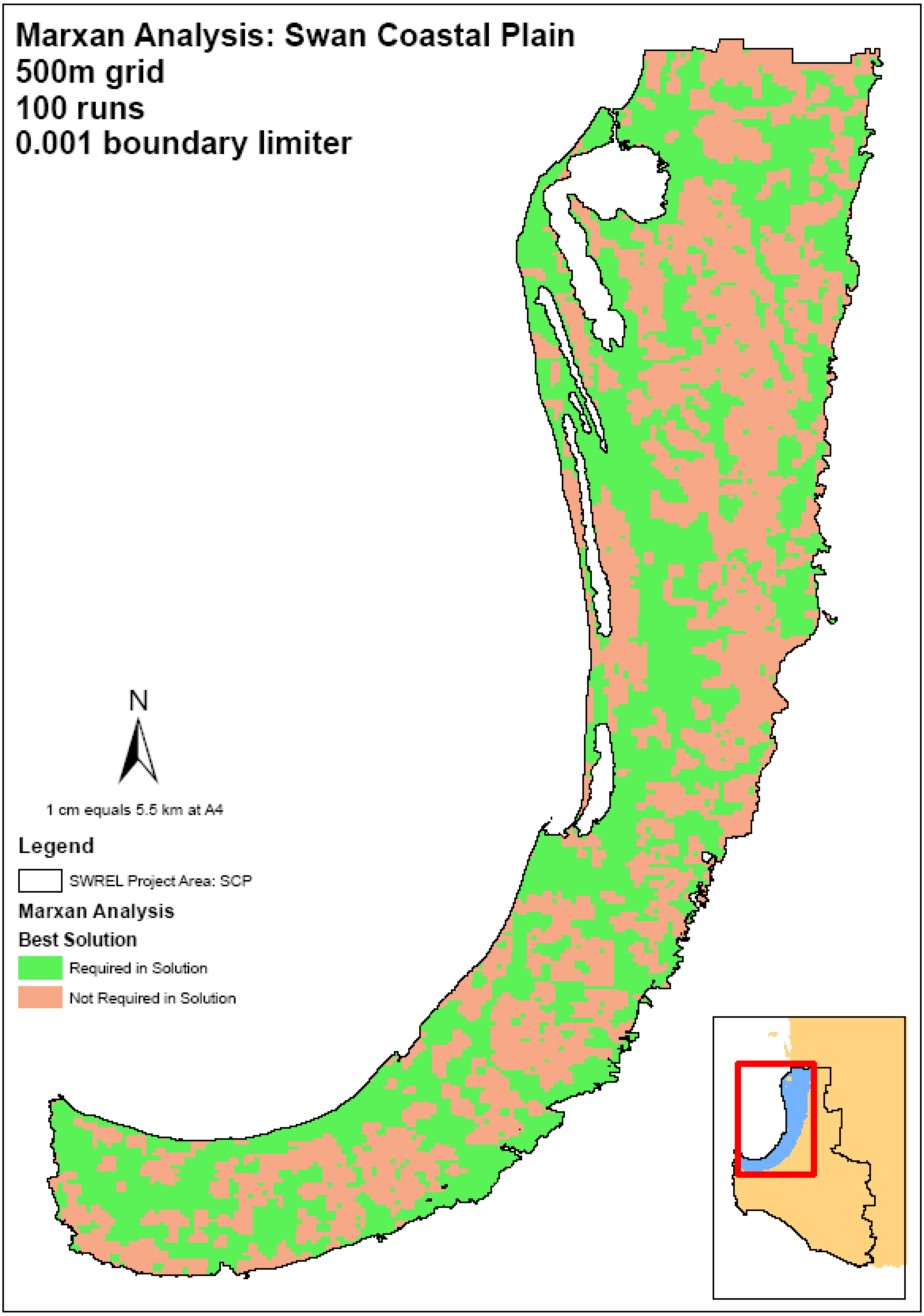


Figure 3: Areas Required in Solution for Swan Coastal Plain

Table 2: Conservation features / species used in the analysis and the target amounts set in the Warren Region portion of the project area.

Conservation Features	% Target	species penalty factor
Crown Reserves	100	1
DEC Covenants	100	1
Priority Fauna	50	1
Declared Threatened Fauna	100	1
Other Specially Protected Fauna	50	1
Rare Flora	100	1
Priority Flora	50	1
LFW Covenants	100	1
NHTWA covenants	100	1
System 6 Sites	100	1
Syst 1 to 5 and 7 to 12 Sites	100	1
TEC Boundaries	100	1
Important Wetlands	100	1
Final FHZ	100	1
Old Growth Forest	100	1
Vegetation Complexes		
Angove (A)	35	1
Balingup (BL)	95	1
Barlee (Ba)	35	1
Bevan (BE1)	85	1
Bevan (BE2)	35	1
Bevan (Beb)	35	1
Bevan (BEy1)	35	1
Blackwater (BW)	35	1
Blackwater (BWp)	35	1
Blackwood (B)	85	1
Blackwood (Bd)	35	1
Blackwood (Bf)	85	1
Blackwood (BK)	35	1
Blackwood (Bw)	85	1
Blackwood (Bwy)	95	1
Bridgetown (BT)	95	1
Broad Swamps (S4)	85	1
Burnett (BU)	35	1
Caldyanup (CA)	35	1
Camballup (CM)	35	1
Cattaminup (CP)	35	1
Catterick (CC1)	85	1
Catterick (CC2)	35	1
Cleave (CV)	35	1
Coate (CE)	85	1
Collis (CO1)	95	1
Collis (Cob)	35	1
Collis (Cod)	35	1
Collis (COy1)	35	1
Corbalup (CL1)	95	1
Corbalup (CL2)	35	1
Cormint (CT)	35	1
Cowaramup (C1)	95	1

Conservation Features	% Target	species penalty factor
Cowaramup (C2)	95	1
Cowaramup (Cd)	85	1
Cowaramup (Cr)	85	1
Cowaramup (Cw1)	95	1
Cowaramup (Cw2)	95	1
Crowea (CRb)	35	1
Crowea (CRd)	35	1
Crowea (Cry)	85	1
Darling Scarp (DS1)	85	1
Darradup (DP)	35	1
D'Entrecasteaux (D)	95	1
D'Entrecasteaux (D5)	95	1
D'Entrecasteaux (Dd)	35	1
D'Entrecasteaux (Dd5)	35	1
D'Entrecasteaux (DE5)	35	1
D'Entrecasteaux (Dr)	95	1
D'Entrecasteaux (Drd)	95	1
D'Entrecasteaux (E)	35	1
Donnelly (DO)	35	1
Gardner (Gg)	35	1
Glenarty Hills (H)	95	1
Glenarty Hills (Hd)	35	1
Glenarty Hills (Hw)	95	1
Gracetown (G2)	35	1
Gracetown (G3)	35	1
Gracetown (GE)	35	1
Gracetown (Ge)	35	1
Gracetown (Gv)	95	1
Gracetown karst (Gk)	35	1
Granite Valleys (S1)	35	1
Granite Valleys (S2)	35	1
Granite Valleys (V1)	35	1
Granite Valleys (V4)	35	1
Granite Valleys (Vh2)	35	1
Granite Valleys (Vh3)	35	1
Hawk (HK)	35	1
Hazelvale (HA)	85	1
Jangardup (JN)	35	1
Jasper (JA)	35	1
Keystone (Kb)	35	1
Keystone (Kg)	35	1
Keystone (Ks)	85	1
Keystone (Ky)	35	1
Kilcarnup (KbE)	35	1
Kilcarnup (KE)	35	1
Kilcarnup (Kef)	35	1
Kilcarnup (Kf)	85	1
Kilcarnup (Kr)	35	1
Kingia (KI)	85	1

Conservation Features	% Target	species penalty factor
Kordabup (KO)	85	1
Lakes and Open Water (L)	95	1
Lefroy (LF)	35	1
Mattaband (MT1)	95	1
Mattaband (MTb)	35	1
Mattaband (MTy1)	35	1
Meerup (Mc)	35	1
Meerup (Mf)	35	1
Meerup (Mp)	35	1
Meerup (Mr)	35	1
Meerup (Ms)	35	1
Meerup (Mu)	35	1
Meerup (My)	95	1
Nillup (N)	35	1
Nillup (Nd)	35	1
Nillup (Nw)	35	1
Owingup (OW)	35	1
Pemberton (PM1)	85	1
Pemberton (PM2)	95	1
Pingerup (Pi)	35	1
Quagering (Q)	35	1
Quartzite Hills (QT)	35	1
Quindabellup (QN)	35	1
Quininup (QP)	85	1
Scott (Sd)	85	1
Scott (Sd2)	35	1
Scott (Sw)	95	1
Scott (Swd)	35	1
Scott (Swi)	95	1
Shallow Valleys (S3)	35	1
Sidcup (SC)	95	1
Stratton (ST)	35	1
Toponup (TP)	95	1
Treeton (T)	95	1
Treeton (Tw)	95	1
Trent (TR1)	35	1
Walpole (Wp)	85	1
Warren (WA)	35	1
Wheatley (WH1)	35	1
Wheatley (WH2)	85	1
Wilgarup (WL)	85	1
Wilyabrup (W1)	85	1
Wilyabrup (W2)	95	1
Wilyabrup (Wd)	95	1
Wilyabrup (We)	35	1
Wilyabrup (WE)	35	1
Wilyabrup (Wew)	35	1
Wilyabrup (Wr)	95	1
Wilyabrup (Ww1)	85	1
Wilyabrup (Ww2)	95	1
Wishart (WS2)	85	1
Yanmah (YN1)	35	1
Yanmah (YN2)	85	1
Yornup (YR)	85	1

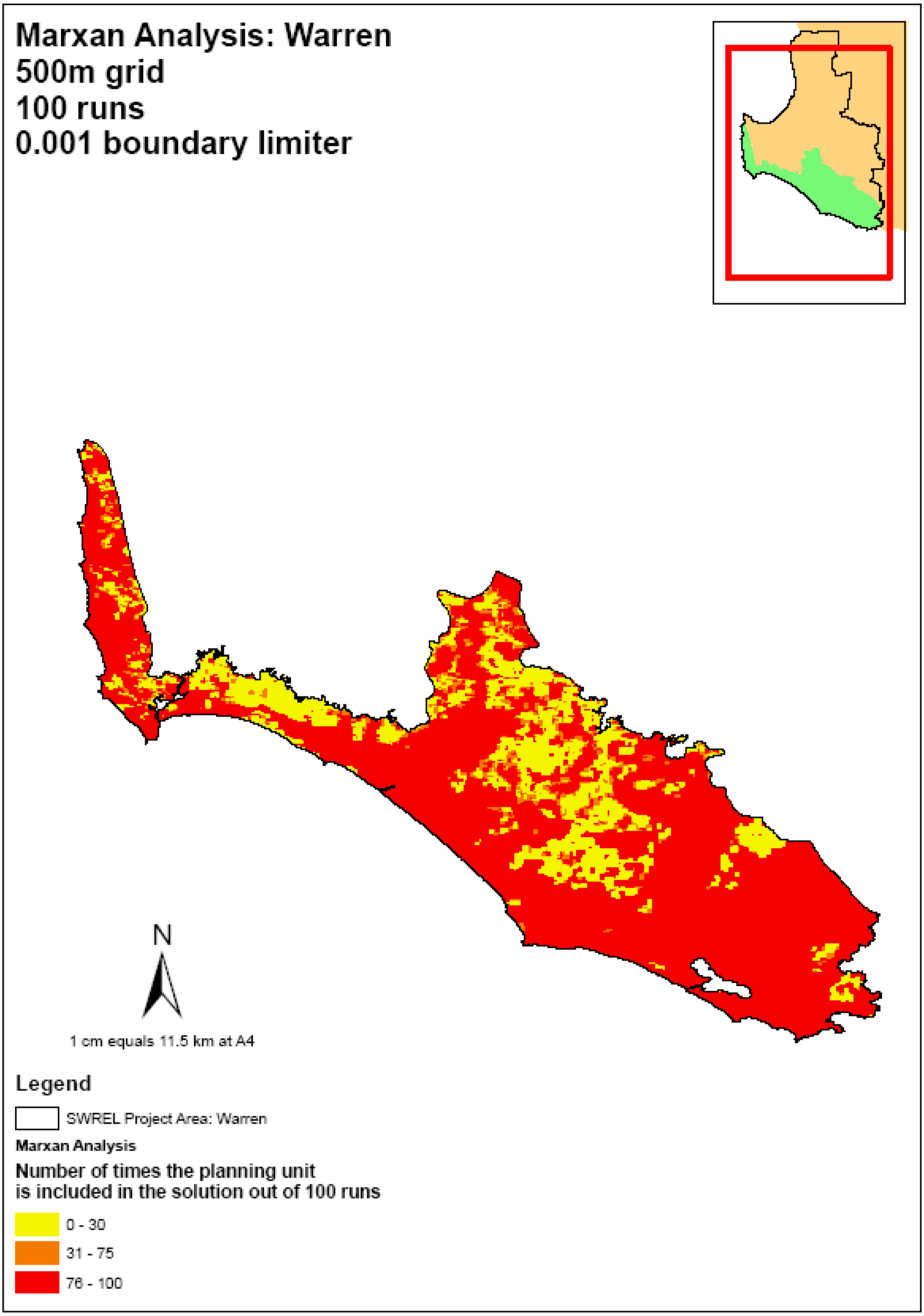


Figure 4: Number of Times the Planning Unit is Included in Solution for Warren

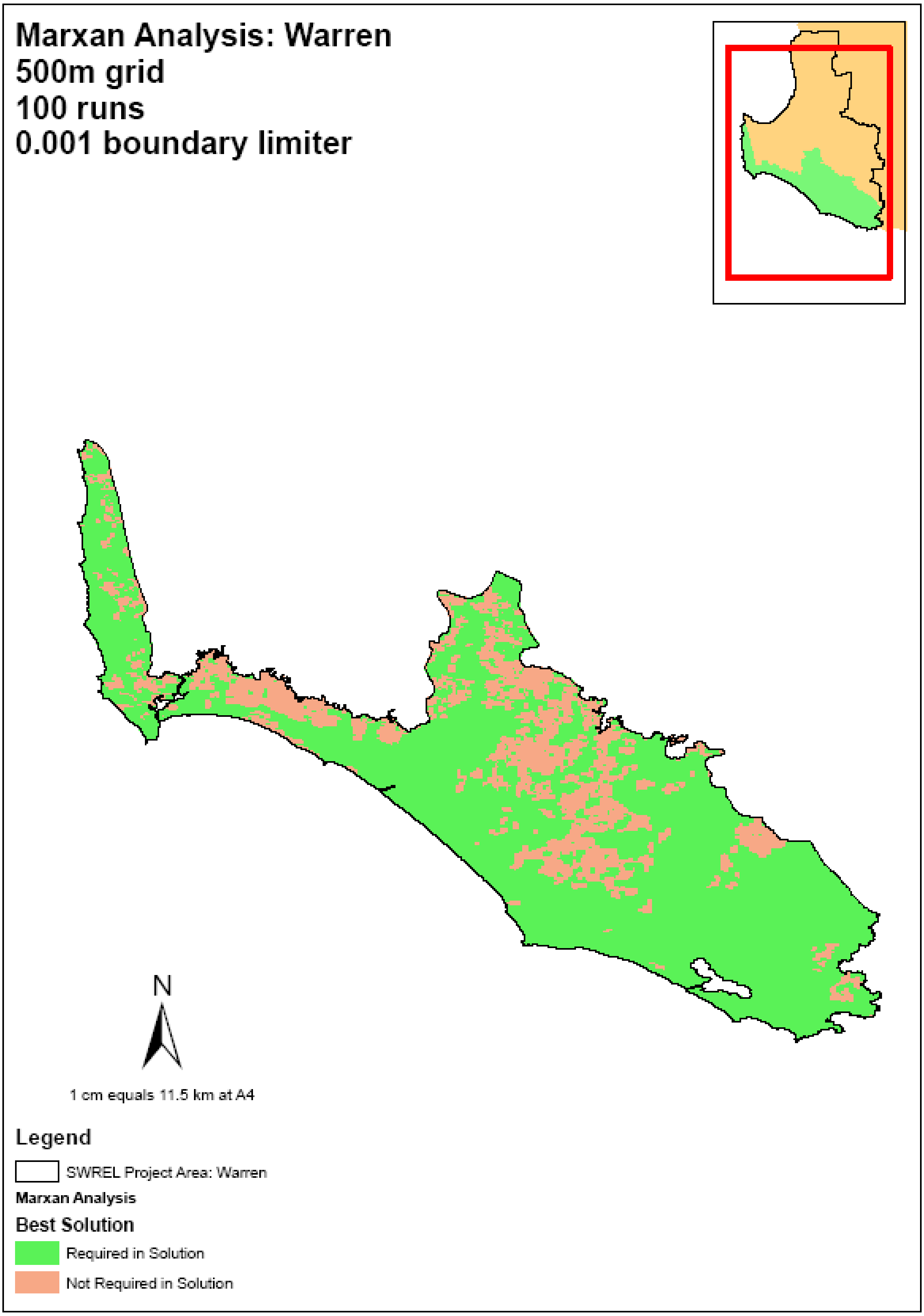


Figure 5: Areas Required in Solution for Warren

Table 3: Conservation features / species used in the analysis and the target amounts set in the Jarrah Forest portion of the project area.

