Gnangara Sustainability Strategy

An across-government initiative

Groundwater – Biodiversity – Land use

ECOLOGICAL LINKAGES PROPOSED FOR THE GNANGARA GROUNDWATER SYSTEM

Brown, P.H., Davis, R.A., Sonneman, T. and Kinloch, J.

Department of Environment and Conservation

The University of Western Australia

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Report for the Department of Environment and Conservation for the Gnangara Sustainability Strategy

Brown, P.H., Davis, R.A.*, Sonneman, T. and Kinloch, J.

Department of Environment and Conservation

* University of Western Australia

Government of Western Australia
Department of Environment and Conservation

Gnangara Sustainability Strategy Taskforce
Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.gnangara.water.wa.gov.au

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Introduction

Habitat loss and fragmentation are recognised as the two primary causes of species loss in Australia's southern temperate zone (Morton 1999). The detrimental impacts of habitat fragmentation on flora and fauna in the agricultural regions of this zone have been well documented (Brooker and Brooker 2003; Fortin and Arnold 1997; Kitchener and How 1982; Sarre *et al.* 1995; Saunders 1989) and consequently, habitat loss and fragmentation are implicated as the key mechanisms driving species extinction (Hobbs and Hopkins 1990).

Remnant habitats become highly fragmented, often with a low degree of connectivity, due to the barrier effect of roads (Baker *et al.* 2003) or agricultural land. The predicted genetic consequences of habitat fragmentation are severe, including reduced gene flow (Cunningham and Moritz 1998) and inbreeding depression (Lacy and Lindenmayer 1995). Persistence of a species at a regional level may therefore ultimately depend on the existence of metapopulations. Metapopulations exist as regional ensembles of transient populations, through dispersal and recolonisation of vacant habitats (Harrison 1991). They depend on the movement of individuals between local populations, maintaining gene flow and lessening the likelihood of extinction through demographic, stochastic or natural catastrophes (Gibbs 1998). Local populations within a metapopulation have a reduced chance of extinction through immigration of dispersers from neighbouring patches, known as the rescue effect (Brown and Kodric-Brown 1977).

Where fragments are poorly connected, where there are barriers to dispersal (Mumme *et al.* 2000) or species have biological attributes that are not conducive to dispersal (Driscoll 1997), a non-equilibrium metapopulation may occur (Harrison 1991) in which extinction may be inevitable.

The metapopulation structure of species in fragmented landscapes is dictated by the size and spatial arrangement of remnants and the nature of the matrix surrounding the remnants.

The permeability of this matrix depends on the ecology of the species in question. Whilst some species may be able to disperse across human-altered landscapes, many cannot, and may require linkages of suitable habitat for long-term population persistence.

The remnant vegetation of the Gnangara Sustainability Strategy (GSS) study area contains large tracts of *Banksia* woodland, which offer high quality habitat for a range of native fauna species. However, current and proposed future land-uses have, or will, fragment this vegetation into smaller remnants that are separated by urban development, agricultural land and other barriers to dispersal, such as major roads and highways.

The approximately 101 000ha of remnant native vegetation in the GSS study area contains some of the largest intact areas of vegetation remaining on the Swan Coastal Plain. These remnants range in condition and size from small urban remnants to larger rural nature reserves. Although a number of larger areas of vegetation still exist, if we wish to maintain biodiversity, it is imperative to design a landscape that allows for movement of individuals, and hence their genes, between remnants at both a local and landscape level. Much of the vegetation in the GSS study area, particularly in the north, provides an almost continuously vegetated link to key places such as the areas of heathland, north of Gingin Brook and from the coast to the Darling Range in an east-west direction. Whilst other remnants are small in size and isolated, they can still provide an opportunity for linkage if appropriate revegetation strategies are implemented.

The design of linkages is dependent upon the purpose of the linkage, which usually reflects the type of species that are expected to utilise the linkage. A comprehensive set of guidelines for ecological linkages for terrestrial birds on the Swan Coastal Plain have been created based upon the current literature and is available as a separate report (Davis 2009).

The primary objectives of the ecological linkages project in the GSS were twofold:

1. To design ecological linkages that allow for landscape-level connectivity; and
2. To design ecological linkages of importance at a sub-regional level that are focused around key assets.

Methods

Part A: Information Analysis

Desktop Analysis - Existing Linkages

A desktop analysis was undertaken which involved compiling all existing linkage strategies as well as identifying potential new linkages and creating a regional ecological linkage network for the Gnangara Sustainability Strategy study area. A number of local and regional linkages have been identified in various biodiversity conservation and land use planning strategies over the last ten years, and the initial step in the desktop analysis involved compiling existing spatial information about linkages.

The linkages were then reviewed to:

- identify areas on the Gnangara groundwater system not covered by existing linkage networks;
- determine if landscape ecology principles were used when routing existing linkages; and
- determine what remnant vegetation along the linkage has been protected and/or vested in the conservation estate.

Community Consultation

After the initial desktop studies had been completed to identify key linkages in the GSS study area, community consultation and stakeholder involvement was sought for the process of designing and placing the linkages. Consequently, three major geographical regions for ecological linkages were identified and workshops were held in each region (in conjunction with the Swan Catchment Council (now Perth Region Natural Resources Management) and facilitated by Blue Sands Environmental) to undertake community engagement. This included Chittering (for linkages on the northern and eastern side of the GSS study area), Midland (for linkages through Gnangara Park and Whiteman Park) and Wanneroo (for linkages in the City of Wanneroo and Joondalup coastal and near-coastal zone).

The format of the workshops, and their outcomes, are described in detail in Appendix 1. In brief, an initial presentation was given which outlined the GSS and provided background on current land-uses and issues in the GSS study area as well as some future land-use options. This was followed by a presentation of the Ecological Linkage Guidelines for birds (Davis 2009), as well as some information on the landscape-level requirements of Perth's birds (Davis *et al.* 2008). Participants were then presented with a map showing proposed linkages from the desktop assessment for their area. They were asked to prioritise the key linkages by numbering them from 1 to 3 with 1 being the most important. They were also asked to comment on any constraints to the proposed linkages (such as tenure, social or community issues, or likelihood of success) and raise any new issues that they felt needed to be considered in the process.

These constraints and issues were then applied to the desktop analysis and used to refocus linkages where required.

Landscape Threshold of 60% Total Vegetation Cover

Information on the landscape requirements of sensitive avifauna species on the Swan Coastal Plain (Davis *et al.* 2008) identified a threshold of 61% total vegetation cover within a 2km area for the most sensitive species (Scarlet Robin). The community workshops and specialist advice clarified that areas of the landscape that had 60% remnant vegetation would provide adequate habitat for most bush birds and therefore did not need additional linkages designated within them.

To aid linkage design, Neighbourhood Statistics, in the GIS software program ArcGIS Spatial Analyst, were used to determine those areas that had greater than 60% native vegetation cover within a $2km^2$ quadrant. This was done by calculating native vegetation cover in a moving window neighbourhood of $2km^2$, which passed over the Gnangara groundwater system and an additional adjoining 10km buffer. The majority of corridors and linkages designated in previous studies (e.g. by local governments) across these 60% 'core' areas were deleted, and no new linkages where designated across these vegetated landscapes. Linkages that remained within the 60% core areas generally overlaid areas which did not have secure tenure (i.e. not a conservation reserve) and/or are zoned urban-urban deferred in the Metropolitan Region Scheme.

Ground-truthing of Potential Linkages

Rob Davis (UWA) and Tracy Sonneman (DEC) undertook an on-ground site assessment of the potential ecological linkages on the eastern edge of the GSS study area. These areas included both the cleared parts of the landscape, and remnant vegetation, on private property that could be identified to link the 'core' arc of native vegetation with the Darling Scarp. The purposes of these site visits were to gain a visual appreciation of the condition of the remnant vegetation, current land uses and potential threats. Detailed biological or land use assessments were not undertaken. Where possible the field visits were undertaken with local environmental personnel e.g. Chittering Land Care Centre staff.

Discussions were also undertaken with representatives from Whiteman Park Management, City of Wanneroo and the Shire of Gingin. These were used to confirm desktop placements of linkages, to fine tune the boundaries of potential linkages or to check on alternative routes for sections of linkages.

Part B: Ecological Linkages for the GSS

New and Revised Linkages

Many linkages had already been proposed for the GSS study area, including some which overlap, therefore a process of review and rationalisation was undertaken to produce a single set of linkages across the Gnangara groundwater system. All linkages identified as 'regional' linkages by other studies were included. Where several regional linkages overlapped, they were rationalised to a single linkage for the area. The priority was to get adequate 'regional' linkages across the whole of the Gnangara groundwater system. Therefore only selected 'local' corridors were included where these linkages filled spatial gaps in the regional linkage network. This study strongly supports the development and maintenance of local corridors to supplement the regional ecological linkage network proposed in this study.

An examination of the corrected existing linkages highlighted spatial gaps in the linkage network across the GSS study area and provided a starting point for new linkages. A desktop assessment of spatial information relating to remnant vegetation cover, vegetation complex type, the level of retention and protection of vegetation complexes, waterways,

protection status of land parcels, zoning of land under the Perth Metropolitan Region and Town Planning Schemes and orthophotos was used when identifying new linkages.

The factors that were considered when routing new ecological linkages included:

- Where possible ecological linkages were routed so that they connected 'core' landscape areas (both within and outside of the GSS) that have > 60 % remnant vegetation cover over a 2km square area;
- Maximise the number of viable remnants (particularly conservation reserves, Bush Forever sites and other bushland patches) along the linkage and thus minimise the need for re-vegetation;
- Where possible ecological linkages were routed so that the ends of the linkage were in an area protected within the DEC Conservation Estate or a Bush Forever site;
- Vegetated waterways and drainage lines were identified as linkages because they are unique ecosystems in the GSS, form natural linkage corridors and generally the retention of remnant vegetation along waterways is supported through state and local government policy irrespective of land tenure;
- Input from the community workshops in terms of priority linkages, suggested actions to improve linkages and issues impacting ecological linkages;
- Extension of ecological linkages identified in the past (e.g. far northern coast). It would be expected that when an assessment of regionally significant bushland occurs across the Swan Coastal Plain bio-region north of Perth that these areas will be a priority for protection;
- Remnants which are of a vegetation complex which has low levels of retention and protection across the GSS study area and Swan Coastal Plain (Kinloch and Valentine in prep.) were a priority for inclusion within an ecological linkage; and
- Pine Linkages – linkages were designed to strategically incorporate existing patches of remnant bushland and native vegetation within pine plantations, although they will require some future revegetation (Brown *et al.* in prep.).

Once individual ecological linkages were determined, all Bush Forever sites within or touching the linkage 'corridor' were mapped. This provided a first cut visual framework of the amount of protected land already supporting each ecological linkage.

We have referred to land parcels that need to be protected in order to maintain the linkage as ‘linkage sites'. For some of the ecological linkages that were identified by Bush Forever and are in the Perth Metropolitan Region Scheme (MRS) portion of the Gnangara groundwater system, this process of identifying ‘linkage sites’ has begun. However, through further desktop study, ground-truthing and community consultation new ‘linkage sites’ will be identified. These will then need to be adopted into the statutory planning process through structure plans and Local Government planning documents before being purchased and added to the respective linkage estate.