Conservation Features	% Target	species penalty factor
System 6 Sites	100	1
TEC Boundary	100	1
Declared Threatened Fauna	100	1
Priority Fauna	100	1
Other Specially Protected Fauna	100	1
Rare Flora	100	1
Priority Flora	100	1
NHTWA Covenants	100	1
LFW Covenants	100	1
DEC Covenants	100	1
Crown Reserves	100	1
System 1 to 5 and 7 to 12 Sites	100	1
Final FHZ	100	1
Old Growth Forest	100	1
Important Wetlands	100	1
Vegetation Complexes		
Angove (A)	35	1
Abba (AB)	95	1
Abba (Ad)	85	1
Blackwood (B)	85	1
Barlee (Ba)	35	1
Bidella (BD)	35	1
Blackwood (Bd)	35	1
Bevan (BE1)	85	1
Bevan (BE2)	85	1
Bevan (BE3)	35	1
Bevan (Beb)	35	1
Bevan (Bes)	35	1
Bevan (BEy1)	35	1
Bevan (BEy2)	85	1
Blackwood (Bf)	85	1
Blackwood (BK)	35	1
Balingup (BL)	85	1
Balingup (BLf)	85	1
Bentley (BN)	85	1
Boonarie (BO)	85	1
Boscabel (Bo1)	85	1
Boscabel (Bo1s)	85	1
Brockman (BR)	95	1
Bridgetown (BT)	85	1
Bridgetown (BTf)	85	1
Blackwood (Bw)	85	1
Cowaramup (C1)	85	1

Conservation Features	% Target	species penalty factor
Cowaramup (C2)	85	1
Caldyanup (CA)	35	1
Carbanup (CB)	35	1
Catterick (CC1)	85	1
Catterick (CC2)	35	1
Cowaramup (Cd)	85	1
Cooke (Ce)	85	1
Coate (CE)	85	1
Cardiff (CF)	85	1
Collie (CI)	85	1
Coolakin (Ck)	85	1
Corbalup (CL1)	85	1
Corbalup (CL2)	35	1
Camballup (CM)	35	1
Collis (CO1)	85	1
Collis (CO2)	85	1
Collis (COy1)	35	1
Collis (COy2)	35	1
Cattaminup (CP)	35	1
Condinup (CP1)	85	1
Condinup (CP2)	85	1
Crowea (CRb)	85	1
Crowea (CRd)	35	1
Crowea (CRy)	85	1
Cormint (CT)	35	1
Cowaramup (Cw1)	85	1
Cowaramup (Cw2)	85	1
Dwellingup (D1)	85	1
Dwellingup (D2)	85	1
Dwellingup (D4)	85	1
Donnybrook (DB3)	85	1
Darkin 1 (Dk1)	85	1
Darkin 2 (Dk2)	95	1
Darkin 3 (Dk3)	95	1
Darkin 4 (Dk4)	95	1
Darkin 5 (Dk5)	85	1
Darkin 5f (Dk5f)	85	1
Dalmore (DM1)	85	1
Dalmore (DM2)	85	1
Dalmore (DMg)	95	1
Donnelly (DO)	35	1
Darradup (DP)	35	1
Darling Scarp (DS1)	85	1
Darling Scarp (DS2)	85	1
Farrar 1 (Fa1)	85	1
Farrar 2 (Fa2)	95	1

Conservation Features	% Target	species penalty factor
Farrar 3 (Fa3)	95	1
Farrar 4 (Fa4)	95	1
Frankland Hills (FH1)	85	1
Frankland Hills (FH2)	85	1
Frankland Hills (FH3)	85	1
Frankland Hills (FH4)	85	1
Frankland Hills (FH5)	85	1
Forrestfield (Fo)	95	1
Goonaping (Go)	35	1
Gracetown (G3)	35	1
Gale (GA)	85	1
Gordon Flats (GD1)	85	1
Gordon Flats (GD2)	85	1
Gordon Flats (GD4)	85	1
Gracetown (GE)	35	1
Gracetown (Ge)	35	1
Grimwade (GR)	85	1
Gnowergerup (GW)	85	1
Glenarty Hills (H)	85	1
Glenarty Hills (Hd)	35	1
Helena (He1)	85	1
Hester (HR)	85	1
Glenarty Hills (Hw)	85	1
Jalbaragup (JL)	85	1
Jangardup (JN)	35	1
Jingalup (JP2)	95	1
Kilcarnup (KbE)	35	1
Kilcarnup (KE)	35	1
Kingia (KI)	85	1
Kapalarup (KP)	85	1
Kirup (KR)	85	1
Kilcarnup (Kr)	35	1
Kulikup (KU1)	85	1
Kulikup 2 (KU2)	85	1
Kulikup (Kuw)	95	1
Keystone (Ky)	35	1
Lakes and Open Water (L)	95	1
Lefroy (LF)	35	1
Lindesay (Lg)	35	1
Lukin (LK1)	85	1
Lukin (LK2)	85	1
Lowdon (Lo)	85	1
Lindesay (Lp)	35	1
Ludlow (LW)	85	1
Ludlow (Lw)	85	1
Layman (LY)	85	1

Conservation Features	% Target	species penalty factor
Metricup (M)	85	1
Michibin (Mi)	85	1
Muja (MJ)	85	1
Mumballup (ML)	95	1
Milyeanup (MP)	85	1
Mattaband (MT1)	85	1
Mattaband (MT2)	85	1
Mattaband (MTb)	35	1
Mattaband (MTy1)	35	1
Metricup (Mv)	85	1
Murray (My1)	85	1
Murray 2 (My2)	85	1
Nillup (N)	35	1
Nillup (Nd)	35	1
Nillup (Nw)	35	1
Newgalup 1 (NW1)	85	1
Newgalup 2 (NW2)	85	1
Newgalup 1 (NWf1)	85	1
Newgalup 2 (NWf2)	85	1
Newgalup 1 (NWg1)	95	1
Newgalup 2 (NWg2)	95	1
Pingerup (Pi)	35	1
Pemberton (PM1)	85	1
Pemberton (PM2)	85	1
Pindalup (Pn)	85	1
Preston (PR)	85	1
Quagering (Q)	35	1
Quindabellup (QN)	35	1
Quininup (QP)	85	1
Quartzite Hills (QT)	85	1
Qualeup (QU)	85	1
Qualeup (Quw)	85	1
Queenwood (QW)	85	1
Queenwood (QWf)	85	1
Rosa (RO)	85	1
Swamp (S)	35	1
Granite Valleys (S1)	35	1
Granite Valleys (S2)	85	1
Shallow Valleys (S3)	35	1
Sandalwood (SD)	85	1
Scott (Sd)	85	1
Stockton (SK)	35	1
Southhampton (SP)	85	1
Scott Scarp (SS)	35	1
Stratton (ST)	35	1
Swan (SW)	95	1

Conservation Features	% Target	species penalty factor
Scott (Swd)	35	1
Valley Terrace (t)	35	1
Treeton (T)	85	1
Treeton (Td)	35	1
Telerah (TL)	85	1
Toponup (TP)	85	1
Treeton (Tw)	85	1
Unicup (UC1)	85	1
Unicup (UC2)	35	1
Unicup (UC3)	85	1
Unicup (UC4)	35	1
Granite Valleys (V4)	35	1
Granite Valleys (Va2)	35	1
Granite Valleys (Va3)	35	1
Granite Valleys (Vh2)	35	1
Wilyabrup (W1)	85	1
Wilyabrup (W2)	85	1
Warren (WA)	35	1
Whicher Scarp (WC)	85	1
Whicher Scarp (WCv)	85	1
Wilyabrup (Wd)	85	1
Wilyabrup (We)	35	1
Wilga (WG)	85	1
Wheatley (WH1)	85	1
Wheatley (WH2)	85	1
Wheatley (WH3)	85	1
Wilgarup (WL)	85	1
Wilyabrup (Wr)	85	1
Wishart (WS2)	85	1
Wishart (WSv)	85	1
Wilyabrup (Ww1)	85	1
Wilyabrup (Ww2)	85	1
Yelverton (Y)	85	1
Yalanbee (Y5)	85	1
Yelverton (Yd)	85	1
Yerraminnup (YE)	35	1
Yerraminnup (Yef)	35	1
Yelverton (Yf)	85	1
Yarragil 1 (Yg1)	85	1
Yarragil 2 (Yg2)	85	1
Yanmah (YN1)	85	1
Yanmah (YN2)	85	1
Yornup (YR)	85	1
Yelverton (Yw)	85	1

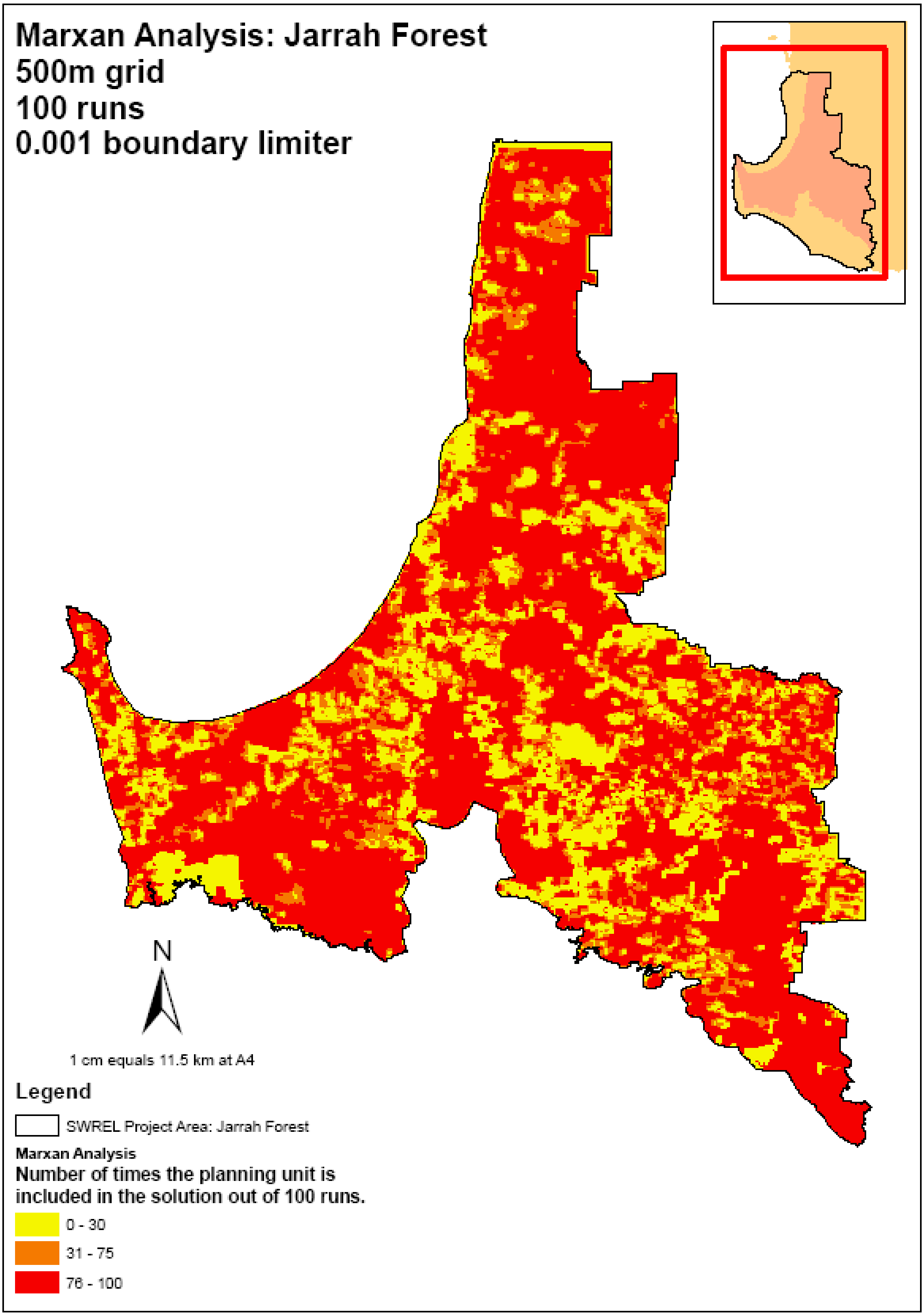


Figure 6: Number of Times the Planning Unit is Included in Solution for Jarrah Forest