Gnangara Ecological Linkage Framework

The work outlined above will provide the basis for the proposed Gnangara Ecological Linkage Framework (GELF) presented in this report. The Framework will have four components:

- Core – areas of the landscape that have >60% remaining native vegetation. The core parts of the landscape that are also protected by Crown land vesting will generally not contain ecological linkages;
- Conceptual Linkage – these are proposed ecological linkages based on past studies and new linkages across the landscapes with <60% native vegetation retained or on core landscapes that are predominantly over private property. There are two sites labelled “Area for Conceptual Linkage” that require more work to determine the preferred alignment of the linkage through that landscape;
- Post-pine Linkage – designated in a complementary study by (Brown *et al.* in prep.) for ecological linkages through the approximate 23 000ha of State forest previously or currently planted to commercial pine plantation; and
- Linkage Sites – either proposed reserves identified by Bush Forever or those already listed in statutory planning documents associated with identified ecological linkages in the Framework.

Gnangara Ecological Linkage Framework – at GSS Zone Scale

In addition to the overall Gnangara Sustainability Strategy, which addresses impacts, management and governance for the whole system, issues and recommendations from the GSS are addressed at a zone level i.e. within each of the seven GSS Zones (based on landuse and hydrology) (Government of Western Australia 2009). Correspondingly, the Gnangara Ecological Linkage Framework is also addressed at a more local scale, i.e. at the zone level. For each zone, a larger scale plan is provided, a short discussion on the main issues and a table of strengths and challenges of linkages within the specific GSS Zone.

Results and Discussion

Part A: Information Analysis

Desktop Analysis – Existing Linkages

The concept of ecological linkages is not a new one and various linkage schemes have been previously proposed for the Perth region. Arrays of existing and potential landscape-level ecological linkages were identified from previous studies (Table 1 and Figure 1).

Bush Forever, an initiative of the WA State Government, identified important ecological linkages as part of its final report (Government of Western Australia 2000). The ecological linkages identified by the Western Australian Local Government Association (WALGA) in its Perth Biodiversity Project (PBP) incorporated the Bush Forever linkages and included input from the Department of Conservation and Land Management (CALM), Department of Environment (DoE) and Department for Planning and Infrastructure (DPI), and were made available as a series of hard copy maps and a digital dataset (Del Marco *et al.* 2004).

The PBP established principles for ecological linkages. It discussed both local linkages and landscape-level regional linkages, recognising that effective regional linkages need to incorporate the variation in faunal and floral diversity that is typical of the region so that linkages could be utilised by the greatest range of species possible (Del Marco *et al.* 2004). The vision of the PBP work was that regional linkages would be prioritised and local governments could identify and create local linkages that supported these regional linkages (Del Marco *et al.* 2004).

The *Avon Arc Sub-regional Strategy* (Western Australian Planning Commission 2001) included the Shires of Gingin and Chittering on the north and east side of the GSS study area. The strategy supported the establishment of regional linkages and a regional greenway system. The Western Australian Planning Commission (2001) schematic land use plan (Figure 1 on page 27 of the report) depicted the following parts of the Avon Arc regional greenway system impacting the GSS study area:

- The large block of bushland on the Gnangara groundwater system as 'Core Greenbelt';
- The Gingin Brook and Moore River as 'Avon Arc Green Link' and riverine linkage; and
- Two 'Vegetation protection – Botanical linkages' east-west between the Darling Scarp and the GSS study area in the Shire of Gingin.

Some Local Government Authorities (City of Wanneroo, City of Swan and Shire of Chittering) within the GSS study area have identified local corridors with varying degrees of precision, application of ecological principals and implementation. The Shire of Chittering identified both regional and local linkages within the shire and surrounding area (Malloy 2008) by applying the guidelines developed by Del Marco *et al.* (2004). The City of Swan also identified regional and local linkages with the assistance of environmental consultants. Finally, the City of Wanneroo utilised the PBP linkages as regional linkages and supplemented these with new local linkages. These linkages have not all been adapted by the city, however they "can be adapted and expanded during development on a case-by-case basis" (City of Wanneroo 2008, pg 63).

Ecological linkages were recently defined for the approximate 23 000ha of pine plantation, within State forest, on the Gnangara groundwater system (Brown *et al.* in prep.). This involved field assessments of remnant bushland patches, including the vegetation condition (using the scale from Keighery 1994), and then ranking them using a series of scores which took into account attributes such as size, perimeter to area ratio, proximity to other remnant vegetation and vegetation complex. These ranked patches provided a key attribute in determining the locations of the proposed ecological linkages, as higher ranked patches indicate higher ecological value, and therefore it was a priority to encompass those with the highest ranking. The cover of native understorey and overstorey was also assessed and any areas which had greater than 10% cover were included as 'good quality' native

vegetation i.e. less rehabilitation would be required for these areas. Utilising all this information, the linkages maintained a minimum 500m width whilst maximising the proportion of existing bushland and areas of good native vegetation persisting within the pine compartments. While these linkages will require rehabilitation, once the pines are harvested, they will allow ecological connectivity across the landscape whilst allowing for maximum water recharge in complementary areas of ex-pine plantation.

The review of all existing ecological linkages showed that the far northern areas of the Gnangara groundwater system (outside of the Bush Forever study area and Shire of Chittering) required additional or new ecological linkages to be identified (Figure 1). Even though ecological linkages had been considered in broad planning strategies in this area, any linkages identified were only indicative, as criteria based on landscape ecology principals had not necessarily been used (Table 1).

The coastal areas north of Alkimos and south of Guilderton were also identified as requiring additional linkages. These areas currently have greater than 60% remnant vegetation cover (Figures 1 and 2); however the land is privately owned and zoned for urban development. Linkages therefore need to be identified as quickly as possible so they can be included in future structure planning processes.

Table 1: Ecological linkages identified by State and Local Government on the Gnangara groundwater system since 2000.

Ecological Linkage Name	**Spatial Extent**	**Landscape ecology criteria used in identification of linkages?**
Existing and Potential Bushland-Wetland Linkages in the Perth Metropolitan Region [Bush Forever] (Government of Western Australia 2000)	Perth Metropolitan Region Scheme area	Yes
Perth Biodiversity Project Regional Ecological Linkages (Del Marco *et al.* 2004)	Perth Metropolitan Region Scheme area	Yes, further refinement of Bush Forever linkages.

Avon Arc Green Link and Vegetation Protection/Botanical Linkages in the Avon Arc Sub-Region (Western Australian Planning Commission 2001)	Local Governments of Brookton, Beverley, York, Shire and Town of Northam, Toodyay, Chittering and the area east of the Brand Highway in Gingin	Not necessarily. The strategy provides a policy framework to support Local Governments to undertake the process of identify local ecological linkages to support the Avon Arc Regional Greenway system.
City of Swan Local Corridors (City of Swan 2005)	City of Swan	Yes, based on the principles established by PBP.
Potential Botanical Linkages in the Gingin Coast Structure Plan Area (Western Australian Planning Commission 2006)	The study area is wholly within the Shire of Gingin and extends from the coast to the Brand Highway	Not necessarily. Plan identifies potential linkages which reflects desire to enhance connectivity for flora and fauna protection and recommends further investigations and consultation with government agencies and community to establish the linkages.
Shire of Chittering draft Regional and Local Linkages (Malloy 2008)	Within and adjacent to the Shire of Chittering	Yes, based on the principles established by PBP
City of Wanneroo draft Local Linkages (City of Wanneroo 2008)	City of Wanneroo	Yes, based on the principles established by PBP
Pine plantation remnant native vegetation linkages (Brown *et al.* in prep.)	GSS study area sub-areas of Gnangara, West Gnangara, West Pinjar, East Yanchep	Yes, including SWOT analysis.

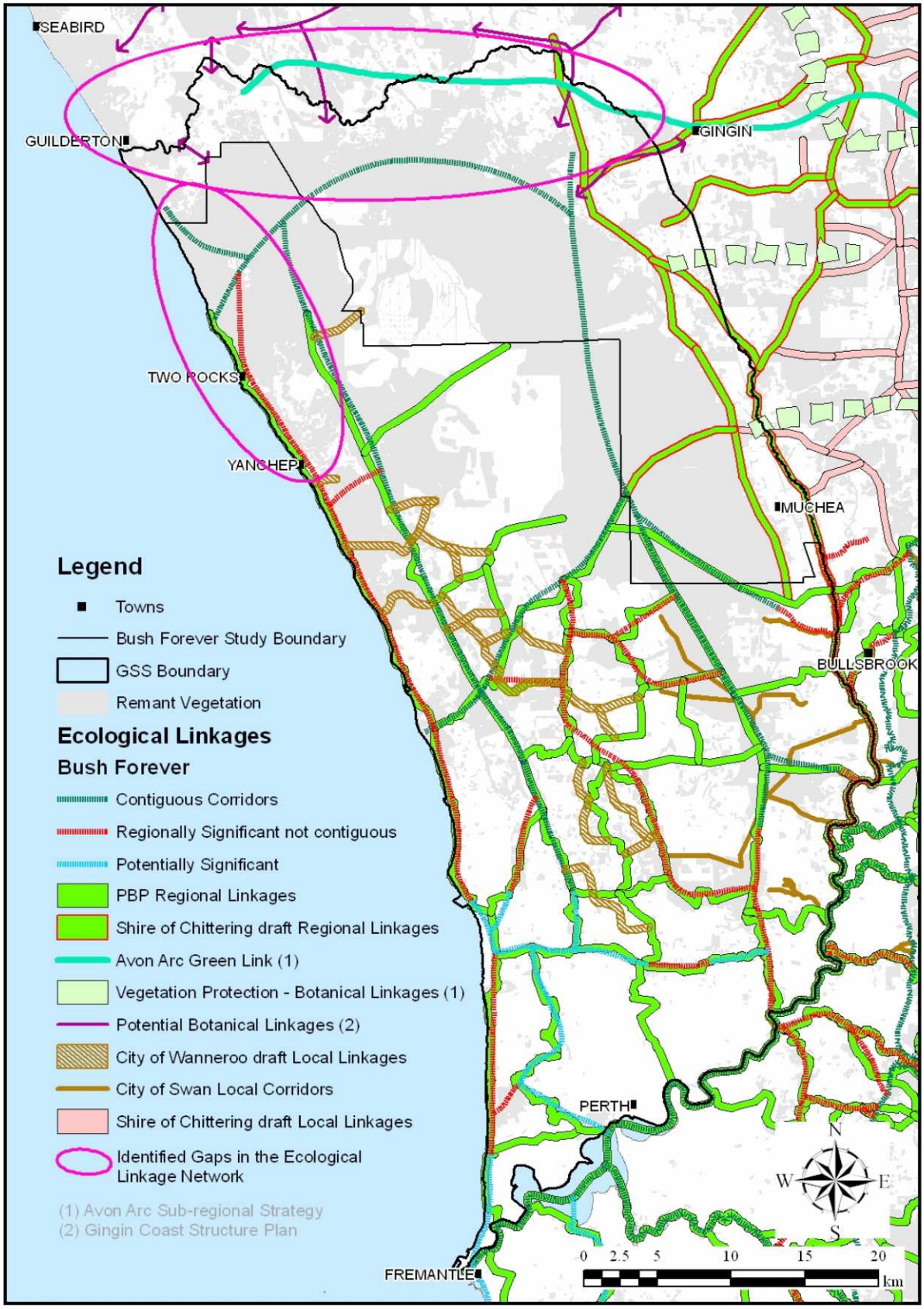

Figure 1: Existing or proposed ecological linkages across the Gnangara groundwater system.

Community Consultation

The summary of the key findings of the community workshops are presented here. The full documentation can be found in Appendix 1.

The ecological linkages identified as being the most important to workshop participants at each of the three community workshops (Chittering, Midland and Wanneroo) are presented in Table 2.

Table 2: Ecological linkages identified by workshop participants at the three workshops as being their most important.

Chittering
East-West
1. Along Gingin Brook
2. Linkage connecting remnant vegetation north of Neaves Road with Darling Scarp vegetation.
North-South
1. Linkage following the Great Northern Highway and Brand Highway to Gingin Brook
2. Linkage following the Great Northern Highway and Brand Highway and then branching off in a North-East direction through remnant vegetation with >60% cover
3. Linkage connecting Bindoon down to the Darling Scarp
Midland
East-West
1. Linkage connecting Swan River to Lake Jandabup (through Whiteman Park and the western edge of the Gnangara pine plantation)
2. Linkage connecting Walyunga National Park with Lake Jandabup (through the Gnangara pine plantation along Warbrook Road)
North-South
1. Linkage connecting Swan River to Neaves Road
Wanneroo
East-West
1. Linkage connecting Lake Jandabup with Burns Beach (crossing Lake Joondalup)
2. Linkage through Yanchep National Park (connecting Wanneroo Road with coastline)
North-South
1. Linkage following Yellagonga National Park to Wilbinga
2. Linkage following the coastline

Suggested Actions to Improve Linkages

Workshop participants were asked for suggestions about what needed to be done to improve or maintain these ecological linkages. There were 98 suggestions provided by participants from all three workshops, with most participants listing more than one suggestion (Table 3).

The most common suggestion was that the responsible agencies should undertake community education and awareness, so that the broader community are made aware of the direct and indirect benefits of linkages. Participants suggested involving 'friends of' groups to care for the linkage in conjunction with youth groups, schools and other community associations. Whilst a lack of community understanding of ecological linkages was mentioned as an issue at the Wanneroo workshop, it did not rate highly compared to other issues such as land development and feral species. This may be because participants felt that the lack of community understanding was the underlying reason for many of the other issues, such as feral species, fire, disease and rubbish dumping.

Restoration and revegetation was ranked equally with the development of adequate policy and legislation (with the aim of ensuring long-term protection of proposed linkages and bushland remnants), receiving 14 comments. In regards to restoration and revegetation, there were suggestions to improve vegetation cover to achieve a minimum of 60% cover by undertaking infill plantings using endemic species. There was a desire to involve and inform community groups of this work, which could partially achieve another suggested action of improved stakeholder consultation and collaboration, which rated highly at the Midland workshop. There were also calls for greater use of understorey species in revegetation projects. Participants were eager to see native species planted soon after the pines were harvested so the area could provide biodiversity values.

Participants felt strongly about the use of policies and legislation to ensure protection of linkages. It was suggested that government should introduced a tiered planning framework where ecological linkages and reserves were protected by Statements of Planning Policy (SPPs) down to local planning policies at local government level. A policy on the use of tracks and trails was also suggested to ensure adverse impacts were minimised by activities in these areas.

Table 3: Actions suggested by participants to improve regional ecological linkages

Action	Chittering (n=30)	Midland (n=25)	Wanneroo (n=42)	Total (n=97)
Community education and awareness	5	4	13	22
Restoration and revegetation	4	4	6	14
Develop adequate policy and legislation to ensure long-term protection	4	6	4	14
Feral species control	4	2	3	9
Secure long-term funding		3	5	8
Improved consultation and collaboration with stakeholders	6			6
Manage access	2	3	1	6
Undertake detailed resource assessments and provide information and data to stakeholders			4	4
Water resource management			4	4
Fire management	2			2
Introduce program that secures conservation of land in private ownership (i.e. Wetland Watch, covenants)		1	1	2
Control vandals	1			1
Maintain land productivity	1			1
Ensure linkages connect nature reserves that offer long term protection	1			1
Encourage innovations to provide safe travel for fauna (i.e. underpasses)			1	1
Fauna management		1		1
Heritage listing		1		1

Issues Impacting Ecological Linkages

Table 4 outlines the issues that participants believed would adversely impact on regional ecological linkages. There were a total of 99 issues listed by participants from all three workshops, with most participants listing more than one issue.

Urbanisation was the most common issue, listed 21 times. Some participants chose to elaborate on this issue, indicating that developers were seeking to develop environmentally constrained or sensitive land in the absence of land which is degraded or could be easily developed. Additionally, participants felt that developers and the Department for Planning and Infrastructure did not appreciate the indirect services that are provided by biodiversity (i.e. air quality, water quality and recreation). Consequently, participants rated the issue of needing adequate policy and legislation as a high priority action to ensure the protection of biodiversity from urbanisation and land clearing.

Feral species (including flora and fauna), was the second highest ranked issue, listed nine times.

Private land tenure, which was mentioned at the Chittering and Wanneroo workshops only, was seen as a potential threat to those linkages which incorporated private land, due to the unsecured nature of this tenure. Participants felt that private land ownership was a significant issue (related to land development) and suggested that private ownership compromises the long term viability of many of these linkages as some owners may not manage their land with biodiversity as a top priority. However, participants were generally unsure of how to address this potential threat. Those that did provide recommendations suggested the use of covenants or adapting programs such as Wetland Watch, which aims to conserve wetlands and bushland through a more collaborative approach with land holders.

Table 4: Issues participants listed as impacting on regional ecological linkages

Issue	Chittering (n=34)	Midland (n=35)	Wanneroo (n=30)	Total (n=99)
Urbanisation/land development	10	3	8	21
Feral species	1	5	3	9
Private land ownership	4		4	8
Long term management and viability	4	2	1	7
Fire	3	3		6
Fragmentation	1	1	4	6
Roads/railway	2	3		5
Recreation		5		5
Water quality and quantity	1	1	3	5
Vegetation condition	4	1		5
Lack of community understanding			3	3
Inadequate legislative protection	1		2	3
Lack of long term funding	1	1	1	3
Rubbish dumping		2		2
Dieback and disease		2		2
Width of linkages		2		2
Lack of indigenous involvement in planning		2		2
Land degradation (i.e. erosion, salinity, acid sulfate soils)		2		2
Industry impacts	1			1
Number of linkages	1			1
Edge effects			1	1

Synthesis of Community Input and Future Directions

The community workshops showed that there is support for the linkages previously identified from desktop studies and they particularly emphasised the importance of connections with remnants in the Darling Range, as well as links along the coast. The

community showed strong support for this project and echoed the same concerns about the issues of management, costs and how achievable targets would be in heavily urbanised areas.

Participants appeared to have a clear understanding of what constitutes a priority regional ecological linkage, with many selecting existing linkages that traversed wetlands and waterways. Many also had a desire for linkages to connect bushland that had greater than 60% remnant vegetation cover, possibly influenced by the information presented to participants that emphasised the importance of this criteria.

A considerable number of participants were from local friends groups, so in some instances prioritisation reflected a desire to 'protect their own patch'. However, it is likely that these friends groups would have an interest in maintaining these linkages themselves, which must be considered when determining the most appropriate linkages to retain.

The proposed ecological linkages present an array of challenges in implementation, particularly in terms of pressure from existing and future development that may result in the ongoing loss of remnant native vegetation, which makes it difficult to achieve linkages with 500m widths in some areas. The highest priority for linkages is the connection with the Darling Range in the north-east of the study area, the coastal linkages and north-south and east-west linkages throughout the GSS study area. These linkages will allow for the movement of migratory species and the continuation of normal ecosystem processes.

In summary, the security of these linkages was an overwhelming concern to participants. In general, participants felt that if the linkages could be secured and protected from clearing then they would be more viable and attract funding for collaborative projects for improvement and maintenance. The concept of Ecological Linkages was embraced by the general public and stakeholders who also recognised the challenges involved. Although there will be challenges, successful implementation is both crucial and very timely, and will require consideration of offsets towards targets as well as land-swaps and purchases to achieve the linkages.

Landscape Threshold of 60% Total Vegetation Cover

The analysis showed that in the northern half of the GSS study area, a continuous arc exists (marked in red hatching in Figure 2), where greater than 60% remnant vegetation cover still remains and covers an area of approximately 74 000ha. This arc starts just north of Ellenbrook townsite, runs north through Melaleuca Park (west of Bullsbrook), the RAAF lands west of Muchea, Yeal Nature Reserve (west of Gingin), west through State forest to the coast through the proposed Wilbinga Reserve and south to Yanchep National Park and the Ridges area (Figures 2 and 3). This 'core' block is the largest continuous remnant of bushland remaining on the Swan Coastal Plain south of the Moore River and is predominantly Crown Land. A large section in the middle of this arc is standing pine or cleared pine plantation on State forest (Figure 3) that could be rehabilitated to add to the core bushland on the Gnangara groundwater system.

The analysis mapped ten smaller 'core' remnants of native vegetation remaining within the GSS study area (from south to north):

- Bold Park and beach bushland Zone 7
- Kings Park Zone 7
- Whiteman Park Bushland Zone 1
- Bush Forever site east of Jandabup Zone 2
- Bush Forever site south of Mindarie Zone 4
- East Wanneroo Zone 2 & 4
- Gnangara Plantation north-west Zone 1
- Pinjar Plantation south Zone 2
- Yanchep Plantation north Zone 6
- South of Gingin (area for linkage) Zone 5

There are also 'core' remnant landscape areas identified outside but close to the border of the GSS study area both on the Darling Scarp and on the Swan Coastal Plain north of Moore River or Gingin Brook (see Figure 2). (Note: Areas south of the Swan River within 10km of the boundary of the GSS were also assessed as to whether they met the 60% criteria, but few areas met this criterion in comparison to the GSS study area.)

Those areas within and adjoining the GSS study area that have 60% or greater remnant vegetation cover, and are within the conservation estate (Figure 2) do not require internal ecological linkages as this scale of landscape connectivity is adequate for most vertebrate fauna species. Rather, linkages need to be identified to connect these 'core' areas of remnant vegetation with smaller remnants in the land developed for agriculture in the north and east and for urbanisation in the south and west.

This analysis can also be viewed in its 'mirror image' by focusing on the areas *without* 60% remnant vegetation in the landscape. This illustrates that many of the landscapes in the GSS study area have been preferentially cleared of native vegetation, including:

- The heavier soils of the eastern side of the Swan Coastal Plain (GSS Zones 3 & 5) where up to 95% of remnant vegetation has been cleared from the loams, gravels and clays of the Pinjarra Plain;
- The whole of urban Perth (GSS Zone 1) from Fremantle along the Swan River through Perth to Midland and north to the edge of the suburbs – Joondalup, Burns Beach, East Wanneroo, around Whiteman Park, Swan Valley to the Ellenbrook townsite;
- There is a strong preference for urbanisation along the coastal strip from Fremantle to Burns Beach (GSS Zones 1 & 4);
- The swath of 23 000ha planted to pine plantation (GSS Zones 1 & 6) through the middle of the 'core' arc of remnant vegetation on the Gnangara groundwater system; and
- Along the southern side of the Moore River and along the Gingin Brook (GSS Zone 5) from the coast through to the Gingin townsite.