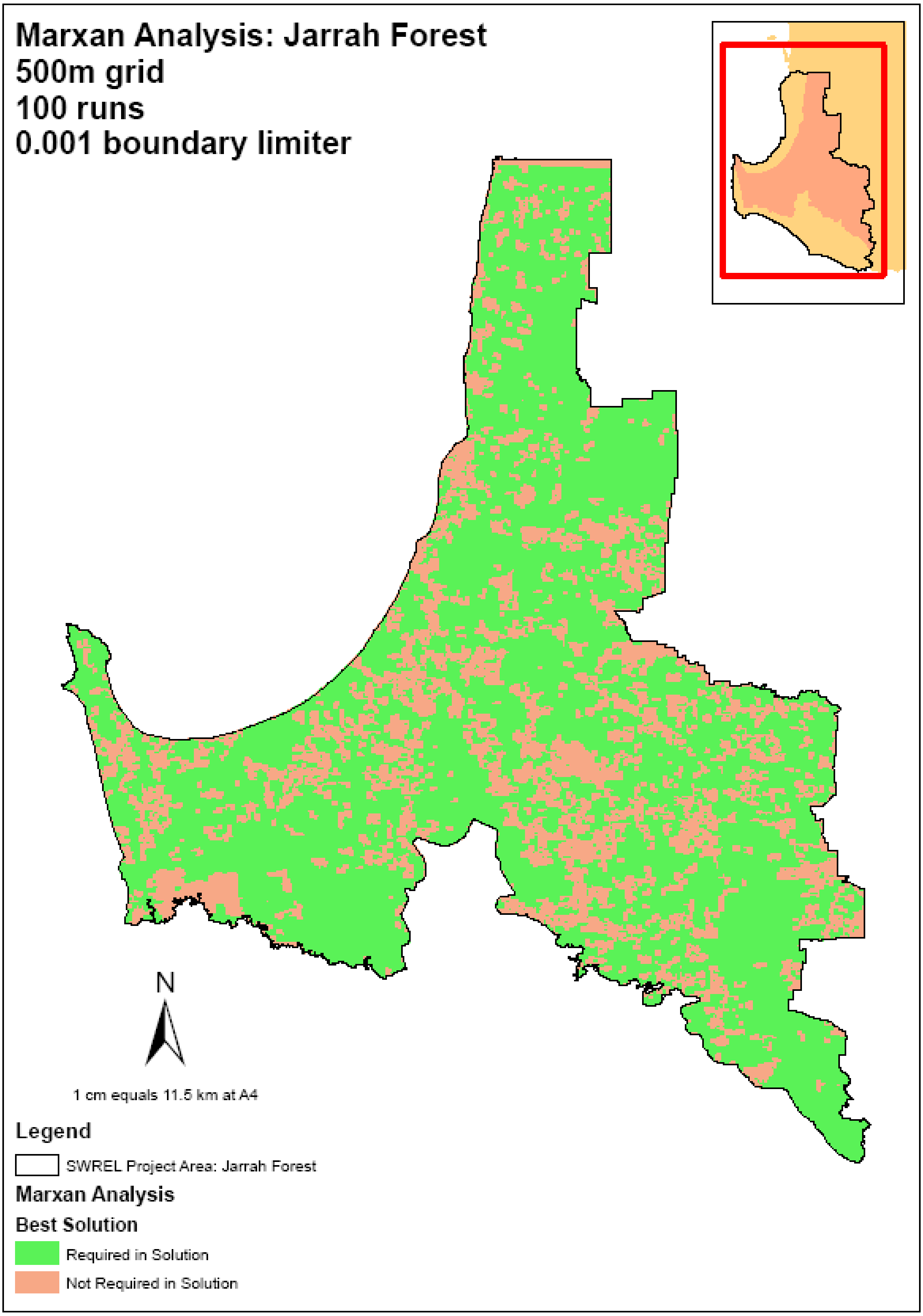


Figure 7: Areas Required in Solution for Jarrah Forest

Table 4: List of GIS Data Sets Used in Marxan Analysis

List of GIS Data Sets Used in Marxan Analysis			
Theme	**Title**	**Custodian**	**Meta Data Date**
Imagery	Orthophotography – Image Tiles (1:50,000 double format sheets)	Department of Land Information WA (DLI)	1991 to 2006 (according to 2006 meta data statement)
Remnant vegetation Mapping	Swan Bioplan Mapping Remnant vegetation mapping (No meta data yet available)	Environment and Conservation WA (DEC) Swan Bioplan Project.	N/A
	Remnant Vegetation	DEC/Department of Agriculture and Food WA	September 2007
Biodiversity conservation on private lands	National Trust of Australia (WA) Nature Conservation Covenant Sites	National Trust of Australia WA	August 2008
	DEC Covenant Sites	DEC	October 2008
	Land for Wildlife Site Polygons	DEC	November 2008
Threatened Species and Communities	Declared and Endangered Flora	DEC	August 2006
	Threatened and Priority Fauna Database	DEC	September 2007
	Threatened Ecological Community Boundaries	DEC	Jan 2009
Vegetation Complex Mapping	Native Vegetation Extent by Vegetation Complex	Western Australian Local Government Association's (WALGA) South Western Biodiversity Project (SWBP)	2007
Reserve and DEC vested lands	Existing DEC Managed Lands and Waters	DEC	June 2008
	EPA Proposed Conservation Reserves (Red Book, Systems 1-12)	DEC	July 2006
Wetlands	Geomorphic Wetlands of the Swan Coastal Plain	DEC	October 2008
Regional Boundaries	Interim Biogeographic Regionalisation for Australia (IBRA), Version 6.1	Australian Government Department of Environment and Heritage	September 2005
Vegetation Extent	Wandoo Occurrence	DEC	August 2008
	DEC Flora survey's (Gibson *et al.*, EEEA and Whicher)	DEC	Not available
	Tuart Woodlands	DEC	August 2005

References

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Environmental Protection Authority (2003) *Guidance Statement No. 10: Guidance for the Assessment of Environmental Factors – Level of assessment for proposals affecting natural areas within the System 6 region and Swan Coastal Plain portion of the System 1 region.* Environmental Protection Authority. Perth Western Australia.

Environmental Protection Authority (2006). *Guidance Statement No. 10: Guidance for the Assessment of Environmental Factors – Level of assessment for proposals affecting natural areas within the System 6 region and Swan Coastal Plain portion of the System 1 region.* Environmental Protection Authority. Perth Western Australia.

Environmental Protection Authority (2008) *Guidance Statement No. 33: Environmental Guidance for Planning and Development.* Environmental Protection Authority. Perth Western Australia.

EPA: see Environmental Protection Authority

Game, E.T. and Grantham, H.S. (2008*). Marxan User Manual: For Marxan version1.8.10.* University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Molloy, S., O'Connor, T., Wood, J. and Wallrodt, S. (2007). *Addendum for the South West Biodiversity Project Area,* Western Australian Local Government Association, West Perth.

Possingham, H.P., I.R. Ball and S. Andelman (2000) Mathematical methods for identifying representative reserve networks. In: S. Ferson and M. Burgman (eds) *Quantitative methods for conservation biology*. Springer-Verlag, New York, pp. 291-305.

Appendix 4 : Proximity Analysis Tool Version 1: Users' Guide

An ArcGIS 9.2 Tool Developed by the South West Regional Ecological Linkages Project for use in the Identification of the South West Regional Ecological Linkages.

By Jodie Wood and Shaun Molloy

March 2009

1. Introduction

Note: The information provided in this users guide applies only to version 1 of the proximity analysis tool when used in conjunction with ArcGIS 9.2. It should be noted that using this version of the tool on later versions of ArcGIS may lead to unforeseen complications. It should also be noted that future proximity analysis tools will be developed in response to changing demands, technologies and circumstances. It is therefore considered appropriate that any revised proximity analysis tool will be produced in association with it's own users guide.

A fragmented landscape is one where clearing has occurred to the extent that once continuous native vegetation has been reduced to small, insular patches of remnant vegetation, thereby reducing habitat and isolating populations of native species. Therefore, the ability of a patch to persist as a functional ecological assemblage is largely influenced by its size, proximity to other patches and the quality of the linkage between them.

The South West Regional Ecological Linkages project has developed a tool that can be used in ArcGIS 9.2 to determine various levels of proximity between patches of remnant vegetation in relation to any identified polygon, the SWREL axis line or point. This tool was developed to provide a means of conducting proximity analyses within the context of subject landscapes, thereby providing biodiversity planners and managers with a user friendly way to examine this fundamental but often overlooked facet of ecological function.

A more comprehensive explanation of the uses for proximity analysis in landscape ecology and the science behind the setting of parameters is available in: "A methodology for the South West Regional Ecological Linkages Project: Methodology Support Paper"

1.1 Other Applications of Proximity Analysis

Proximity analysis relies on the measurement of a set of predetermined compound distances relevant to any nominated point or feature represented on a map. Therefore, any proximity analysis relative to any given asset or patch of remnant vegetation is pertinent only to the nominated point or feature from which proximity is measured. Consequently, by changing that point or feature we are able to view proximity analysis in regard to that same asset from different perspectives, or viewpoints, each of which will provide a different set of results when subjected to proximity analysis. This ability to view the same situation from different perspectives allows biodiversity planners and managers to gain a better insight into the potential consequences which may occur within a nominated landscape resulting from the removal of a nominated patch of remnant vegetation.

This tool not only enables proximity analysis to be undertaken in relation to a line on a map (the usual way of marking linkages) it also enables proximity analysis to be undertaken in relation to any point or polygon within a landscape which can be represented in a GIS shapefile. This, in turn, enables biodiversity conservation planners and managers to be able to assess the impacts, using different perspectives on connectivity and ecological function within a landscape that may arise from the removal of a patch of remnant vegetation from a landscape. The proximity analysis tool also has the capacity to demonstrate the impacts on connectivity and ecological function that may arise through the establishment or landscape rehabilitation of habitat areas, by adding an object to an input shapefile and running a proximity analysis from that object.

1.2 Limitations

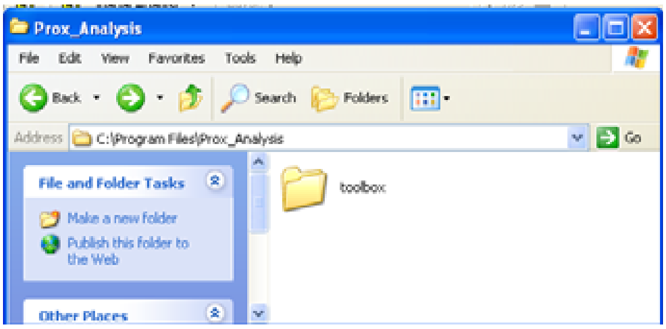
The proximity analysis tool was developed to provide additional support to the decision making process when identifying regional ecological linkages. The tool is only a decision support tool and must be used accordingly. WALGA and DEC take no responsibility for the use of this tool outside of the SWBP and the SWREL project.

2. Computer Requirements

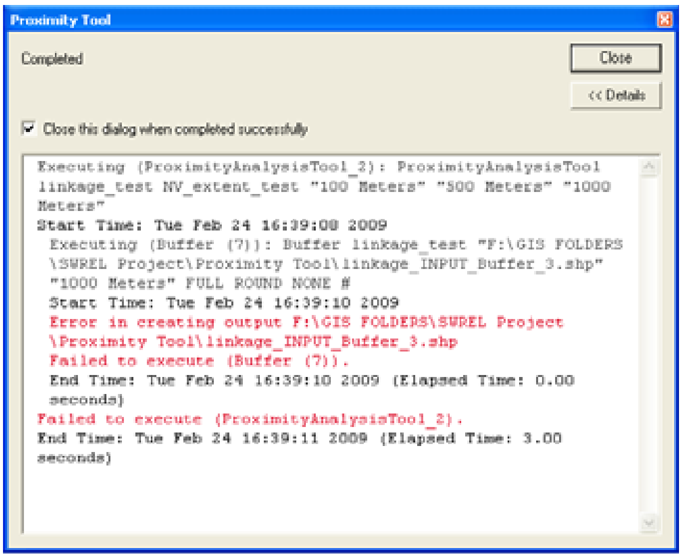
The proximity tool has been developed in ArcGIS 9.2 and as such can only be installed and used in ArcGIS 9.2 and later. The tool uses basic ArcGIS 9.2 processes and does not require additional extensions to be installed.

3. Installation

The Proximity analysis toolbox needs to be installed on the C drive in the following file directory:
C:\Program Files\Prox_Analysis\



You will need to create this file in this location as the tool saves temporary files to this directory and links back to these files while running. If you do not install it in this exact location the tool will not run and you will get an error message similar to that shown below.



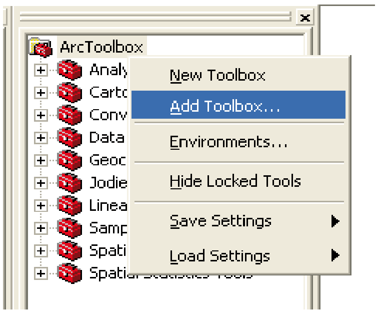
4. Using the Proximity Analysis Tool

4.1 Adding the Proximity Analysis Toolbox to ArcMap

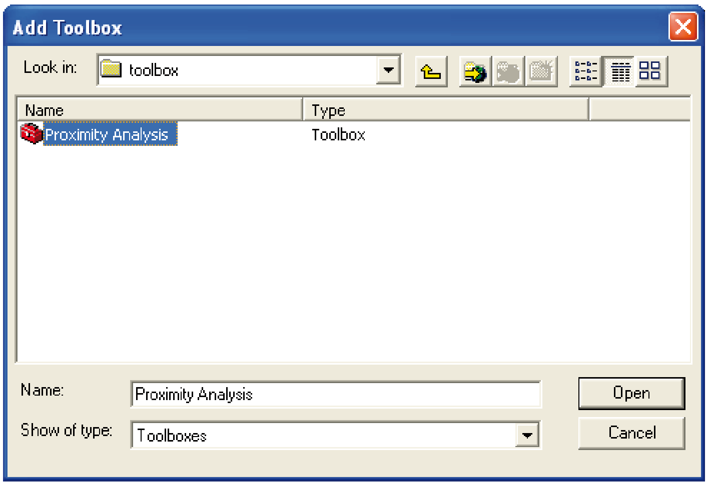
After installing the Proximity Analysis toolbox in the correct location on C drive, open ArcMap.