Part B: Ecological Linkages for the GSS

New and Revised Linkages

The final ecological linkages proposed for the GSS study area are a combination of the six key aspects of the following work:

1. The 'core' areas that retain >60% remnant vegetation in the landscape and thus do not require any designated ecological linkages across the 'core' blocks;
2. The existing framework of ecological linkages developed through the extensive work completed for Bush Forever (Government of Western Australia 2000) and Perth Biodiversity Plan (Del Marco *et al.* 2004) in the Metropolitan Region Scheme area;
3. The addition of the ecological linkages through the 23 000ha of pine plantations on the Gnangara groundwater system as proposed by (Brown *et al.* in prep.);
4. The integration of existing Bush Forever sites into the existing ecological linkages and as a back-bone for new or revised linkages;
5. Development of new ecological linkages in the 40% of the GSS study area outside the MRS and linking 'core' areas in on the Gnangara system, in the Darling-Dandaragan Plateau, along the coast and along the Moore River- Gingin Brook; and
6. Revision of each of the above linkages based on input from the community workshops, expert knowledge, local government corridor studies, field visits and further analysis of bushland distribution.

These final proposed linkages are shown in Figures 2 and 3. These have substantially consolidated the existing array of proposed linkages (Figure 1), which has primarily been achieved by basing linkages upon existing 'core' areas of >60% remnant native vegetation.

Gnangara Ecological Linkage (GEL) Framework

Figure 2 shows the proposed Gnangara Ecological Linkage Framework with the 'core' areas of the landscape with >60% remaining native vegetation as its base layer (pushed to the front). All Bush Forever sites embedded in or adjoining, proposed ecological linkages are shown in green as an indicator of the 'protected' bushland within linkages. The 'Post-

Pine Banksia Rehabilitation' areas are linkages through the existing pine plantations proposed by (Brown *et al.* in prep.). The linkages in the GSS Gnangara, West Gnangara and West Pinjar sub-areas (Zones 1 and 2) are well developed, but the linkages in the GSS East Yanchep sub-area (Zone 6) require further work to define their boundaries.

The 500m wide 'Conceptual Linkages' (blue lines in Figure 2) are the components of the proposed ecological linkages that are not currently protected (in reserves or Bush Forever sites). Therefore they will require acquisition, covenants with land owners and generally rehabilitation. These 'Conceptual Linkages' will need to be assessed individually to determine the exact on-ground boundaries, based on remnant vegetation, land use and availability for purchase. Where possible any remnant vegetation or local natural areas should be retained in their entirety, rather than just the portion of these areas which fall within the mapped 500m wide linkage. **In other words they should not be used as definite boundaries where everything that falls outside the line can be considered to be cleared of remnant vegetation.**

Figure 3 shows the same Gnangara Ecological Linkage Framework as in Figure 2 but with the results of the 'core' area analysis replaced by the public land tenure across the top of the Gnangara groundwater system based on a simplified version of mapping done by (Sonneman and Brown 2008). Unallocated Crown Land (UCL), DEC-managed State forest with pine plantations and DEC-managed land with native woodlands are included. This tenure plan demonstrates that most of the 'core' areas in the arc are currently on Crown Land, predominantly vested in the WA Conservation Commission and managed by the DEC. The exceptions are (a) the large area of UCL managed by the Commonwealth Government associated with the Pearce Air force Base and flight-bombing ranges; and (b) the privately owned bushland west and south of Yanchep National Park (much of which is proposed for urban development).

Figure 4 shows the Gnangara Ecological Linkage Framework over the seven GSS Zones illustrated by different colours. As the GSS documentation to the Government will be presented against these seven zones, we have described below the key points of the Gnangara Ecological Linkage Framework against each of the GSS Zones. Figures 5-9 are enlarged sections of Figure 2 showing the linkages in each of the GSS Zones.

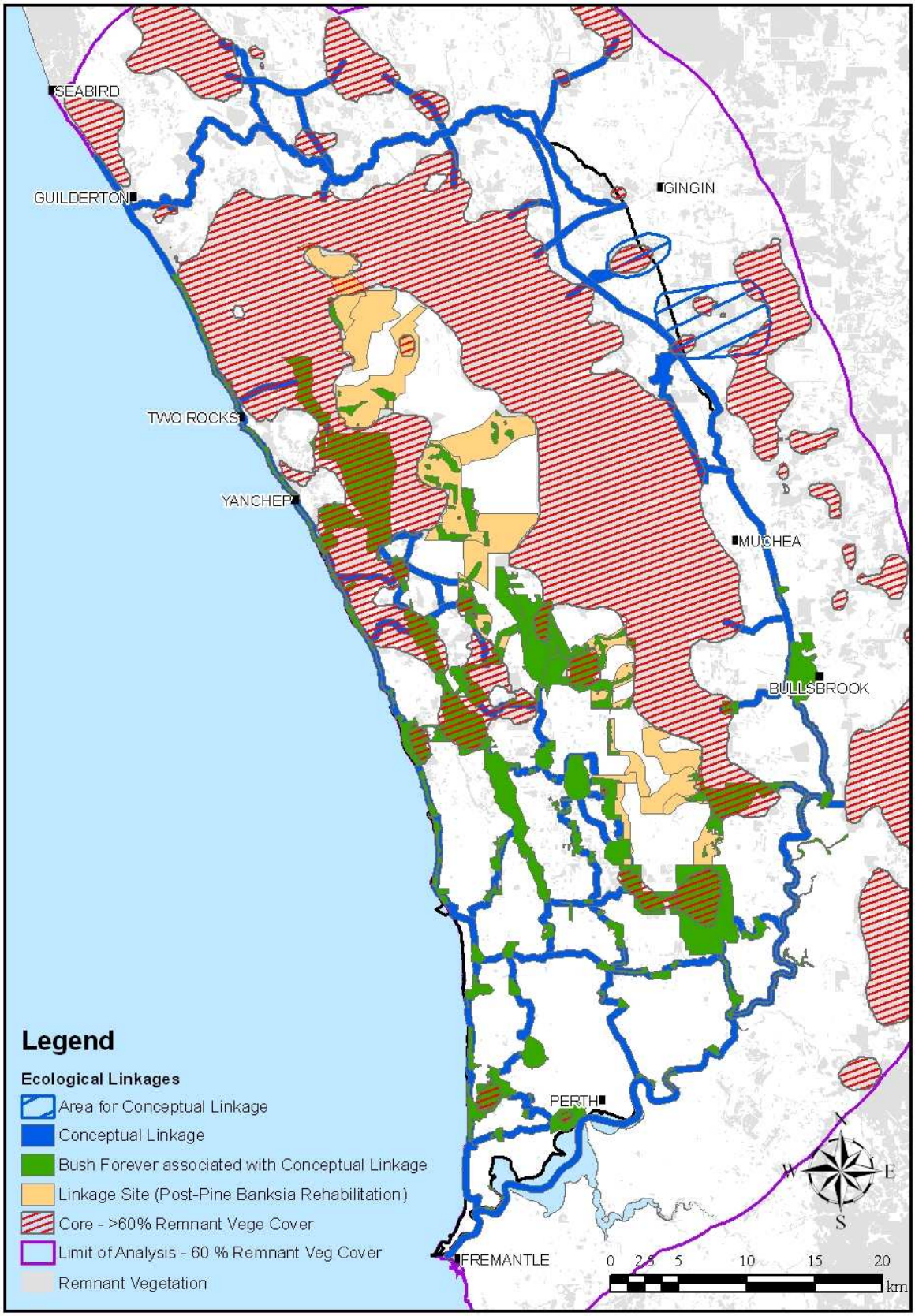

Figure 2: Final ecological linkages for the GSS area incorporating Bush Forever sites and highlighting >60% remnant vegetation core areas.

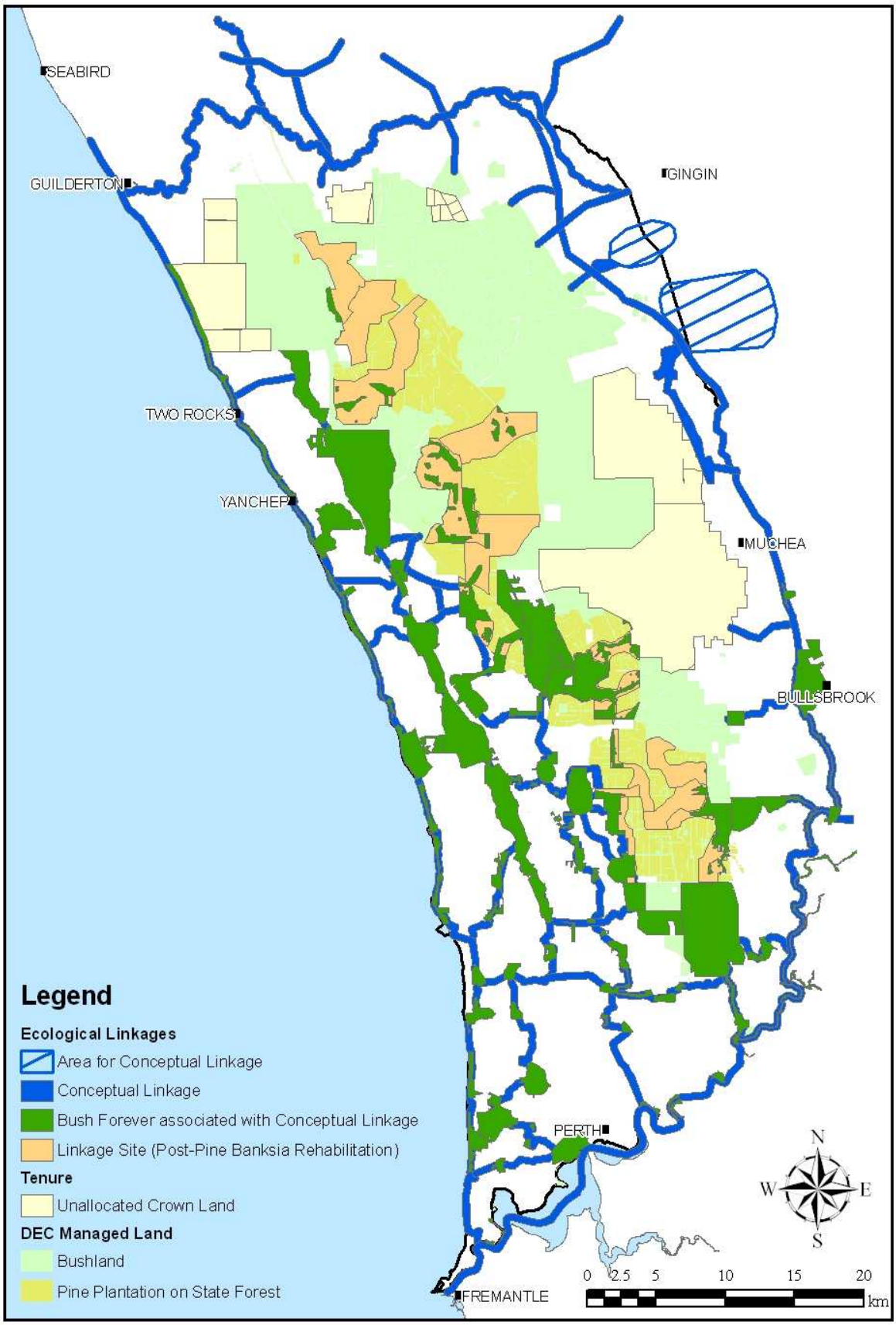

Figure 3: Ecological linkages in the GSS study area, highlighting existing land tenure.