Click on the toolbox symbol  if the toolbox is not currently displayed in the project

Right click on the Toolbox – add toolbox



- Navigate to where the toolbox is located - needs to be C:\Program Files\Prox_Analysis\

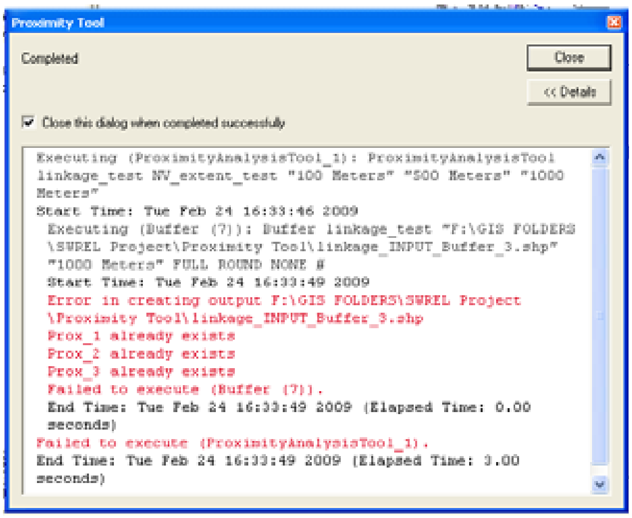


4.2 Using the Proximity Analysis Toolbox

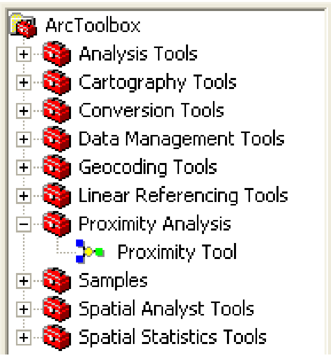
Please Note:
If you are using a remnant vegetation layer that has already been used in the proximity tool, a number of files will have been created at that time and will now need to be deleted before being used in the tool a second time. You will need to delete from this shapefile the following fields as they will be added into the shapefile again when used in the tool:

Prox_3	Prox_2	Prox_1	Prox
3a	2a	1a	1a

If you haven't deleted these fields, the following error will be reported:



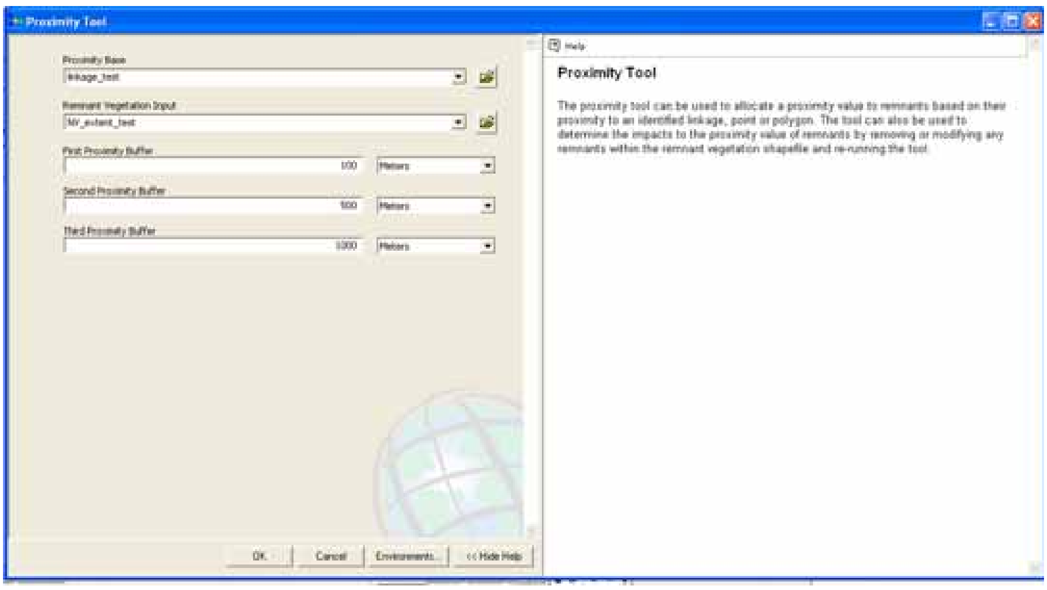
- Expand the Proximity Analysis Toolbox in the window



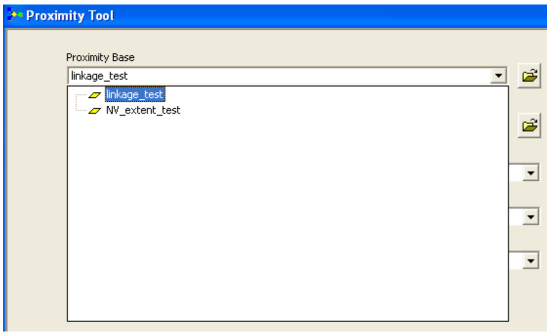
Right click on Proximity Tool 

and click on Open.

- The proximity analysis tool front-end will open.

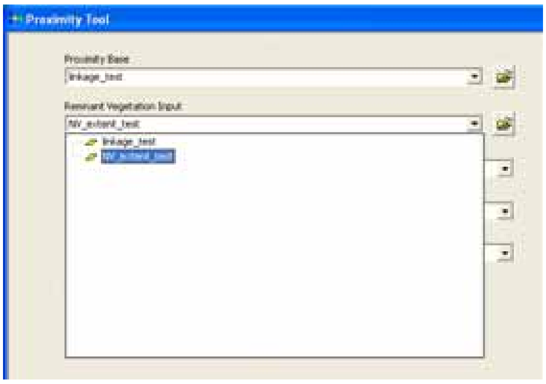


- Select the shapefile that the remnants are to buffered against i.e. if you are determining the proximity value of remnants to a point, line or polygon, select the shapefile that contains that point, line or polygon.

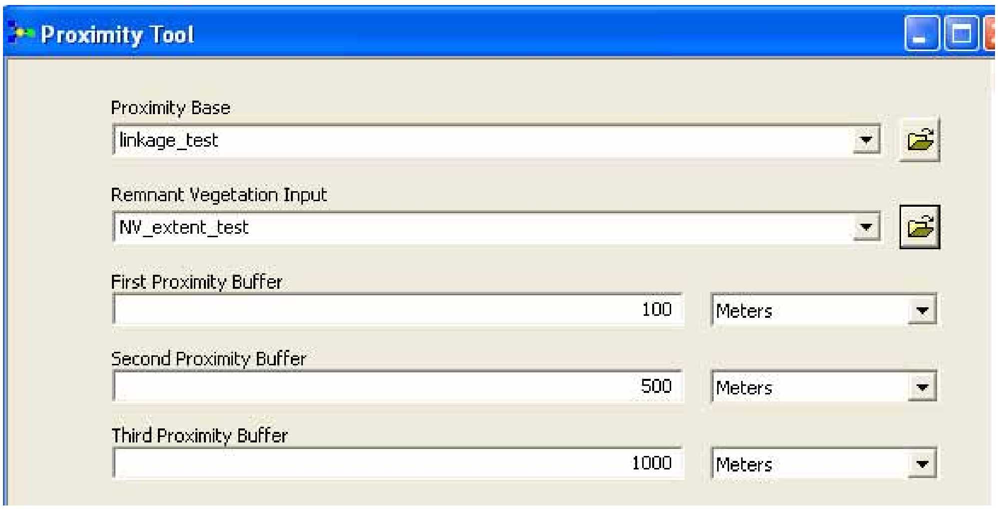


- Select the remnant vegetation shapefile (needs to be a polygon shapefile)

  Note: In version 1 of the proximity analysis tool all shapefiles within the appropriate map layer can be selected from the dropdown options from both the Proximity Base and Remnant Vegetation Inputs. However, when using the browser to find the required Remnant Vegetation input, the presence of layerfiles in relevant data folders may result in shapefiles not being displayed. In such circumstances it is recommended that the required shapefile is added to the appropriate map layer and from there selected through the relevant dropdown option.



- Input the values for the first, second and third proximity buffers or accept the default values of 100, 500 and 1000m.



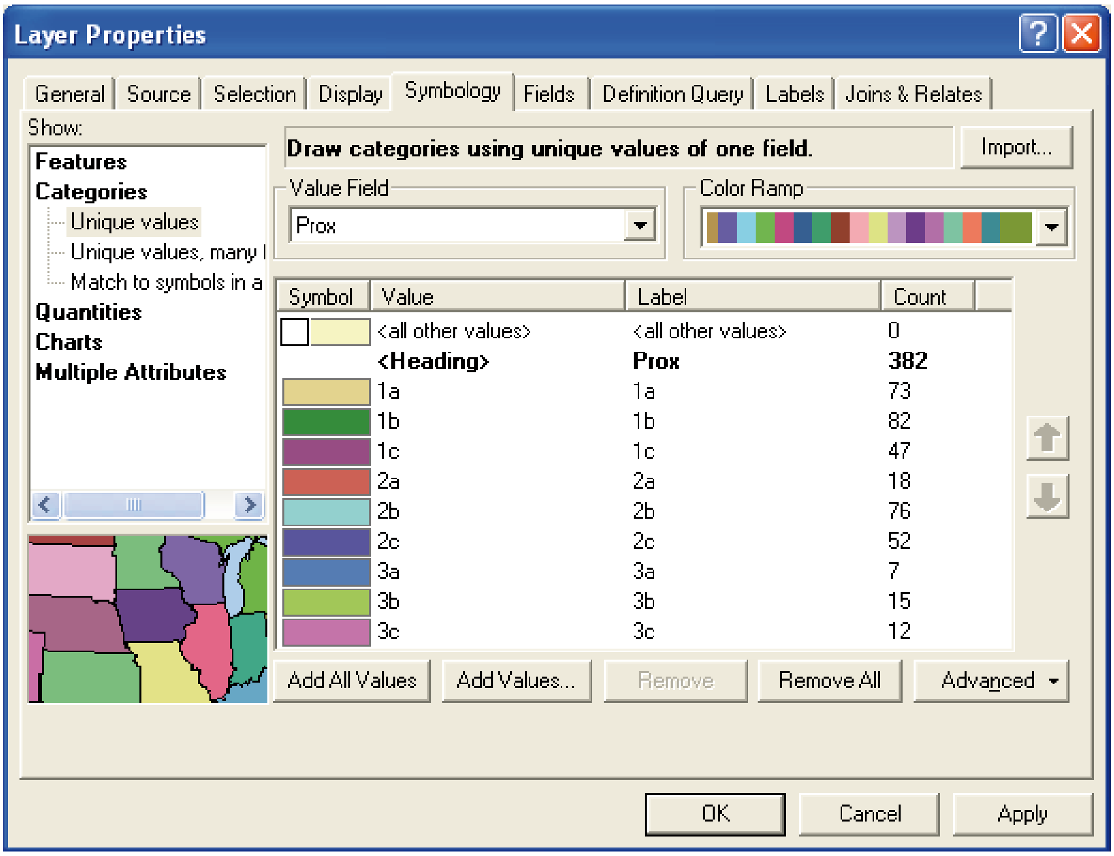
- Press OK to run the tool and a dialogue box will open which tracks the running of the tool. If any errors are encountered while running the tool they will be described in red text in this box.

4.3 Displaying the results

When the tool has completed its run, the fields Prox_3 | Prox_2 | Prox_1 | Prox will have been added to the Remnant Vegetation shapefile.

- Right click on the Remnant Vegetation layer
- Go to Properties
- Click on the Symbology tab
- Click on Categories – Unique Values
- Select Prox in the Value Field dropdown menu
- Add All Values

  (your screen should look as below)



If there are polygons that have not been given a proximity value of 1a, 1b, 1c, 2a, 2b, 2c or 3a, 3b or 3c you will see a blank record next to a symbol. These should be labeled “All remaining natural areas outside of Levels 1, 2 and 3”

4.4 Suggested symbology

(Linkage could be replaced with whatever you used as a Proximity Base)

Native Vegetation Extent by Proximity Value (SWREL Project)

- 1a: with an edge touching or <100m from a linkage
- 1b: with an edge touching or <100m from a natural area selected in 1a
- 1c: with an edge touching or <100m from a natural area selected in 1b
- 2a: with an edge touching or <500m from a linkage
- 2b: with an edge touching or <500m from a natural area selected in 2a
- 2c: with an edge touching or <500m from a natural area selected in 2b
- 3a: with an edge touching or <1000m from a linkage
- 3b: with an edge touching or <1000m from a natural area selected in 3a
- 3c: with an edge touching or <1000m from a natural area selected in 3b
- All remaining natural areas outside of groups 1,2 and 3

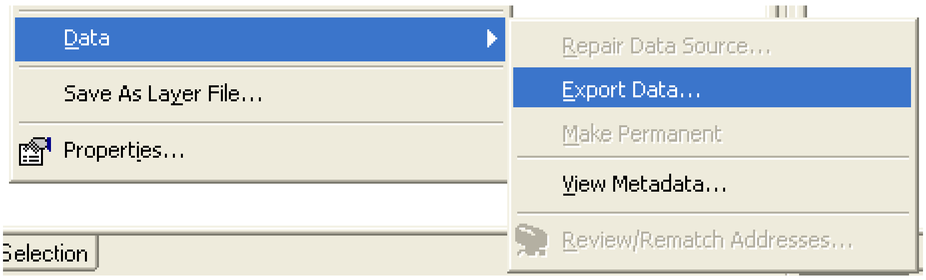
(1a, 1b and 1c can also be grouped as Level 1 as can the 2s and 3s in order to reduce the number of colours being displayed)

5. Using the tool to determine landscape impacts of clearing of remnant vegetation

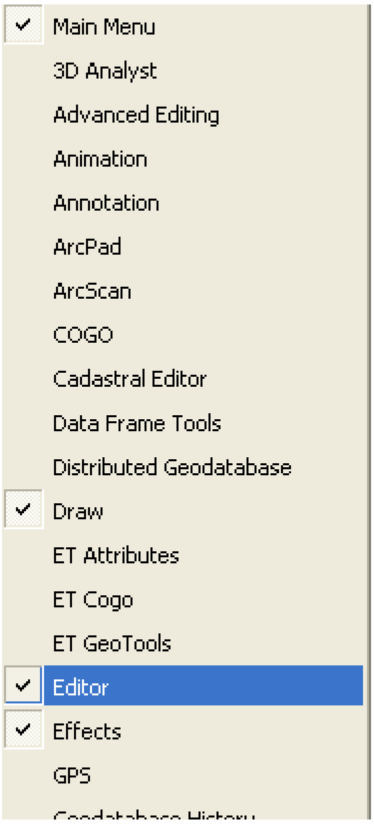
You may wish to look at the impact of removing remnant vegetation on the surrounding landscape. To do so, first you will need to edit the remnant vegetation shapefile to remove or modify the remnant in question.

NB: first export the shapefile in order to keep the original shapefile unmodified.

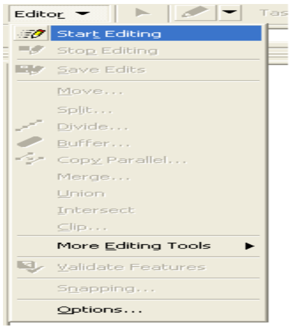
- Right click on the layer name
- Click on Data and then Export data



- Save as new name and add to project
- If Editor is not added to your project, right click on the toolbar space and add



- Go to Editor and Start Editing



- Check that your Remnant Vegetation dataset is in Editor textbox
- Delete or modify polygons in the shapefile.
- Stop Editing
- Delete the Proximity Fields from the shapefile and run the tool again.
- Compare results with previous runs to see how the loss of this vegetation impacts on the proximity of remnant vegetation across the landscape.

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Part C
Incorporating SWREL into Land-Use Planning Processes & Procedures

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Incorporating South West Regional Ecological Linkages into Land-Use Planning Processes and Procedures

Note: **Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.**

And: **Ecological linkages are already matters for consideration within the current land-use planning process. Consideration of the impact of development on an ecological linkage within the assessment of environmental issues provides greater clarity in the existing decision making process which will lead to more sustainable planning outcomes.**

1.1 Introduction

The south western corner of Australia is recognised internationally as a "biodiversity hotspot", not only for the biological richness of species and their uniqueness but also for the level of threat to these species. It is the only international hotspot in Australia recognised by the International Union for the Conservation of Nature. With more than 140,000 persons residing in the South West and an expected 190,000 by 2031, it is the fastest growing region in Western Australia (WAPC 2008).

This growth rate incorporates a significant demand for urban and peri-urban development. Urban development typically expands into rural areas where there are significant areas of remnant vegetation (Government of Western Australia, 2003). The key to providing sustainable growth, which considers the quadruple bottom line of economic, environmental, social and cultural issues, is comprehensive strategic planning. The aim is not to constrain or impede economic prosperity in order to protect the environment, but rather to undertake growth and development in a way which not only preserves and sustains our environment but also enhances it (Molloy *et al*. 2007).

State and regional strategic planning policies relevant to the project area recognise, to varying degrees, the significance of biodiversity and the need for sustainable development. Other than Environmental Protection Authority (EPA) Bulletin 1108 on the Greater Bunbury Region Scheme (EPA 2003) and State Planning Policy 6.1 Leeuwin-Naturaliste Ridge Policy (WAPC 2003), there is no framework recognising the specific importance of regional ecological linkages. The inclusion of the importance of ecological linkages within the current town planning procedures and how linkages are to be given consideration in conjunction with all other planning matters, is discussed in more detail below.

The environmental assessment of proposals and schemes which propose a change to land use that has the potential for adverse impacts on natural areas are generally considered against the provisions of EPA Guidance Statements 10 (EPA 2006) and 33 (EPA 2008). To further assist land use planners and managers in the consideration of a proposal for a change in land use, the SWREL project has identified a series of regional ecological linkages within its study area and developed a Proximity Analysis Tool to support decision making. The Proximity Analysis Tool is designed to aid in determining the compatibility of that change in land use on the viability and ecological function of patches of remnant vegetation as identified within the South West Regional Ecological Linkages (SWREL).

The consideration of the viability and functioning of ecological linkages within the existing strategic planning framework and statutory planning processes and procedures will contribute to the opportunity for more sustainable planning outcomes. The SWREL project envisages that ecological linkage functions will be considered along with all planning matters and other biodiversity conservation values and policy expectations, such as those outlined in EPA Guidance Statements 10 (EPA 2006) and 33 (EPA 2008)

South West Regional Ecological Linkages Map

Map 1 of Part D of this Technical Report depicts the SWREL at a project area scale. Map 2 depicts the core linkages of the SWREL.

For the purposes of this project the SWREL are defined as;

> *"a series of (both contiguous and non-contiguous) patches of native vegetation which, by virtue of their proximity to each other, act as stepping stones of habitat which facilitate the maintenance of ecological processes and the movement of organisms within, and across, a landscape".*

A more comprehensive explanation of Map 1, the science behind identification of the SWREL and the setting of proximity parameters is available in Part B of this Technical Report.

2. Proximity Analysis Tool

The SWREL project has used the Proximity Analysis Tool to provide decision support data for the development of the SWREL. This tool enables the measurement of a set of predetermined compound distances relevant to any nominated point or feature represented on a map. In determining the SWREL this tool has been used to define spatial relationships between linkage axis lines (and/or other nominated conservation assets) and relevant patches of remnant vegetation. In this way the Proximity Analysis Tool enables land use planners and managers to assess, within current planning procedures, potential impacts on landscape connectivity that may arise from removing of a patch of remnant vegetation (see Appendix 2 to Part B of this Technical Report).

The Proximity Analysis Tool also has the capacity to demonstrate improvements to connectivity and ecological function that may arise through the establishment or enhancement of habitat areas which may be added as a condition of planning consent. A more comprehensive explanation of how the proximity tool can be applied within the current land use planning process is available within Appendix 4 to Part B.

Proximity Analysis Tool and the Land Use Planning Process

Application of the Proximity Analysis Tool does not represent an additional assessment procedure, and is purely a decision support tool which can assist land use planners in determining how development is likely to impact on the functioning of an ecological linkage. Its application within the statutory land use process is not constrained by zoning and can be applied in all applications that propose land use change.

It must be stated that adherence to the SWREL project objectives does not suggest that development within an ecological linkage will automatically be precluded. The objectives will however, provide an opportunity for sustainable planning and development to be supported where the core linkage and the level of proximity within an ecological linkage is maintained.

In Map 1 the SWREL project has classified patches of native vegetation within public and private land holdings outside of DEC's estates as having a proximity value when measured from a SWREL axis line, represented by a purple dashed line. The proximity values assigned to areas of native vegetation which form part of the SWREL are detailed within Box 1.

Proximity Value

1a: a patch with an edge touching or <100m from a linkage.

1b: a patch with an edge touching or <100m from a natural area selected in 1a.

1c: a patch with an edge touching or <100m from a natural area selected in 1b.

2a: a patch with an edge touching or <500m from a linkage.

2b: a patch with an edge touching or <500m from a natural area selected in 2a.

2c: a patch with an edge touching or <500m from a natural area selected in 2b.

3a: a patch with an edge touching or <1000m from a linkage.

3b: a patch with an edge touching or <1000m from a natural area selected in 3a.

3c: a patch with an edge touching or <1000m from a natural area selected in 3b.

Box 1: Proximity Values.

Assessment of Impact on Ecosystem Function of a Linkage

An application for a change in land use (rezoning, structure plan, subdivision etc) within which patches of vegetation are proposed to be cleared in part or in total, is to be assessed against all matters for consideration, including the functional capacity of that ecological linkage to accommodate that change. **If the function of the SWREL is impaired (as described below) then the proposal in its current form is deemed to have a potentially significant impact in regard to the ecological function of a linkage and will therefore be subject to further examination to determine the extent of that impairment** (refer to Flow Chart 1 for proposals dealing with development applications, development guide plans, structure plans and rezoning; and Flow Chart 2 for proposals dealing with subdivision applications).

Note: The ecological value of all remaining patches of native vegetation becomes increasingly important as landscapes become progressively more fragmented as a result of clearing activities. Consequently, Western Australian and national biodiversity conservation targets, and WA planning regulations, recommend the retention of at least 30% of remnant native vegetation. Further, EPA Guidance Statements 10 (EPA 2006) and 33 (EPA 2008) both state a preference for future development to occur on lands that have already been cleared.

There are two aspects to determining impaired function, both of which should be considered in determining the acceptability of the proposal. These aspects relate to changes to **core linkage** and/or **landscape function**.

Core linkage: All patches that touch or whose edges come within 100m of an SWREL axis line (i.e. those patches with a proximity value of 1a) should be retained, and the quality of the linkage between them given consideration for appropriate land use, as these are the core assets which, when removed have the potential to significantly impair the core linkage capacity of the SWREL.

Landscape function: The landscape function of an ecological linkage will be considered impaired where the proposed development causes the proximity value:

- of a level 1 patch of remnant vegetation to change to a level 2;
- of a level 2 patch of greater than 4ha in area of remnant vegetation to change to a level 3; or
- of a level 3 patch of greater than 4ha in area of remnant vegetation to be lost.

These changes demonstrate a capacity for significant change in ecological connectivity within the linkage and/or within the surrounding landscape.

In summary:

1. If the removal of remnant vegetation impairs the functional capacity of a SWREL in regard to either core linkage or landscape function it may be deemed to have a potentially significant impact in regard to the ecological function of that linkage. But this will have to be considered together with all other matters pertaining to the proposal. The design or form of the proposal may need to be reconsidered.
2. If the removal of remnant vegetation impairs the functional capacity of a SWREL in regard to either core linkage or landscape function, it will be deemed to have a potentially significant impact on the ecological function of that linkage. It is expected that development plans/proposals should not significantly impair core linkage function. Where possible, proposals that could impact on landscape function should be redesigned to avoid such impact, particularly in fragmented landscapes where remaining native vegetation is approaching or less than 30%.
3. When evaluating or reviewing any proposal which may impact on native vegetation, the principles outlined in EPA Guidance Statements 10 (EPA 2006) and 33 (EPA 2008) at chapters B1, B2 and B3 (EPA 2006, EPA 2008) must be given due consideration. In particular, consideration should always be given to the 30% target for remnant vegetation retention. Note that Native Vegetation Clearing Regulations may also apply.

The long-term viability of natural areas in conventional special rural or rural-residential subdivisions is generally poor. Experience throughout the South West and the metropolitan area has shown that the vegetation is removed or degraded by the cumulative effect of many actions. This is sometimes referred to as ‘death by a thousand cuts’ as the degrading impacts are often individually small, but occur over a period of years or decades (Del Marco *et al.* 2004). Where an application proposes development within a patch of bush such as in traditional rural-residential development (lots size less than 4ha with building envelopes), it is recommended that, when running the Proximity Analysis Tool, the entire patch of bush is to be removed from the remnant input data set. This is because the removal of the entire patch from the planning scenario often provides a more realistic understanding of the irreversible long-term impact on biodiversity and diminished contribution to the functioning of an ecological linkage.

It must be noted that an application which is considered sustainable, in so far as it does not impair the ecological function of the SWREL, yet involves land clearing, will still need to be assessed in accordance with other wider environmental considerations such as EPA Guidance Statement 10 (EPA 2006) and EPA Guidance Statement 33 (EPA 2008) prior to planning approval.

In situations where conditions or modifications are insufficient to prevent an adverse outcome, the consideration of environmental offsets may be an option, but only when all other negotiations or options have failed. Consideration of, and the nature of preferred offsets, is to be guided by EPA Position Statement No. 9b, EPA Guidance Statement No. 19 (EPA 2008a) and EPA Bulletin No.1, Environmental Offsets – Biodiversity (EPA, 2008b).

See Flow Charts 1 and 2 for processes.

Flow Chart 1 - Proximity Analysis Tool , Structure Plans, Subdivision Applications and Development Applications.

(This chart does not represent the entire land-use planning assessment process. The chart merely shows how the Proximity Analysis Tool can be incorporated into the current procedure by Local Government Authorities, referral agencies and the Department of Planning, when considering all other planning and environmental matters.)

Preparation of Application
Where a proposal involves development within a SWREL, the following guidance is recommended:

- The proponent is encouraged to include a Proximity Analysis assessment within the application. (Proponent may seek preliminary advice/guidance from DEC).
- The proposal should be designed to avoid significant impacts within the SWREL.
- Documentation supporting the application should aim to provide sufficient environmental information to allow the proposal to be reviewed against EPA Guidance Statements 10 and 33 (chapters B1, B2 and B3 are relevant to ecological linkages).

↓

Submission of Application
Upon submission, the decision making authority (DMA) review all planning and environmental considerations including the Proximity Analysis provided by proponent.

↓

Preliminary Assessment of Proximity Analysis.
Is ecological function of the SWREL **impaired?**

Yes
- DMA takes into account whether the proposal is a 'proposal under an assessed scheme' and any advice provided by the EPA on the issue of flora, fauna and native vegetation.
- DMA may seek additional information/ clarification of the Proximity Analysis provided.
- DMA may seek modification of the proposal to retain ecological function of the SWREL.
- DMA may refer proposal to DEC for advice where appropriate.

→ Proposal modified resulting in development which does not impair the SWREL function. → No

No
No further consideration of the SWREL is required.

↓ (from Yes)

Proposal not modified to avoid significant impairment to ecological function of SWREL

↓

Proposal Not Supported
If level of impairment remains significant and all other planning and environmental matters do not justify support the DMA may not approve the proposal.

DMA may refer proposal to EPA
In accordance with s38 of EP Act, as likely to cause significant environmental impact.

↓ (from No)

Proposal Supported
When all planning and environmental matters warrant support, the proposal can be approved by the DMA.

A conditional approval may include the need to prepare an appropriate Management Plan to ensure the enhancement and management of a recognised ecological linkage.

Flow Chart 2 - Proximity Analysis Tool, Local Government Scheme Amendments.
(This chart does not represent the entire land-use planning assessment process. The charts merely shows how the Proximity Analysis Tool can be incorporated into the current procedure by Local Government Authorities, referral agencies and the Department of Planning, when considering all other planning and environmental matters.)

Preparation of Scheme Amendment Documents
Where a proposal involves development within a SWREL, the following guidance is recommended:
- The proponent is encouraged to include a Proximity Analysis assessment within the application (Proponent may seek preliminary advice/guidance from DEC).
- The proposal should be designed to avoid significant impacts within the SWREL.
- Documentation supporting the application should aim to provide sufficient environmental information to allow the proposal to be reviewed against the guidance in EPA Guidance Statements 10 and 33 (chapters B1, B2 and B3 are relevant to ecological linkages).

↓

Lodgment of Documents
Upon submission, the Local Government Authority (LGA) review all planning and environmental considerations including the Proximity Analysis provided by proponent. LGA to assess in accordance with wider planning considerations.

↓

Preliminary Assessment of Proximity Analysis
Is ecological function of the SWREL **impaired?**

Yes
- LGA may seek additional information/clarification of the Proximity Analysis provided.
- LGA may seek modification of the proposal to retain ecological function of the SWREL.
- LGA may refer proposal to DEC where appropriate.

→ Proposal is modified and results in development which does not impair the SWREL function. →

No
No further consideration of the SWREL is required.

Initiation Not Supported
If level of impairment remains significant, LGA may not initiate rezoning if other planning and environmental matters do not justify support.

Initiation of Scheme Amendment
When all planning and environmental matters warrant support, the Scheme Amendment can be Initiated by the LGA and referred to EPA for determination on the Level of Environmental Assessment.

'Scheme incapable of being made environmentally acceptable'

This decision may apply where there are significant environmental concerns. Scheme generally cannot be approved.

↓

Decision by Minister for Environment following consultation/agreement with Minister for Planning.

'Scheme Amendment not assessed'
The EPA may provide non-binding advice to the LGA..

↓

LGA to consider final approval in light of EPA advice, public submissions and all comments provided by other referral agencies.

'Scheme Amendment assessed'
Scheme assessed by the EPA.

↓

The scheme may be subject to Ministerial conditions.

LGA to consider final approval in light of EPA/Minister advice, public submissions and all comments provided by other referral agencies.

↓

Finalisation of Scheme Amendment by LGA
When all planning and environmental matters warrant support, the Scheme Amendment can be adopted for final approval by the LGA and referred to the Minister for Planning via the WAPC for final approval.

3. Land Use Planning Processes and Procedures

Town planning coordinates land use and development by balancing economic, social and environment issues. Planning policies, schemes and other statutory processes guide decisions that shape and focus on a satisfactory quality of life for people living in communities (WAPC, 2007).

There are two key components of town planning. Strategic planning which focuses on the big picture or long-term and regional planning throughout Western Australia and statutory planning which is the legal and approval arm of planning. Legislation and regulations ensure appropriate land use and development controls exist to effectively manage the process of land use, land supply and urban development (WAPC, 2007).

The planning tools developed by the SWREL project provides another assessment tool and data set to create a sound and repeatable ecological framework which can better inform the current statutory decision making process when identifying how a change in land use may impact on the viability and ecological function of patches of remnant vegetation. It also enables decision makers to evaluate potential impacts on biodiversity conservation assets that may arise as a result of the loss of patches of native vegetation.

As such, the SWREL project provides comparatively simple and consistent decision support tools for decision makers in the land use planning process. This includes government authorities and bodies, consultants, landholders and developers involved in the systematic and objective assessment of natural resources.

3.1 State & Regional Land Use Planning

State Planning Strategy

The State Planning Strategy (WAPC 1997) provides an overview of future challenges that face the state and sets out key principles to guide the way in which planning decisions should be made in the future. It also provides a comprehensive list of strategies and actions for governments to improve our environment, community, economy and infrastructure. Section 7.1 of the State Planning Strategy includes strategies and actions relating to preventing further loss of biodiversity.

The State Planning Strategy is currently being reviewed by the Department of Planning. It is recommended that specific reference to protect the SWREL be included in the State Planning Strategy to provide direction for strategic regional and local planning.

1) <u>Recommendation</u>

When reviewed and where appropriate, include within the State Planning Strategy reference to the protection of ecological linkages.

State Planning Policies – SPP's

State Planning Policies (SPPs), prepared under the Planning and Development Act 2005, provide guidance on planning matters which may be the subject of a Local Planning Scheme or which relate to a specific region or area of the state.

The preparation of an SPP specific to proximity and the functioning of ecological linkages would provide a high level of strategic direction, and provide recognition of the need to retain regional ecological linkages to support conservation of the South West's unique natural heritage through land use planning processes and procedures. Further, the inclusion of provisions for using proximity analysis as a planning tool into these planning policies will be of practical assistance in the assessment of applications for a change in land use.