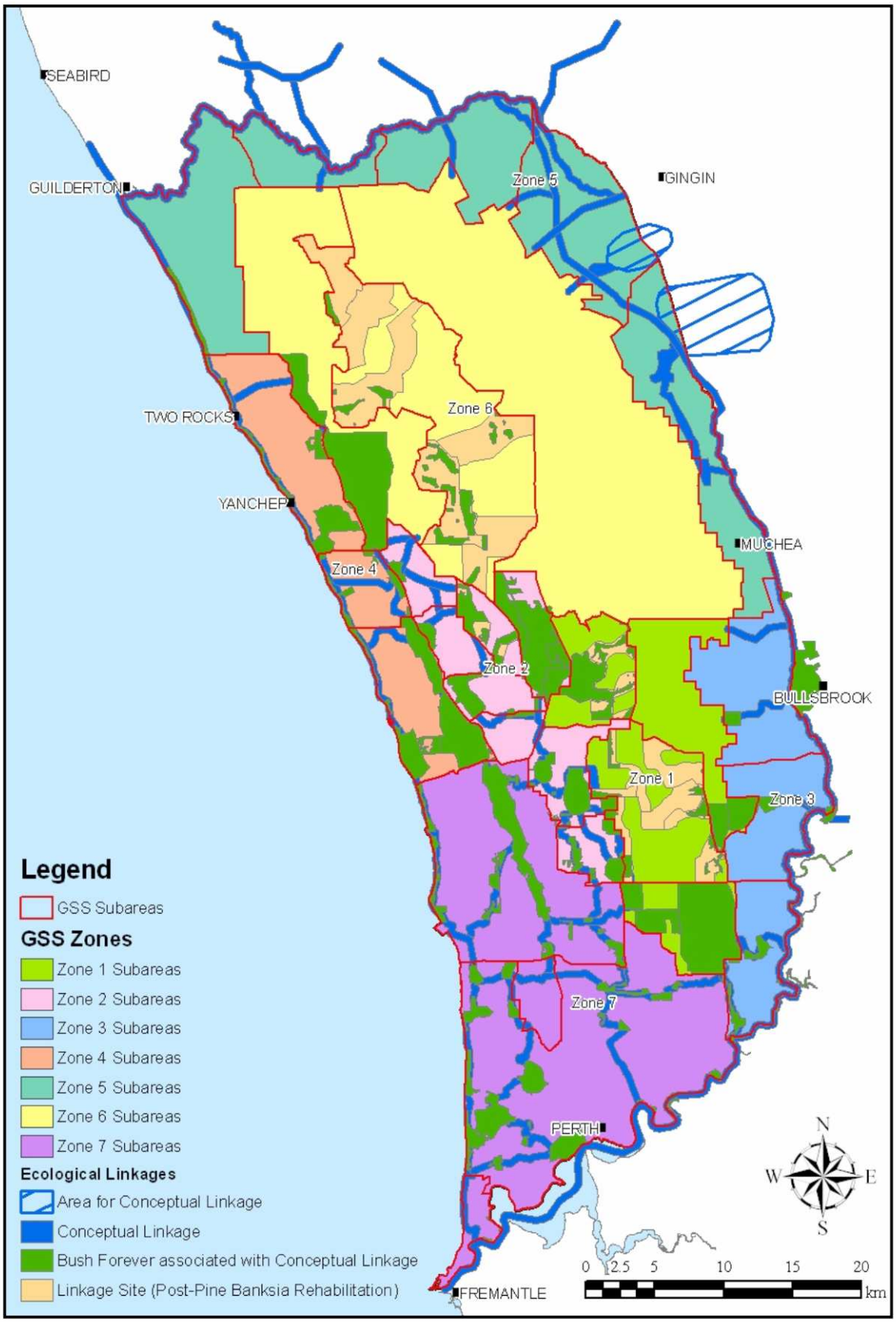

Figure 4: Ecological linkages in the GSS study area based upon the seven GSS Zones.

Gnangara Sustainability Strategy Zones

Zone 1 Linkages

Zone 1 is predominantly Crown land over Whiteman Park, Gnangara pine plantation and the proposed Melaleuca Conservation Park (Figure 5). A key feature of this zone is the presence of 'core' areas of secure tenure with extant native vegetation - within the Whiteman Park and the GSS East Gnangara sub-area (including Melaleuca Conservation Park and State forest). The ecological linkages proposed through Zone 1 extend through ex-pine plantation on State forest (Brown *et al.* in prep.) to link Whiteman Park to the 'core' arc of bushland through Melaleuca Park, as well as linking these east to the Darling Range and west to the coast through Zones 2 and 3.

The bushland adjoining and within Whiteman Park has been adversely impacted by a long history of grazing, low key rural development, *Phytophthora* dieback and major roads. There is a need to initiate an active rehabilitation program within Whiteman Park to build up the functionality of the designated linkages and revegetate the degraded patches of land within the 'core' areas and linkages.

The bushland in the GSS East Gnangara sub-area (proposed Melaleuca Conservation Park) is in excellent condition except for patches of Banksia woodland impacted by *Phytophthora* dieback, sand mining and clearing. Close liaison with the sand mining companies with respect to post-mining rehabilitation and management of dieback spread are essential.

The complementary study of potential ecological linkages within the 23 000ha of pine plantations on the Gnangara groundwater system has been completed (Brown *et al.* in prep.). In Zone 1 this includes the whole of the Gnangara Pine Plantation across the GSS Gnangara and West Gnangara sub-areas. A total of 11 ecological linkages were identified totalling 5 039ha (43% of the total Gnangara plantation area) with 2 183ha (43%) existing bushland and 936ha (19%) with good native vegetation under the pine plantation. Thus in Zone 1 only 38% of the proposed ecological linkage areas require complete rehabilitation and revegetation. These ex-pine linkages contain a number of remnants of native

vegetation which have formed the backbone of proposed linkages and incorporate significant areas of native vegetation under the existing pine plantation.

One of the few linkages on the eastern side of the Swan Coastal Plain (connecting to the Darling Range) incorporates a number of existing or proposed reserves in the Bullsbrook area (Maralla Road Nature Reserve and Bush Forever site no. 300). There is currently a gap in linkages across the eastern side of the GSS study area and overall there are very few areas that have the potential to connect the coastal plain with the Darling Range. These linkages are thus seen as of high importance.

Strengths	**Challenges**
Major remnants of vegetation are connected to enhance ecological function and utilising these in links also reduces the need for revegetation.	
Core areas through Whiteman Park and Gnangara Park provide a focus for connectivity in all directions (coast-hills and north-south).	
Post-pine revegetation will create a strategic and strong linkage in a currently unconnected area. These are all on Crown land managed by DEC and not proposed to be replanted to pine.	A large amount of revegetation in former pine plantations is required. This will take active management, a large expenditure and many years to achieve suitable habitat
A very large core of vegetation greater than 60% is available and with strong linkages will provide resilience against climate change and other threatening processes.	The bulk of Zone 1 is on Bassendean (grey) sands that are generally well protected in the GSS study area.

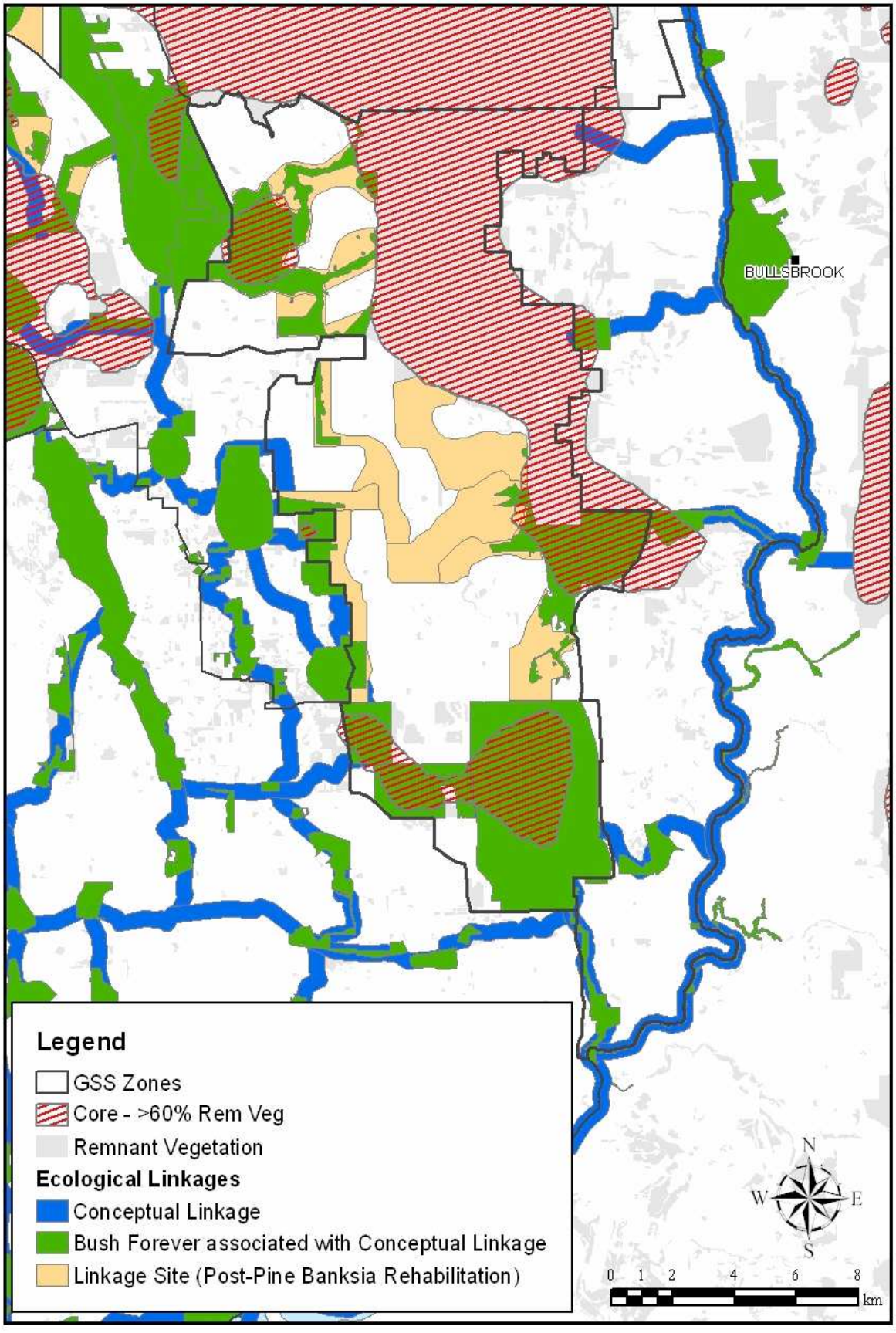

Figure 5: Zones 1 and 3 with the southern portion of Zone 2

Zone 2 Linkages

Zones 2 and 4 are focused on the north-western coastal portion of the GSS, primarily within the City of Wanneroo (Figure 6). They form the main area of the north-west corridor of the Metropolitan Region Scheme, which is expanding rapidly with the conversion of rural landscapes to suburban housing and industrial estate. Many of these areas are covered in *The Future of East Wanneroo* (Western Australian Planning Commission 2007).

There are great challenges in achieving linkages through existing and future urban areas in the City of Wanneroo, and offsetting or land-swapping towards these targets may be required. Landscapes that are already predominantly cleared are being further cleared of remnant bushland across these two zones. It is also recognised that it may be difficult to get 500m-wide linkages in this zone.

The northern third of Zone 2 is in the proposed Carabooda and Nowergup horticultural precinct where the land is zoned rural and is highly cleared of native vegetation. Five ecological linkages are proposed, however these linkages require further ground-truthing to determine their exact boundaries which will require input from State planners, the City of Wanneroo and the community. Possible land swaps with ex-plantation land in Zone 6 may aid in securing these linkages.

The central third of Zone 2 contains the only large block of 60% core native vegetation - along Flynn Drive, through the proposed Meridian Park Industrial Estate and north along the limestone ridges of Carabooda. To protect this core area, negotiation will be required with the limestone industry and planners associated with the Meridian Park Industrial Estate, and some land swaps with areas of State forest in the Pinjar and Gnangara pine plantations will also be required. This core area in Zone 2 links with a core area to the west in Zone 4 associated with Neerabup National Park, Tamala Park and Burn Beach Bushland on the coast. This extended linkage was strongly supported in our community workshops.

Adjoining this core area of bushland in Zone 2 on its east side, is the ‘tear-drop’ section of Pinjar Plantation in the GSS West Pinjar sub-area. Two ecological linkages were identified through the ‘tear-drop’ in a complementary study of potential ecological linkages within

the 23 000ha of pine plantations on the Gnangara groundwater system (Brown *et al.* in prep.). These two linkages totalled 836ha (50% of the total plantation area in this zone) with 559ha (67%) existing bushland. They link the Zone 2 core bushland in the west with Lake Pinjar and the core bushland arc in the east. This will link with remaining and protected bushland identified by Sonneman (in prep.) in a separate study on the condition and extent of bushland in the Bush Forever Lake Pinjar Bushland site no. 382.

The southern third of Zone 2 is a mixed rural zone with horticulture and horses on small blocks, which is under review for urbanisation. It is dominated by four major lakes – Gnangara, Jandabup, Adams and Mariginiup. To the west is a chain of wetlands in Yellagonga Regional Park, in Zone 7, and to the east is the main block of Gnangara Plantation, in Zone 1 (Figure 5). The six proposed ecological linkages through this part of East Wanneroo attempts to link the four lakes, Yellagonga Regional Park, Whiteman Park and the ex-pine linkages proposed by Brown *et al.* (in prep.) through the Gnangara pine plantation.

Strengths	**Challenges**
Major remnants of vegetation in Bush Forever and DEC estate are present and provide a number of strong existing links. Most of Zone 2 is on Spearwood Dune systems where vegetation complexes are under-represented in the conservation estate	It may be very difficult to achieve 500m links in much of the intervening area and very costly to revegetate as it is mostly land on private property and proposed urban land.
Provides critical east-west linkage between the ‘core’ bushland arc and the coastal strip. Key objective is to link to and between major lakes in Zone 2 and the Joondalup Lake complex in Zone 4.	Urban development and impact of falling groundwater on wetlands may limit the inter-connectivity of wetland habitats.
Post-pine revegetation will be able to build on a number of existing patches of native vegetation which will reduce revegetation costs and create a strategic east-west linkage.	A large amount of revegetation in former pine plantations is still required. This will take active management, a large expenditure and many years to achieve suitable habitat

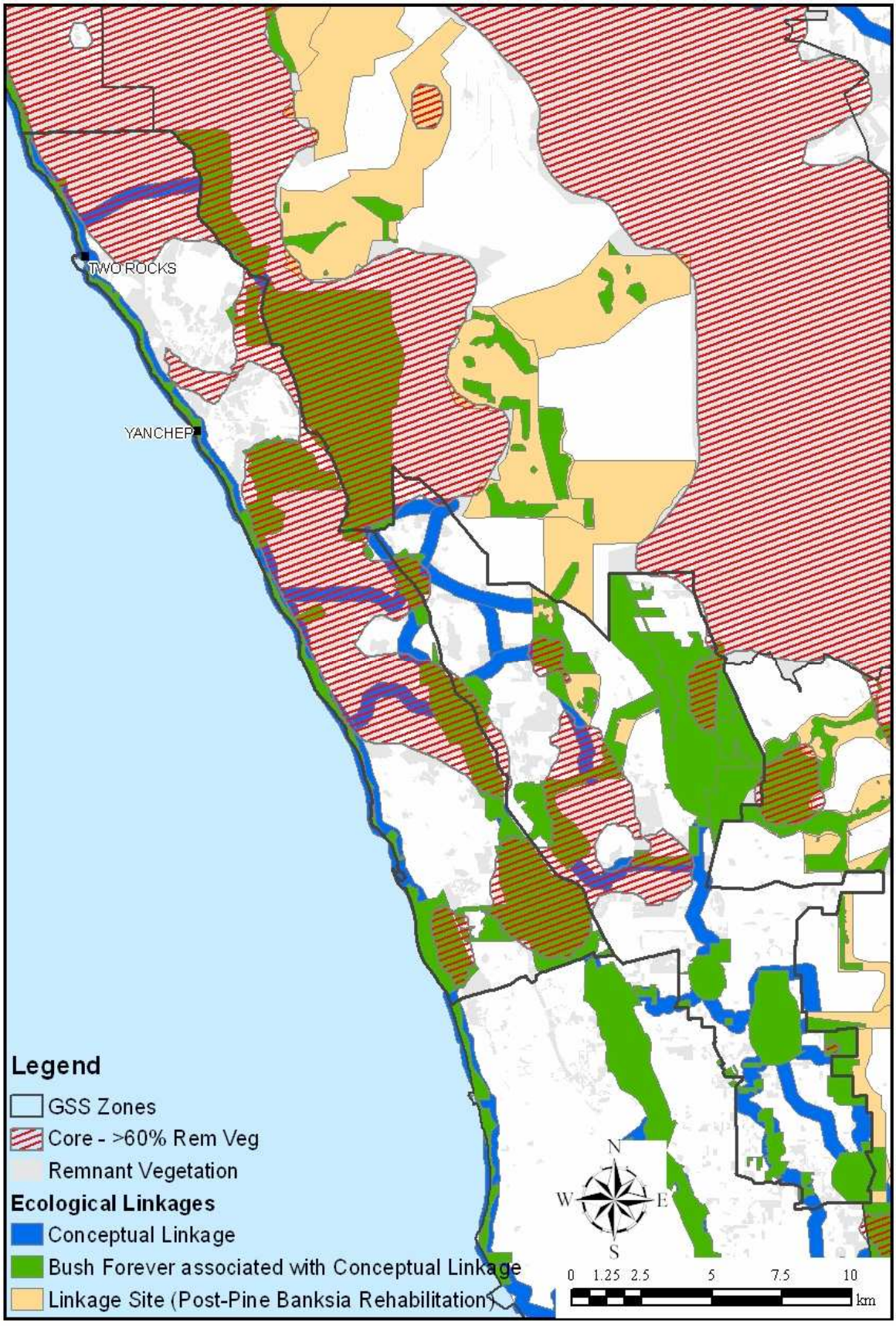

Figure 6: Zones 2, 4 and a portion of 6

Zone 3 Linkages

Zone 3 is predominantly private property west of the Ellen Brook between the Swan River, the Swan Valley and Whiteman Park, north past Ellenbrook townsite and to just north of Bullsbrook townsite (Figure 5). This zone is heavily cleared with no 'core' areas of remnant bushland however it adjoins the eastern edge of the arc of core remnant vegetation in Zone 1 (including Whiteman Park and Melaleuca Park). The Darling Scarp rises up from the Swan Coastal Plain 0.5 to 1.5km east of the Ellen Brook.

The main ecological linkage in Zone 3 is along the Ellen Brook and part of the Swan River. A branch of this riverine linkage also follows the Bennett Brook from the Swan River to Whiteman Park. It is a long established linkage that is already partly established. These provide natural connectivity in the landscape for the movement of both aquatic species along these waterways and terrestrial species through the adjoining bushland.

There are four additional proposed ecological linkages going east-west across the cleared, rural lands in Zone 3 that link the 'core' areas in Zone 1 with the Ellen Brook and into 'core' bushland on the Darling Scarp. These linkages require further ground-truthing to determine their exact boundaries in the field and consultation with State planners, the City of Swan and the community.

Strengths	**Challenges**
Zone 3 adjoins the arc of 'core' remnant vegetation in Zone 1 including Whiteman Park and Melaleuca Park.	Zone 3 on the eastern side of the Swan Coastal Plain is highly cleared and has little 'core' landscape or conservation reserves.
Existing riparian vegetation along the Ellen Brook and a short stretch of the Swan River provides an excellent north-south link and future potential for revegetation.	Multiple landholders, high land values and high human visitation are challenges to using the Swan River and Ellen Brook as a linkage.
Remnant vegetation along the Bennett Brook provides a major linkage between Whiteman Park and the Swan River. This is a long established linkage, which is already partly established.	Any addition to existing conservation/recreation reserves along Bennett Brook, as well as revegetation of these lands, will be costly and difficult.

Major remnants of vegetation are connected to enhance ecological function. Utilising these in linkages also reduces the need for revegetation.	It may be difficult to achieve 500m links across private property for the east-west linkages and very costly to revegetate them due to agricultural and environmental weeds.

Zone 4 Linkages

Zone 4 includes the coastal strip of the north-west corridor of the Metropolitan Region Scheme which is expanding rapidly with the conversion of rural landscapes to suburban housing and industrial estates (Figure 6). It lies predominantly within the City of Wanneroo. Proposed urbanisation will extensively clear the remnant vegetation across this whole zone in the coming 10-20 years.

Zones 2 and 4 are separated north-south by a major ecological linkage and chain of wetlands through Yellagonga Regional Park, Neerabup National Park and Yanchep National Park. This chain of wetlands is part of a major aboriginal cultural trail from the Swan River to the Moore River. The Yaberoo Badjarra walk trail provides people an opportunity to walk this important ecological and cultural linkage. This north-south linkage needs small additions to the conservation estate to develop a continuous bushland and wetland linkage.

An effective bushland strip along the coastline would be an important ecological linkage and assist fauna movement along this natural migration pathway. However, land close to the coast is highly sought after for urban development and coastal recreational facilities.

This report has proposed five east-west ecological linkages through the predominantly private property in Zone 4. Two of these linkages are supported by current Department for Planning and Infrastructure (DPI) and City of Wanneroo draft structure plans:

- The southern quarter of Zone 4 contains a single ecological linkage associated with a block of >60% core native vegetation associated with Neerabup National Park, Tamala Park and Burn Beach Bushland (Bush Forever site no. 322/323) on the coast. These areas were identified by Bush Forever and are already protected in current or proposed conservation reserves. The Burns Beach linkage also links with the core area in Zone 2 to the east and the north-south coastal linkage. This

extended linkage was strongly supported in our community workshops (see Appendix 1); and

- The Ningana Bushland, Bush Forever site no.289, in Yanchep-Eglington, that links the south-western edge of Yanchep National Park and the coast.