It is recognised that the preparation of a comprehensive SPP may not be a current priority of the Department of Planning. Accordingly, it is recommended that the current review of SPP 2.5 Agricultural and Rural Land Use Planning (WAPC 2002) could include reference to the protection of ecological linkages. Over time and where appropriate, it is anticipated that as other SPPs are amended there may be opportunity to include matters pertaining to the protection of ecological linkages.

2) <u>*Recommendation*</u>

WAPC consider:

- *The inclusion of reference to protecting ecological linkages within the current review of SPP2.5 (11) Agricultural and Rural Land Use Planning; and*
- *The inclusion of reference to protecting the SWREL in the preparation of new or amendments to existing SPP's.*

Region Planning Schemes

Region planning schemes provide a statutory mechanism to coordinate the provision of major infrastructure and set aside areas for regional open space and other community purposes.

Peel Region Scheme

The Peel Region Scheme (PRS) (WAPC 2003a) came into operation in March 2003 and provides a regional planning framework to promote sustainable development in respect to environmental, economic and social factors.

The Planning and Development Act requires local government town planning schemes to provide detailed plans for their respective parts of the region. These schemes must be consistent with the PRS.

The PRS comprises a set of maps and a scheme text. The scheme text provides planning objectives for zones and reservations, which are shown on the maps in their respective colours and patterns. To plan for changing needs, the Scheme map needs to be amended from time to time.

Schedule 2 of the PRS provides for the preparation of Environmental Management Plans as conditions of approval to subdivisions, developments and rezoning. These management plans should include consideration for ongoing retention, management and enhancement of the SWREL.

It is noted the Department of Planning has recently prepared the *Southern Metropolitan and Peel Structure Plan* (WAPC 2009) which makes reference to the SWREL project (section 8.1.3 and 8.2.4) and includes a map in Figure 12 of linkages in that region.

Greater Bunbury Region Scheme

The Greater Bunbury Region Scheme (GBRS) (WAPC 2007a) has been in operation since November 2007 and provides a regional planning framework that promotes sustainable development in respect to environmental, economic and social factors.

In 2003 the EPA identified as part of its Section 16 assessment of the GBRS, sixteen preliminary Regional Ecological Linkages which were defined as "regionally-significant sequences of ecological communities within and between the major landform elements". The map detailing these linkages is contained within Appendix 4 of EPA Bulletin 1108 - Report and Recommendations on Greater Bunbury Region Scheme (EPA, 2003).

The SWREL project supports the intent of the 2003 EPA preliminary ecological linkages. The methodology used by the SWREL project has been applied to the GBRS area and essentially identifies the same patches of remnant vegetation with some minor variations in mapping.

3) <u>*Recommendation*</u>

When the Greater Bunbury Region Structure Plan is reviewed along with the GBRS, the DP apply the Proximity Analysis Tool to determine patches to be given consideration for protection as ecological linkages.

Statement of Planning Policy 6.1 - Leeuwin Naturaliste Ridge, Statement of Planning Policy (LNRSPP)

The LNRSPP (WAPPC 2003), released in 1998, recognised the need to protect areas which provide a strategically important environmental linkage between sections of national park and other conservation areas within or external to the policy boundary (PS 2.5 'local environmental corridors'). These linkages are referred to as Regional Environmental Corridors (RECs) and detailed in LUS 3.12 'integrity of ecological linkages'; LUS 3.13 'regional environmental corridors'; and Regional Environmental Corridor Policies LUS 3.18-3.27.

The importance of RECs and Land Use Strategy Policies (LUS 3.18 – 3.27) associated with the protection and re-establishment of vegetation connections is supported. The inclusion of reference to the SWREL and the methodology of the SWREL project will assist in supporting the importance and protection of the RECs contained within the LNRSPP.

4) Recommendation:

Upon review of the LNRSPP, the SWREL project methodology be used to support the designated Regional Environmental Corridors and be given consideration during revision of the Land Use Strategy Policies.

The LNRSPP provides (via LUS 3.4 and 3.8) an incentive for landowners to maintain the conservation and landscape values of their land in perpetuity. The incentive takes the form of permitting one additional lot or low-impact tourism development on the proviso the proposal meets the zoning and conservation and landscape values established in LUS 3.4 and 3.8.

In principle, the incentive based approach towards the protection of natural assets is supported by the SWREL project. However it could be expanded to include, within the necessary conservation and landscape values, the consideration of protecting and ecologically enhancing strategically-significant patches of vegetation within the SWREL. Note: all other criteria should be met.

The policy provisions of the LNRSPP could be enhanced by including the use of proximity analysis as a planning tool to assist in current assessment procedures associated with ecological linkage considerations in applications to change land use.

Development Control Policies

The WAPC also prepares less formal policies such as development control policies. These cover topics including the subdivision of land, development control, public open space and rural land use planning

Similar to the LNRSPP (WAPC 2003), Development Control Policy 3.4 – Subdivision of Rural Land (DC 3.4) (WAPC 2008a), provides via Section 4.8 an incentive for landowners to create a conservation lot, thereby maintaining the environmental features and remnant vegetation of their land in perpetuity. The incentive takes the form of permitting one additional lot without the requirement for rezoning (with exception to the LNRSPP), if the application for subdivision satisfies specific criteria (refer to Section 4.8) and includes, as a condition of approval, the covenanting and ongoing management of existing vegetation.

The assessing criteria within Section 4.8 should be expanded to include not only "vegetation worthy of protection" (refer Appendix 4 of DC 3.4), but the consideration of protecting and ecologically enhancing strategically significant patches of native vegetation within an ecological linkage.

5) Recommendation:

Upon review of DC 3.4, consider the inclusion within the assessing criteria of Section 4.8, the protection of strategically-important patches of native vegetation within an ecological linkage as justification for subdivision.

The creation of multiple conservation lots is also provided for in DC 3.4. Additionally, such lots need to be provided for within Local Planning Strategies and Rural Strategies and be appropriately zoned small rural-holding or rural-residential. In principle, the opportunity to consider a closer form of development, which is designed with conservation protection as its principal objective, is supported by the SWREL project and provides an ideal opportunity for the protection and enhancement of ecological linkages.

Consideration could also be given to zones other than 'small-rural-holding' or 'rural-residential' in the creation of multiple conservation lots. Zones such as "Bushland Protection" or "Conservation" may provide a more appropriate level of protection than the generic urban zones suggested by DC 3.4.

6) Recommendation

Upon review of DC 3.4, consider the opportunity for 'multiple conservation lots' to be zoned "Bushland Protection" or "Conservation".

Planning Bulletins

Planning Bulletins are issued by the WAPC to provide added guidance and advice on statutory planning matters. Given that the Proximity Analysis Tool will be available for inclusion within the statutory planning process, where appropriate, ahead of changes within the strategic planning framework, it would be desirable for the WAPC to prepare a Planning Bulletin specific to the SWREL. However, based on the anticipated support and guidance offered by the pending EPA Bulletin, the preparation of a Planning Bulletin is not considered necessary.

In the absence of a Planning Bulletin, the WAPC could consider releasing a statement concurrently with the EPA publishing an Environmental Bulletin, advising its support for the importance of recognising regional ecological linkages in land use planning processes and how proximity analysis can provide clarity in the assessment of the impact from a change in land use.

7) *Recommendation:*
The WAPC consider releasing a statement concurrently with the EPA's publishing of an Environmental Bulletin outlining the importance of inclusion of the consideration of impact on ecological linkages in the current planning processes.

Using the Proximity Analysis Tool in the Proposed Statutory Planning Process

A proximity analysis on how a proposal impacts on the proximity value of a patch or patches of native vegetation within the SWREL should form part of any application. This is the preferred position of the SWREL project, however, in the immediate to short term, it is understood that not all proponents may have the initial capacity to provide such information.

To this effect, consideration of how the Proximity Analysis Tool can be incorporated within the current land-use planning process is identified within Flow Charts 1 and 2. It must also be noted that ecological linkages are just one matter for consideration within the current land-use planning process and are only one of the biodiversity conservation values of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to add to the land-use planning procedures or replace the need to consider the other biodiversity conservation values of a patch.

8) *Recommendation:*
Over time incorporate a proximity analysis assessment as part of all applications, when it potentially impacts on the SWREL, for structure plans, subdivision/development guide plans, development applications or rezoning applications submitted to LGAs and subdivision applications submitted to the WAPC.

3.2 Local Land Use Planning

Local Planning Strategies

Local Planning Strategies (LPS) prepared by local governments, contain the strategic initiatives and policy direction to be contained within a Local Planning Scheme. They set out the general aims and expectations for sustainable long-term growth and change, and have regard to the social, economic and environmental facets of development.

LPS provide direction on the capacity of a local government to accommodate growth and generally identify the circumstances in which particular land uses and development should be planned.

A Local Biodiversity Strategy (LBS) and/or Local Environmental Strategy (LES) should be prepared to guide the preparation of a LPS and Town Planning Scheme amendment or review, making reference to ecological linkages. The LBS and/or LES should also detail the importance of retaining, maintaining and enhancing them and extend to an action to identify local ecological linkages using the guiding principles and methodology of the SWREL project.

9) *__Recommendation:__*
A Local Biodiversity Strategy and/or Local Environmental Strategy should be prepared to include provisions to provide a planning framework for conservation of biodiversity in the local area using the Local Government Biodiversity Planning Guidelines and including reference to the SWREL methodology.

A Local Planning Strategy should provide guidance on the appropriate provisions for inclusion within a new Local Planning Scheme or Scheme Amendment to ensure ecological linkages are taken into consideration during decision making, particularly for structure plans and outline development plans.

10) *__Recommendation:__*
Preparation of a Local Planning Strategy could be prepared to include, along with all other planning matters provisions that:

- *Respond to the recommendations of a LBS or LES, including identifying and recognising the importance of regional and local ecological linkages;*
- *Reinforce the provisions of the LBS or LES in adding the consideration of proximity analysis to existing environmental, social and economic considerations when determining the compatibility of a change in landuse on the function of an ecological linkage; and*
- *Recommend the inclusion of new Scheme provisions, when an existing scheme is reviewed or amended, to ensure the SWREL are taken into consideration, within the context of existing environmental considerations, in assessing applications for a change in landuse.*

Local Planning Schemes

The requirement for Local Planning Schemes to be regularly amended or reviewed provides an ideal opportunity for the recommendations of a Local Planning Strategy (refer Recommendation 8) to be included within any new Local Planning Scheme.

Scheme provisions which add to the current environmental provisions by protecting and enhancing ecological linkages (identified in a LPS or LBS/LES) will provide opportunities for more ecologically-sound planning and environmental outcomes.

Patches which form part of the SWREL are not automatically recommended for inclusion within Regional or Public Open Space, or a conservation zoning. However for practical purposes, patches within a LGA which form part of the SWREL could be mapped by the LGA as landscape protection overlays within any zone in a LPS. Scheme provisions, guided by a modified Model Scheme Text, could include opportunities to impose conservation covenants or environmental conditions requiring protection, or ceding portions as public or regional open space if, and where, this is appropriate.

The inclusion of appropriate Management Plans will further assist in the long-term conservation of the SWREL.

11) *__Recommendation:__*
The DP consider within the current review of the Model Scheme Text the inclusion of appropriate provisions to ensure consistency across the State in regard to the protection of ecological linkages.

Local Planning Policies

Local governments prepare Local Planning Policies (LPPs) having regard to the State Planning Framework (WAPC 2006), provisions of the Model Scheme Text (WAPC 1967) and recommendations of Local Planning Strategies, to provide internal guidance as to how future local planning decisions will be made. LPPs provide guidance on matters under the scheme. As such, preparation of a LPP supporting recognition of the SWREL would depend on existing provisions of the LPS, dealing with matters such as native vegetation retention.

A LPP may require adoption of the use of the Proximity Analysis Tool within the statutory planning process to ensure the long term protection and enhancement of a Shire's natural assets, and in particular conservation of the SWREL.

12) *Recommendation:*

The LGA prepare a Local Planning Policy which should include, but not be limited to:

- *The recognition of the importance of ecological linkages and the need for their protection and enhancement;*
- *Recognise the SWREL (and possibly local ecological linkages) within its municipality and if need be provide a link to GIS databases;*
- *Apply the Proximity Analysis Tool when assessing the compatibility of a change in land use on the functioning of an ecological linkage; and*
- *Include Flow Chart 1 which details the suggested statutory planning process for the LGA's to adopt in regard to the consideration of impact on ecosystem function.*

4. Environmental Planning Process

EPA Bulletin

It is recommended that the EPA prepare an Environmental Bulletin recognising the importance of conservation of regional ecological linkages, and making reference to the SWREL and the Proximity Analysis Tool assessment process..

13) *Recommendation:*

EPA prepare an Envirinmental Bulletin recognising the importance of conservation of regional ecological linkages, and making reference to the SWREL and the Proximity Analysis Tool assessment process.

Local Ecological Linkages

Local Ecological Linkages aim to link protected locally significant patches to each other, regionally significant patches and Regional Ecological Linkages. Local Ecological Linkages are an important part of improving the viability of patches that may be; too small, of an unsuitable shape, or in a condition which would significantly lessen their ability to otherwise persist.

The SWREL project provides a broad scale framework which can assist smaller scale Local Ecological Linkage projects to contribute to ecological connectivity throughout the greater SWREL project area. The SWREL project has also developed a methodology, tools and data sets that can assist in the development of more ecologically-effective local-scale landscape connectivity projects.

Evaluating clearing proposals

The proximity analysis tool developed by SWREL project can be used by environmental decision makers to evaluate potential impacts on biodiversity conservation assets that may arise as a result of the loss of patches of native vegetation from clearing or development proposals. To determine the effects on a linkage, the proximity analysis process is repeated with the area intended for clearing removed from the remnant vegetation data set. A comparison between this proximity analysis and the original enables a simple assessment of the effects of clearing at the landscape-scale (see Appendix 2 to Part B hereof).

Note: The current methodology limits the consideration of clearing impacts to the local area around the patch proposed to be cleared because it is limited to patches 3 steps removed from the SWREL axis line. This could potentially underestimate the wider landscape-scale impacts of clearing on linkage.

Protection of regional ecological linkages is consistent with a number of the 10 Clearing Principles set out in the *Environmental Protection (Clearing of Native Vegetation) Regulations* 2004. The SWREL methodology and Proximity Analysis Tool are seen as mechanisms which could be useful to support clearing evaluation processes.

Maintaining Currency of Vegetation Mapping

To remain a valid planning tool there is the need for Maps 1 and 2 to be periodically updated to take into account changes within proximity values assigned to native vegetation as a consequence of further development and land clearing, and to incorporate updated databases and new technologies as they become available.

14) <u>Recommendation:</u>

That DAFWA update vegetation extent mapping regularly, as information becomes available, and that the DEC update the mapping undertaken by the SWREL proximity analysis mapping.

The periodic updating of vegetation extent mapping will not only ensure the ongoing usability of SWREL mapping, it will also assist to achieve consistency with other government initiatives which seek to establish:

- A shared government/industry environmental data system to allow more informed project planning by industry, better decision-making by government and reduced duplication of effort and expenditure across the board (EPA 2009); and
- The development of a shared database on native vegetation to allow for improved decision making, monitoring and auditing of land clearing by government and inform landowners and the community (DEC 2009).