In addition to these, just outside Zone 4, on its northern boundary, is the proposed Wilbinga reserve complex (Wilbinga-Caraban Bushland Bush Forever site no. 406) which is also supported by the DPI, DEC and the EPA.

Thus there are three proposed ecological linkages not currently supported within draft structure plans by DPI and the City of Wanneroo. Although the central third and northern quarter of Zone 4 still remains covered in native vegetation and is shown as >60% 'core' landscape in Figure 6, it is all proposed for clearing for urban development. The majority of remnant bushland is privately owned, zoned in the MRS for future urban and shown in draft structure plans for development.

Some gaps in connectivity were obvious along the coast in the City of Wanneroo and the City of Joondalup and these may require revegetation. It is also recognised that it may be difficult to get 500m wide linkages in this zone. There are also great challenges in achieving linkages through existing and future planned urban areas in the City of Wanneroo and offsetting or land-swapping towards these targets may be required.

Strengths	**Challenges**
Major remnants of vegetation in Bush Forever and DEC estate are present and provide a number of strong existing links.	It may be very difficult to achieve 500 m links in much of the intervening area and very costly to revegetate as it is mostly land on private property and mostly urban.
A north-south coastal link is created to ensure protection of this most highly threatened vegetation complex.	Strong development pressure on the coast may make this a difficult target to meet in some areas. Especially as much has also been zoned for future urban.

Zone 4 is on Quindalup and Spearwood Dune systems, which are under-represented in the conservation estate.	Coastal land and western suburban land is of high value for urban development.

Zone 5 Linkages

Zones 5 is a relatively narrow strip of predominantly private property along the coast (north of Two Rocks), then east along the southern bank of the Moore River and the Gingin Brook, and south along the western side of Brand Highway, Chandala Brook and Ellen Brook to south of Muchea (Figures 7 and 8). Zone 5 is extensively cleared of native vegetation for rural development, except for the north-western edge associated with the proposed Wilbinga reserve complex (Wilbinga-Caraban Bush Forever site no. 406).

This predominantly cleared, agricultural zone adjoins the 'core' arc on the Gnangara groundwater system of >60% remnant bushland in GSS Zone 6. The only large area in Zone 5 of core bushland in the landscape is associated with the proposed Wilbinga reserve complex. This area was identified in the 1970's in the Red Book (Environmental Protection Authority 1975) and again in Bush Forever as site no. 406 (Government of Western Australia 2000).

Along the northern boundary of the GSS study area is the Moore River and Gingin Brook. The Moore River is one of the most natural estuaries remaining on the Swan Coastal Plain, with the most northern areas of Tuart woodland found along its banks. The protection of remnant vegetation along its banks and that of the banks of the Gingin Brook would be a major conservation objective. However, this land is also of high rural value and potentially high value for development.

There are four north-south ecological linkages proposed in the western part of Zone 5, linking the core arc in Zone 6, to the Moore River and a number of 'core' bushland remnants north of the GSS boundary (Figure 7). The first is along the coast between the proposed Wilbinga Reserve and the mouth of the Moore River. This could be a key linkage between Wilbinga, the mouth of the Moore River and the Moore River linkage. However, a long standing urban development has been proposed for the southern side of the mouth of the Moore River estuary (although it is currently not supported by the State Government).

The other three proposed linkages require further field assessment and community negotiation.

The north-eastern part of Zone 5 sits above a portion of the hydrological window connecting the Superficial aquifer with the two deeper Leederville and Yarragadee aquifers (Government of Western Australia 2000). It is currently not included in the Priority 1 catchment protection for the Gnangara Mound however the draft GSS proposes it be protected under special planning legislation.

In the north-east part of the GSS study area and Zone 5, there were a number of challenges to the establishment of new linkages (Figure 8). This area is highly cleared and also falls outside the Bush Forever study and other metropolitan planning and conservation schemes. There are only two areas of formal reserve near to the Darling Range (Boonanarring Nature Reserve and an un-named Nature Reserve) and only a few opportunities now remain to establish linkages with bushland on the scarp. Only two major opportunities for hills linkages remain and these are highlighted on Figure 8. Further work is needed to resolve the exact nature, tenure and quality of bushland in these patches and they have currently been designated as conceptual linkage areas. Both these linkages are deemed as critical and urgent in being the only remaining opportunities to include remnant bushland in major linkages to >60% 'core' areas in the Darling Range.

Strengths	**Challenges**
The last opportunity on the Swan Coastal Plain for a 'coast to scarp' linkage exists at Wilbinga-Caraban in Zone 5. This linkage has strong support and MRS endorsement.	Additional coastal roads and urban development south of the mouth of the Moore River may impact on the proposed Wilbinga reserve.
The establishment of strong linkages north across the Moore River and east to the Darling Range will be very important for maintaining biodiversity. These present the last major opportunities in these cleared landscapes to incorporate some high quality remnant vegetation.	Much of the conceptual linkage areas for the Darling Range are on private property or of unknown tenure. Negotiation and compensation may be required to acquire and manage land as part of these linkages.

Moore River, Gingin Brook and Ellen Brook provide excellent opportunities for an east-west and north-south linkage and this will benefit riparian flora and fauna.	Acquisition and/or reservation of land along the river and brooks will be expensive and difficult (most is outside the MRS). There will also be difficulties in achieving targets as most of this is on private land.
The Quindalup Dune, riverine soils and eastern side of the SCP vegetation complexes are all under-represented in the conservation estate.	

Zone 6 Linkages

Zones 6 is mainly on Crown land forming the top half of the proposed Gnangara Park including large areas of State forest, Yanchep National Park, Yeal Nature Reserve and Unallocated Crown Land managed by RAAF (Sonneman and Brown 2008) (Figure 3). Zone 6 includes the bulk of the Pinjar and Yanchep pine plantations.

Fortunately most of this Crown Land in Zone 6 makes up a large section of the 'core' arc of *Banksia* woodland across the top of the Gnangara groundwater system predominantly within the Shire of Gingin (Figures 7 and 8). Therefore there is no need for additional 'Conceptual Linkages' through this zone except for the previously cleared ex-pine plantation areas. Zone 6 covers most of the northern section of the Gnangara groundwater system including a portion of the hydrological window connecting the Superficial aquifer with the two deeper Leederville and Yarragadee aquifers (Government of Western Australia 2009).

The northern boundary for Bush Forever and the Perth Biodiversity Plan studies cut through the south-western portion of Zone 6 (Figure 8), so there are few linkages proposed by previous studies. In addition, there has not been a detailed documentation of the regionally important bushland north of the Bush Forever study boundary and the Metropolitan Region Scheme area. Even without such a study, it is clear that the large, continuous blocks of bushland are regionally important and provide resilience for the flora, fauna and ecological communities on the Gnangara groundwater system and northern Swan Coastal Plain.

A complementary study of potential ecological linkages with in the 23 000ha pine plantations on the Gnangara groundwater system has been completed (Brown *et al.* in prep.). In Zone 6 this includes the bulk of the Pinjar and Yanchep Plantations across the GSS East Yanchep sub-area. A total of six ecological linkages were identified totalling 9 624ha (55% of the total plantation area in this zone) with 2 405ha (20%) existing bushland. These ex-pine linkages contain a number of remnants of native vegetation which have formed the backbone of proposed linkages. However, these linkages are only preliminary as no systematic work has been undertaken to evaluate the native understorey and overstorey under the pine plantation. This work will be undertaken in 2009 and the linkages then revised.

Strengths	**Challenges**
The large areas of core landscape through Zone 6 (Gnangara Park and Yanchep National Park) provide a focus for connectivity in all directions (coast-hills and north-south).	There are alternative land uses proposed for the Pinjar and Yanchep pine plantation areas including replanting to pine, employment generating employment and some horticulture.
Post-pine revegetation will create a strategic and strong linkage in a currently unconnected area. These are all on Crown land managed by the DEC and on Spearwood Dune systems not well protected on the Swan Coastal Plain.	A large amount of revegetation in former pine plantations is required. This will take active management, a large expenditure and many years to achieve suitable habitat. The linkages are all preliminary and will need to be reviewed.
The bushland in Zone 6 protects the top of the Gnangara groundwater system and windows into the deeper, confined aquifers. The whole area is in Priority 1 catchment protection.	

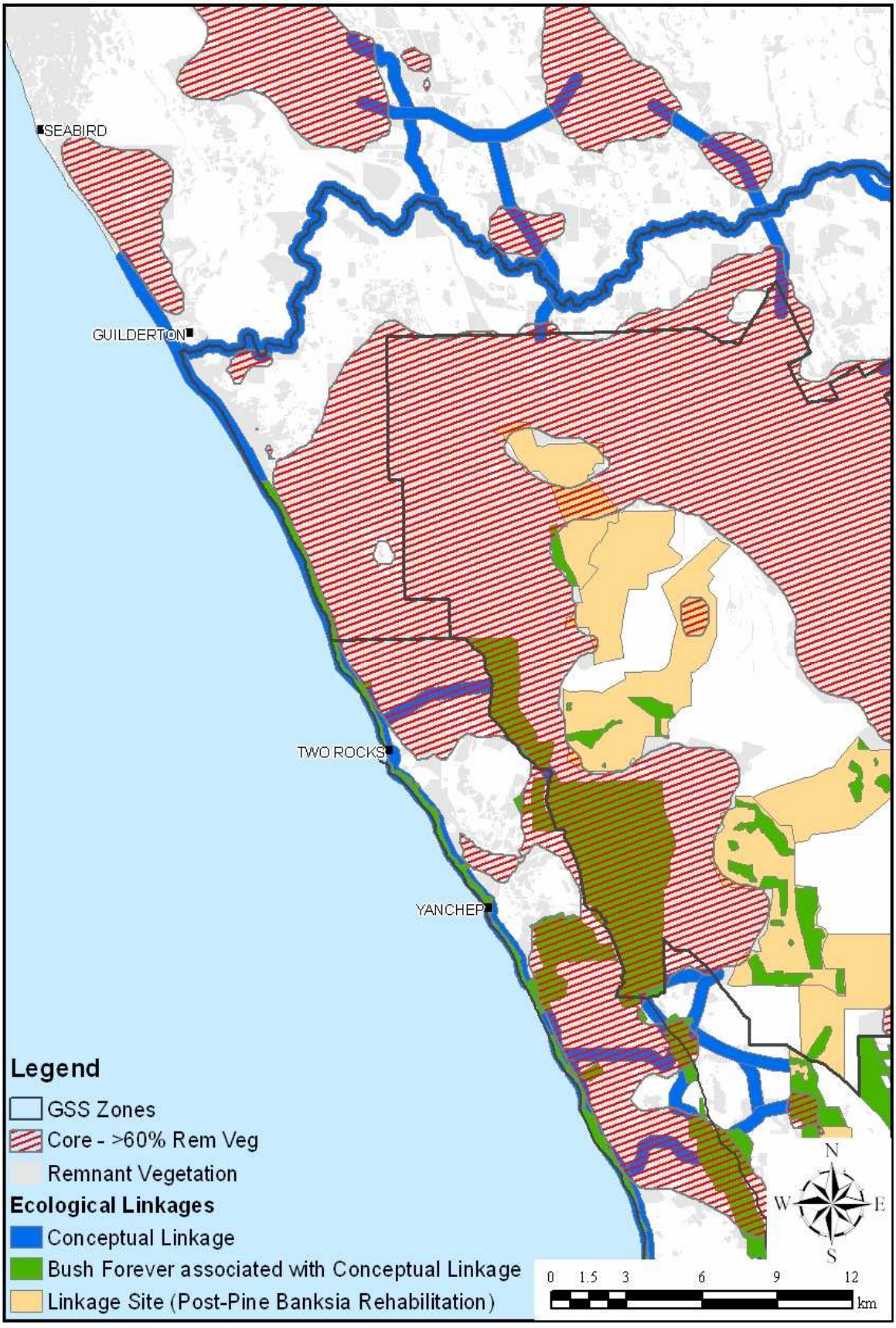

Figure 7: Zone 5 and 6 (north-west)