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Summary of Planning Recommendations

#	Recommendation	Agency	Ideal Timeframe (from Sept 09)	Page
State & Regional Land Use Planning				
1	When reviewed and where appropriate include within the State Planning Strategy reference to the protection of ecological linkages.	DP	2-3 years	105
2	WAPC consider: The inclusion of reference to protecting ecological linkages within the current review of SPP2.5 (11) Agricultural and Rural Land Use Planning; and The inclusion of reference to protecting the SWREL in the preparation of new or amendment of existing SPP's.	DP	1 year	106
3	When the Greater Bunbury Region Structure Plan is reviewed along with the GBRS, the DP apply the Proximity Analysis Tool to determine patches to be given consideration for protection as ecological linkages.	DP	2 years	106
4	Upon review of the LNRSPP, the SWREL project methodology be used to support the designated Regional Environmental Corridors and be given consideration during revision of the Land Use Strategy Policies.	DP	2-3 years	107
5	Upon review of DC 3.4, consider the inclusion within the assessing criteria of Section 4.8 the protection of strategically important patches of vegetation within an ecological linkage as justification for subdivision.	DP	1- 2 years	107
6	Upon review of DC 3.4, include the opportunity for 'multiple conservation lots' to be zoned "Bushland Protection" or "Conservation".	DP	1-2 years	107
7	The WAPC consider release of a statement concurrently with the EPA publishing an Environmental Bulletin outlining the importance of inclusion of the consideration of impact on ecological linkages in current planning processes.	EPA, WAPC	3 months	108
8	Over time incorporate a Proximity Analysis Assessment as part of all applications for development applications, subdivision/development guide plans, structure plans or rezoning applications submitted to LGAs and subdivision application submitted to the WAPC.	LGA	ongoing	108

Local Land Use Planning				
9	A Local Biodiversity Strategy and/or Local Environmental Strategy could be prepared to include provisions to provide a planning framework for conservation of biodiversity in the local area using the Local Government Biodiversity Planning Guidelines and including reference to the SWREL methodology.	LGA	Ongoing	109
10	Preparation of a Local Planning Strategy could be prepared to include, along with all other planning matters provisions that: • Responds to the recommendations of a LBS or LES, including identifying and recognising the importance of regional and local ecological linkages; • Reinforces the provisions of the LBS or LES in regard to adding the consideration of proximity analysis to existing environmental, social and economic considerations when determining the compatibility of a change in landuse on the functioning of an ecological linkage; and • Recommend the inclusion of new Scheme Provisions, when an existing scheme is reviewed or amended, to ensure the SWREL are taken into consideration, within the context of existing environmental considerations, in the assessment of applications for a change in landuse.	LGA	Ongoing	109
11	The DP consider within the current review of the Model Scheme Text the inclusion of appropriate provisions to ensure consistency across the State in regard to the protection of ecological linkages.	DP	2 years	109
12	The LGA prepare a Local Planning Policy which should include, but not be limited to: • The recognition of the importance of ecological linkages and the need for their protection and enhancement; • Recognise the SWREL (and possibly local ecological linkages) within its municipality and if need be provide a link to GIS databases; • Apply the Proximity Analysis Tool when assessing the compatibility of a change in land use on the functioning of the SWREL; and • Include Flow Chart 1 which details the suggested statutory planning process for the LGA's to adopt in regard to the consideration of impact on ecosystem function.	LGA	ongoing	110
13	EPA prepare a Bulletin recognising the importance of conservation of regional ecological linkages, and making reference to the SWREL and the Proximity Analysis Tool assessment process.	EPA	3 months	110
14	DAFWA update vegetation extent mapping regularly, as information comes available, and then DEC update the mapping undertaken by the SWREL proximity analysis mapping.	DAFWA/DEC	Periodically	111

Part D
SWREL Maps

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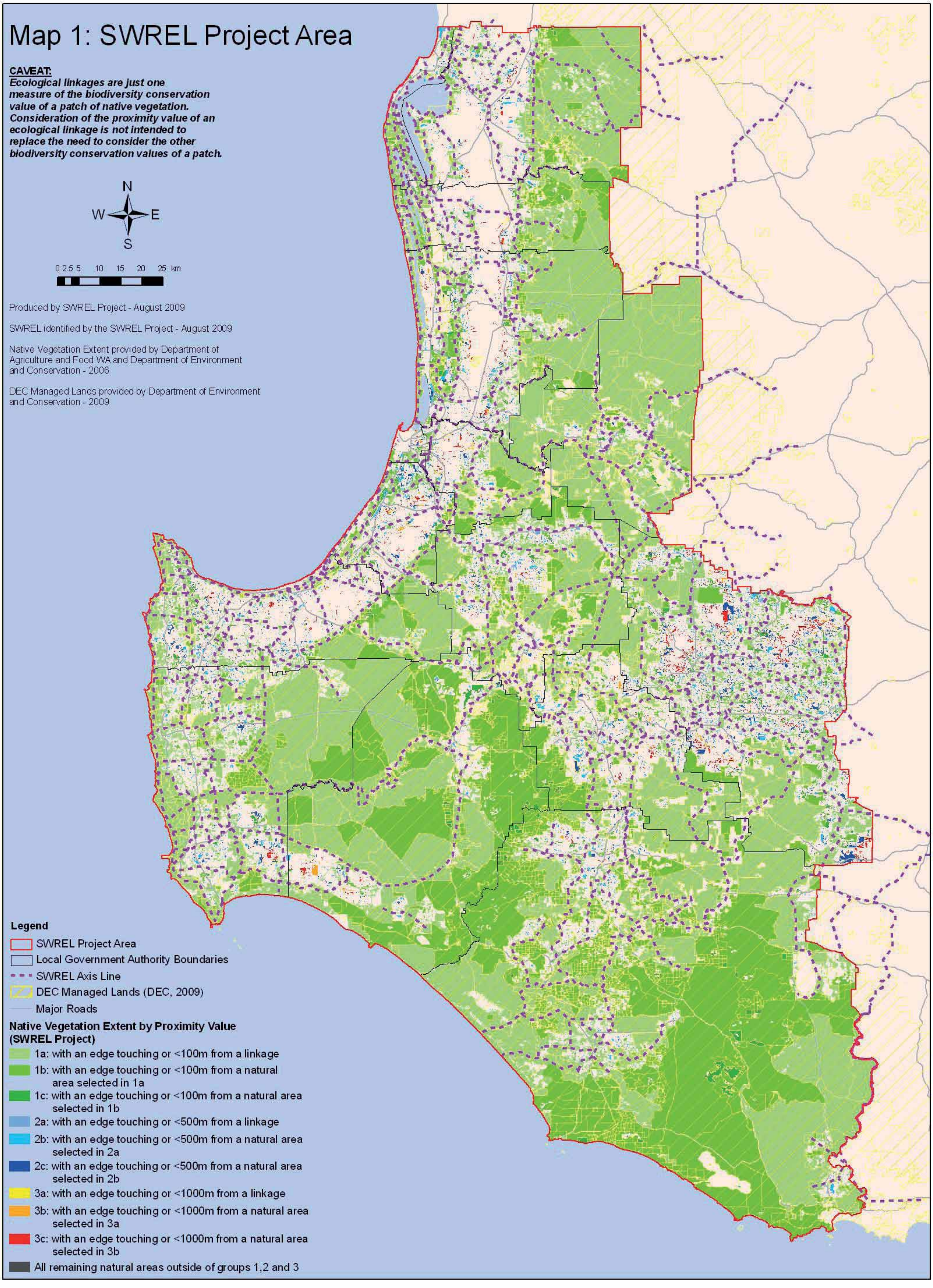

Map 1: SWREL Project Area
CAVEAT:
Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.
N
W
E
S
0 2.5 5 10 15 20 25 km
Produced by SWREL Project - August 2009
SWREL identified by the SWREL Project - August 2009
Native Vegetation Extent provided by Department of Agriculture and Food WA and Department of Environment and Conservation - 2006
DEC Managed Lands provided by Department of Environment and Conservation - 2009
Legend
SWREL Project Area
Local Government Authority Boundaries
SWREL Axis Line
DEC Managed Lands (DEC, 2009)
Major Roads
Native Vegetation Extent by Proximity Value (SWREL Project)
1a: with an edge touching or <100m from a linkage
1b: with an edge touching or <100m from a natural area selected in 1a
1c: with an edge touching or <100m from a natural area selected in 1b
2a: with an edge touching or <500m from a linkage
2b: with an edge touching or <500m from a natural area selected in 2a
2c: with an edge touching or <500m from a natural area selected in 2b
3a: with an edge touching or <1000m from a linkage
3b: with an edge touching or <1000m from a natural area selected in 3a
3c: with an edge touching or <1000m from a natural area selected in 3b
All remaining natural areas outside of groups 1,2 and 3

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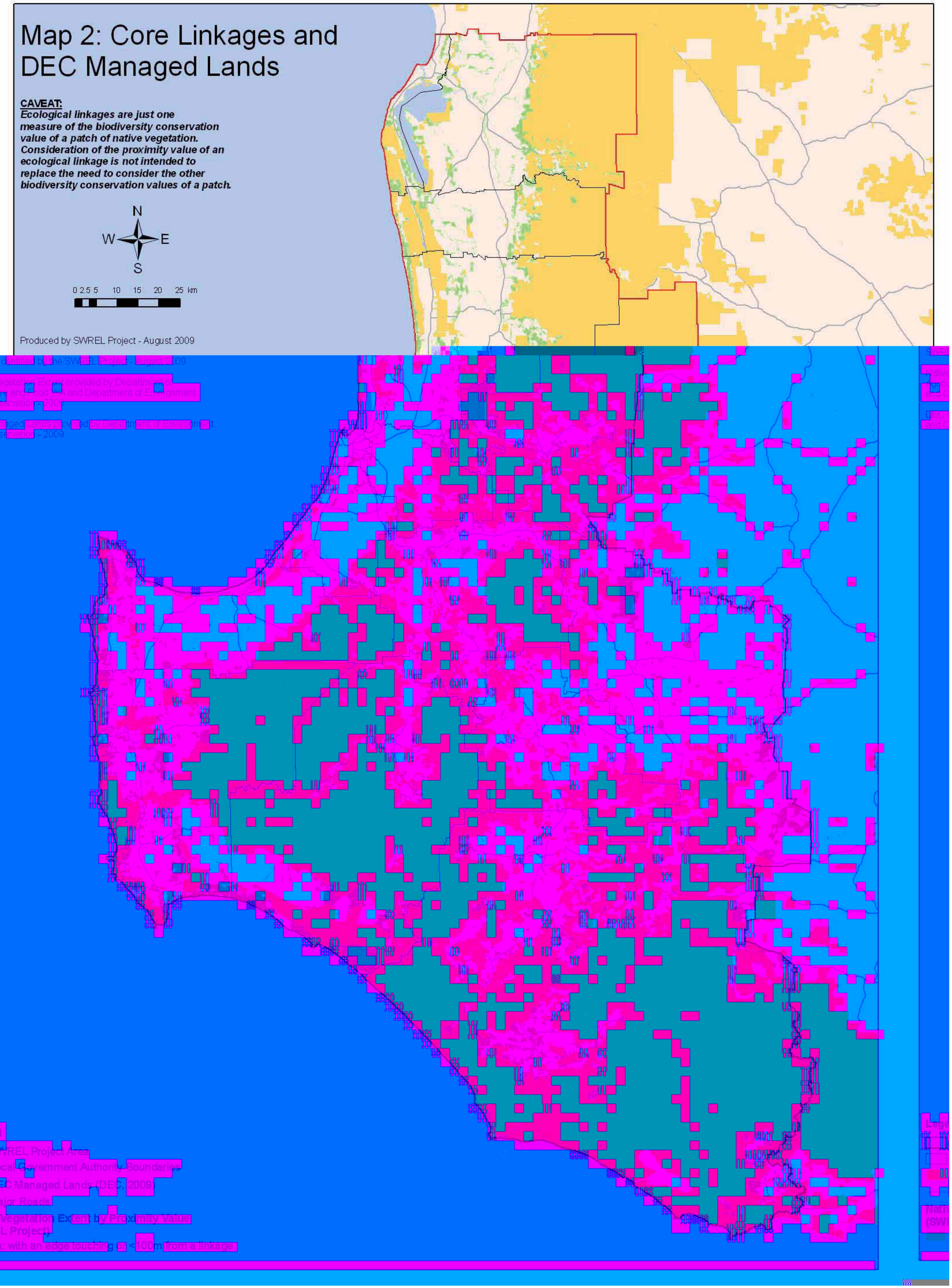

Map 2: Core Linkages and DEC Managed Lands
CAVEAT:
Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.
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Produced by SWREL Project - August 2009

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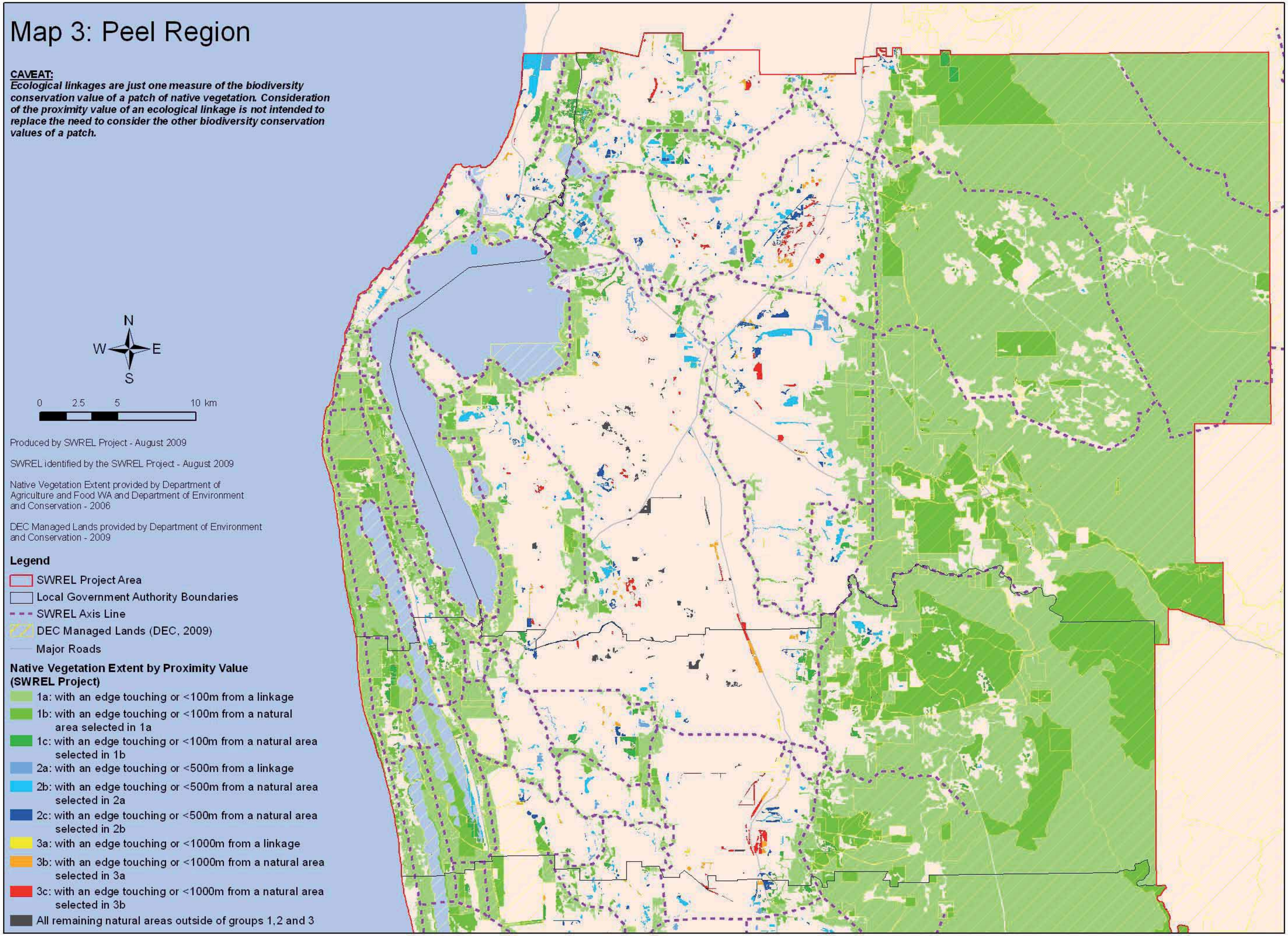
Map 3: Peel Region
CAVEAT:
Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.
N
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0 2.5 5 10 km
Produced by SWREL Project - August 2009
SWREL identified by the SWREL Project - August 2009
Native Vegetation Extent provided by Department of Agriculture and Food WA and Department of Environment and Conservation - 2006
DEC Managed Lands provided by Department of Environment and Conservation - 2009
Legend
SWREL Project Area
Local Government Authority Boundaries
SWREL Axis Line
DEC Managed Lands (DEC, 2009)
Major Roads
Native Vegetation Extent by Proximity Value (SWREL Project)
1a: with an edge touching or <100m from a linkage
1b: with an edge touching or <100m from a natural area selected in 1a
1c: with an edge touching or <100m from a natural area selected in 1b
2a: with an edge touching or <500m from a linkage
2b: with an edge touching or <500m from a natural area selected in 2a
2c: with an edge touching or <500m from a natural area selected in 2b
3a: with an edge touching or <1000m from a linkage
3b: with an edge touching or <1000m from a natural area selected in 3a
3c: with an edge touching or <1000m from a natural area selected in 3b
All remaining natural areas outside of groups 1,2 and 3

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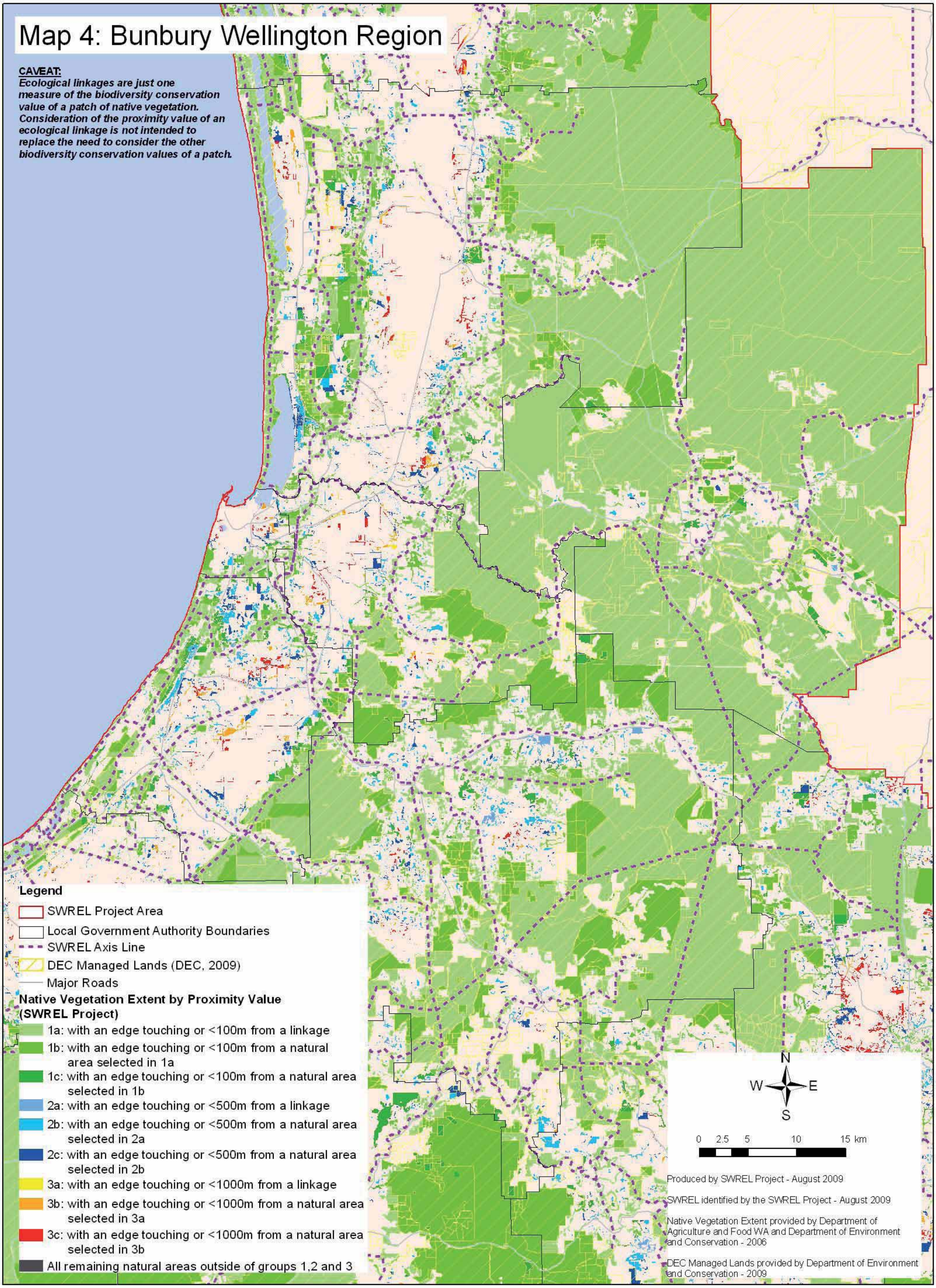

Map 4: Bunbury Wellington Region
CAVEAT:
Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.
Legend
SWREL Project Area
Local Government Authority Boundaries
SWREL Axis Line
DEC Managed Lands (DEC, 2009)
Major Roads
Native Vegetation Extent by Proximity Value (SWREL Project)
1a: with an edge touching or <100m from a linkage
1b: with an edge touching or <100m from a natural area selected in 1a
1c: with an edge touching or <100m from a natural area selected in 1b
2a: with an edge touching or <500m from a linkage
2b: with an edge touching or <500m from a natural area selected in 2a
2c: with an edge touching or <500m from a natural area selected in 2b
3a: with an edge touching or <1000m from a linkage
3b: with an edge touching or <1000m from a natural area selected in 3a
3c: with an edge touching or <1000m from a natural area selected in 3b
All remaining natural areas outside of groups 1,2 and 3
N
W
E
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0 2.5 5 10 15 km
Produced by SWREL Project - August 2009
SWREL identified by the SWREL Project - August 2009
Native Vegetation Extent provided by Department of Agriculture and Food WA and Department of Environment and Conservation - 2006
DEC Managed Lands provided by Department of Environment and Conservation - 2009

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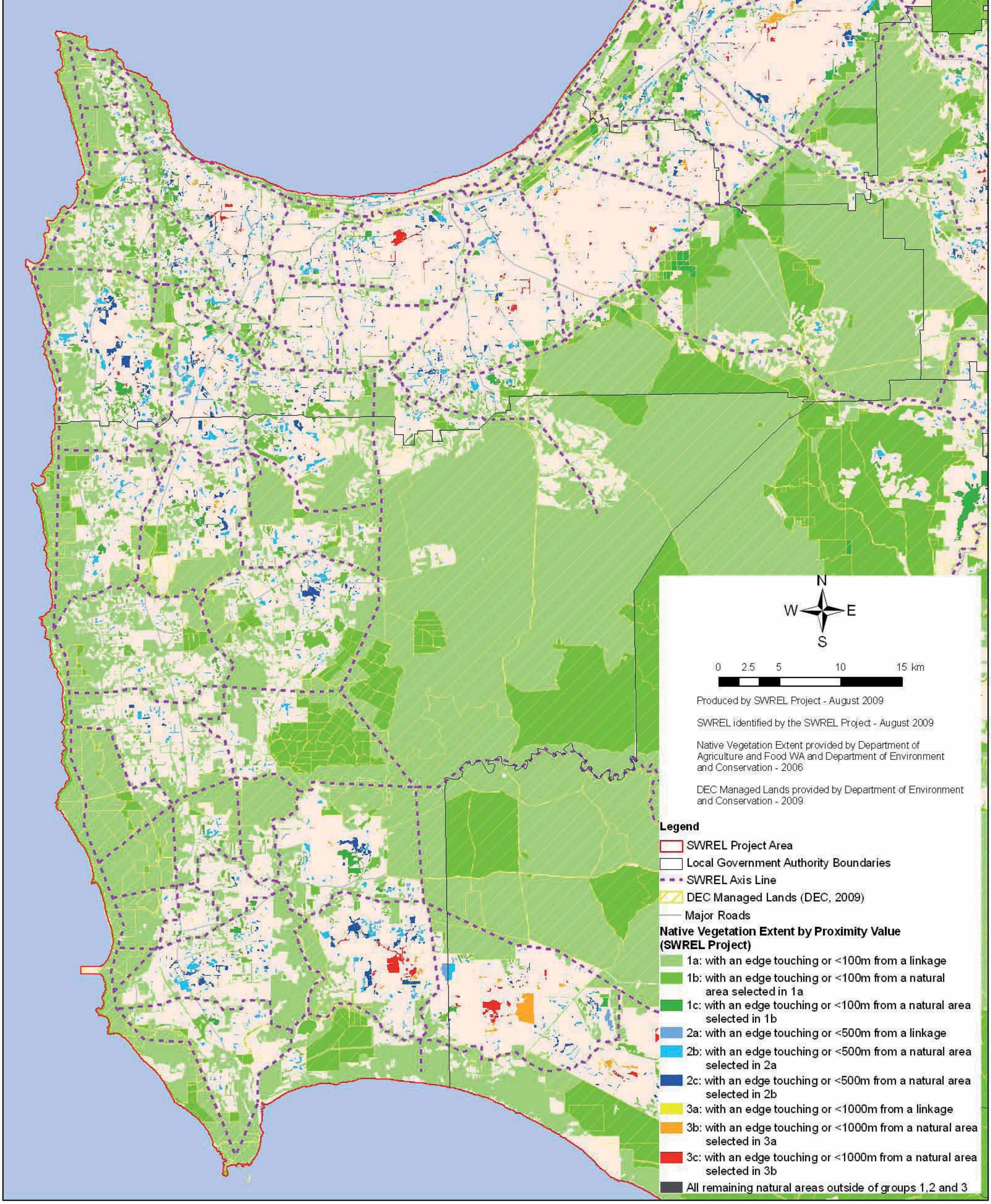
Map 5: Leeuwin Naturaliste Region

CAVEAT:
Ecological linkages are just one measure of the biodiversity conservation value of a patch of native vegetation. Consideration of the proximity value of an ecological linkage is not intended to replace the need to consider the other biodiversity conservation values of a patch.



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Map 6: Warren Blackwood Region

CAVEAT:
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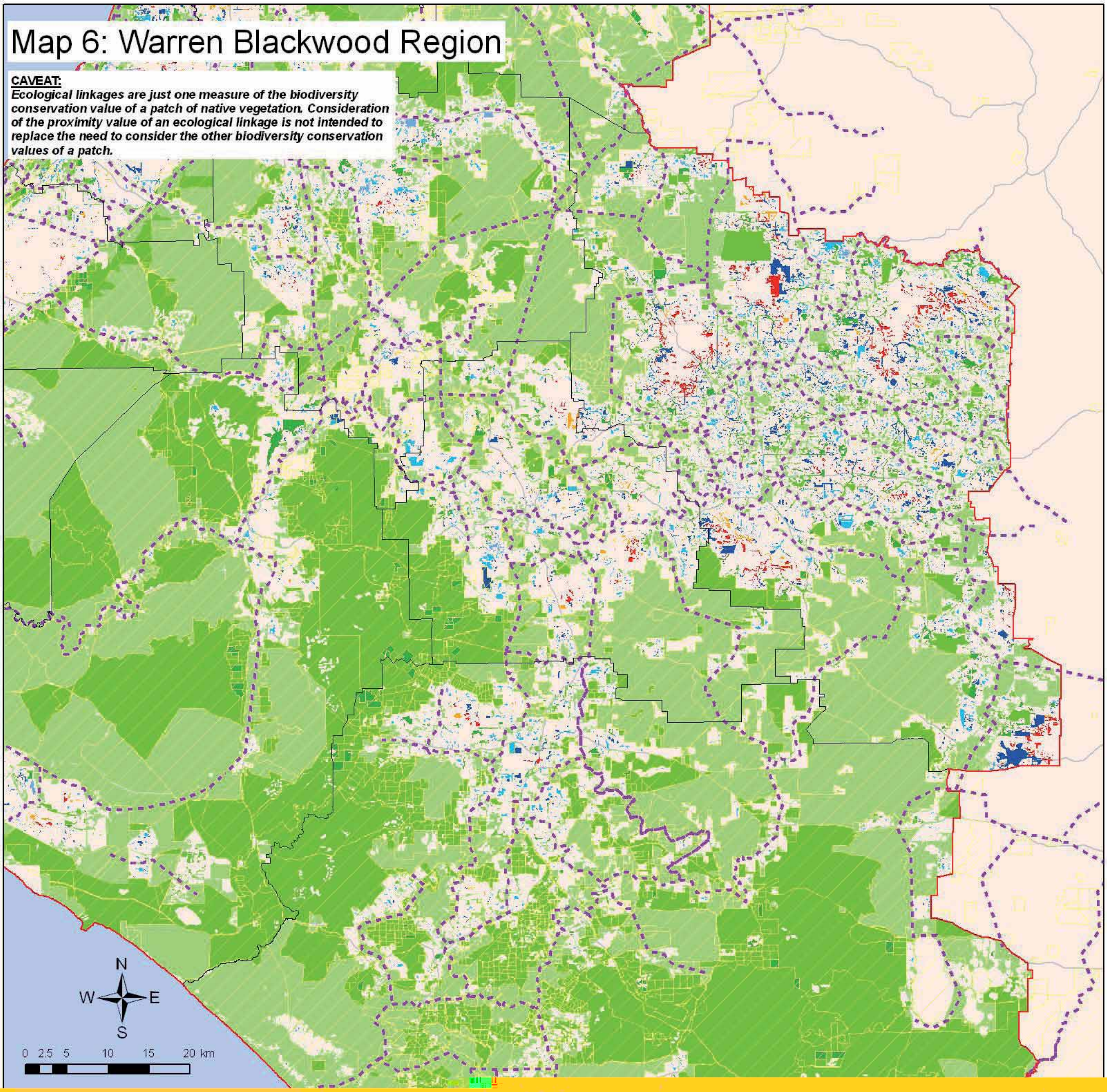

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Department of Environment and Conservation

Our environment, our future

SOUTH WEST CATCHMENTS COUNCIL

WALGA

SOUTH WEST BIODIVERSITY PROJECT

Councils Caring for their Natural Communities