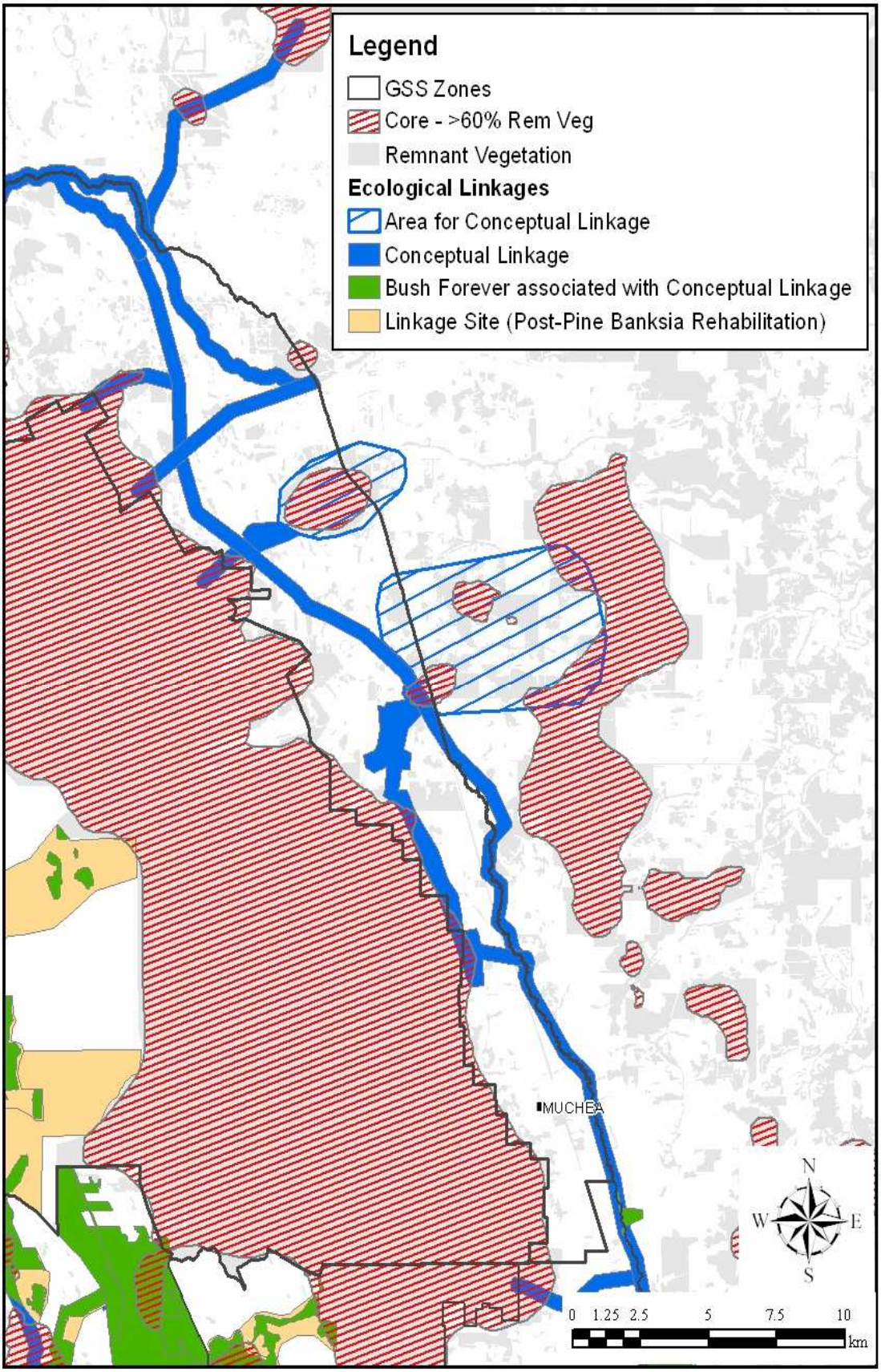

Figure 8: Zones 5 and 6 (north-east)

Zone 7 Linkages

Zone 7 comprises the most built up part of metropolitan Perth north of the Swan River and thus faces the greatest challenges for creating bushland linkages of the suggested width. Therefore, the GSS has not added to the existing linkages through this area already proposed by Bush Forever (Government of Western Australia 2000) and the Perth Biodiversity Plan (Del Marco *et al.* 2004). This zone has only two small 'core' areas with >60% remnant vegetation in the existing landscape, which are associated with Bold Park and Kings Park (Figure 9).

Fortunately a number of large blocks of native vegetation remain in Zone 7, including Bold Park, Kings Park, Trigg Bushland and Yellagonga Regional Park. Vegetation along the Swan River, along the coastline and in large bushland reserves, form essential parts of the linkages in Zone 7. Focusing linkages around these major areas of bushland not only improves the viability of links for fauna populations but emphasises the critical importance of these remnants in the Perth region. It is essential that future efforts are put into retaining and managing the existing remnant bushland in Zone 7 rather than aiming to revegetate the urbanised portion of the metropolitan area which would be an unrealistic and expensive target.

Coastal linkages in this region are a priority for nature conservation as a high proportion of these vegetation complexes have been cleared for urban development. However, a few areas of coastal vegetation remain and many that do are under development pressure. The objective of achieving a north-south coastal link is an important one, but it will require significant revegetation and interaction with urban residents to achieve its goals.

Strengths	**Challenges**
Existing riparian vegetation along the Swan River provides an excellent east-west link and future potential for revegetation. The Swan River is managed by a number of local governments and agencies, coordinated through the Swan River Trust.	Multiple landholders, high land prices and high human visitation are a challenge to using the river as an ecological linkage.
Major remnants of vegetation are connected to enhance ecological function. Utilising these in linkages also reduces the need for revegetation.	It may be almost impossible to achieve 500m links in much of the intervening area and very costly to revegetate as most land is high value, urban private property.
A north-south coastal link is a key priority through Zone 7 to facilitate north-south fauna movement and to ensure protection of this most highly threatened vegetation complex.	Strong development pressure on the coast may make this a difficult target to meet. Climate change impacts on coastlines are a further threat.

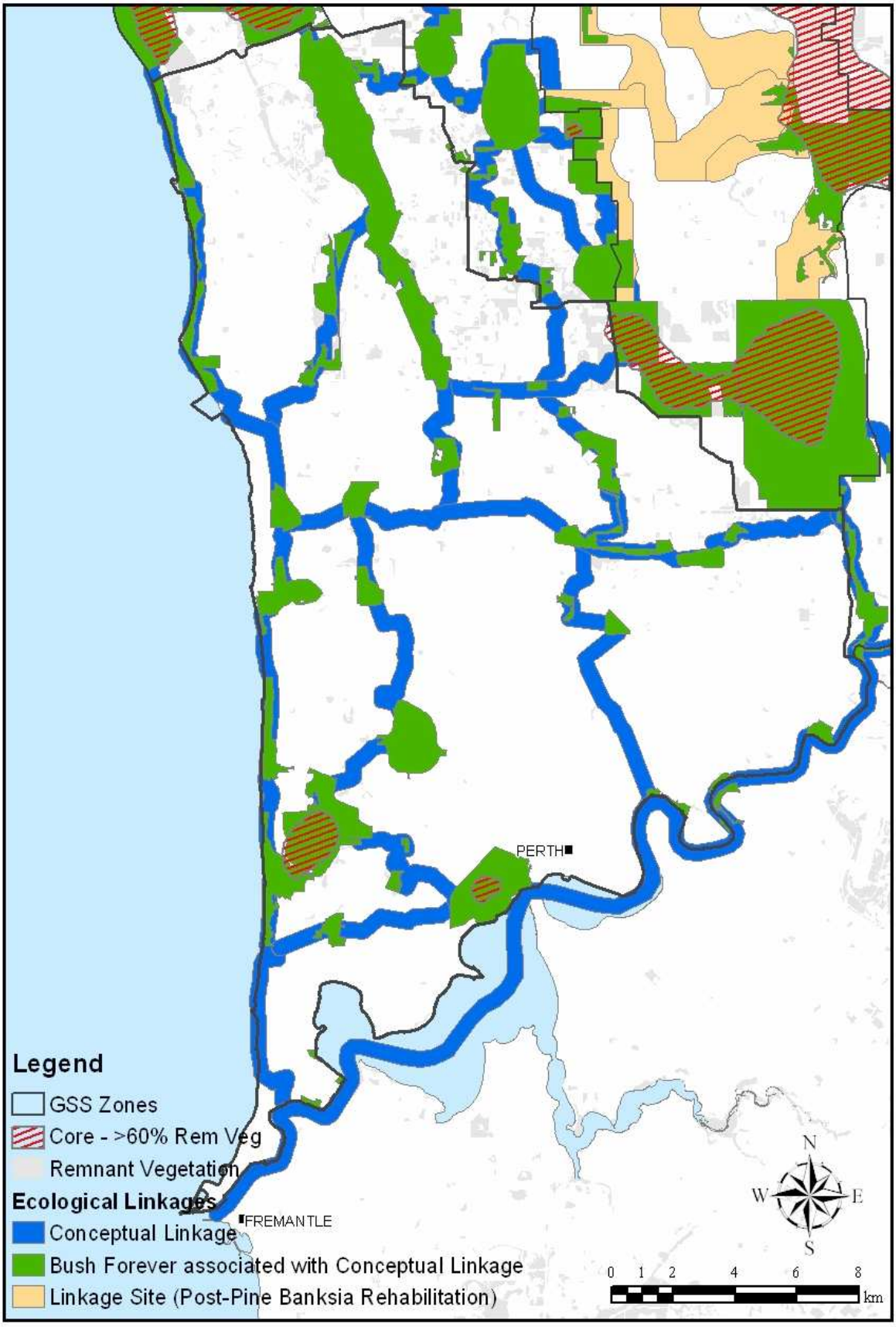

Figure 9: Zone 7

Conclusion

With the aim of creating landscape level connectivity, regional ecological linkages have been delineated for the GSS study area. A fundamental change proposed here, compared to the ecological linkage framework proposed by Bush Forever and the Perth Biodiversity Plan, is the use of the notion that landscapes retaining greater than 60% native vegetation cover already have adequate connectivity and so do not require additional ecological linkages within them. The ecological linkages therefore link vegetated landscape units and are located through fragmented parts of the landscape. No additions to the linkages already proposed for the southern portion of the study area have been made as this is the most built up part of metropolitan Perth north of the Swan River, and thus faces the greatest challenges for creating bushland linkages of the suggested width.

The concept of Ecological Linkages was embraced by the general public and stakeholders, who also recognised the challenges involved. Whilst some linkages are only conceptual, they provide the basis for further work which will enable their on-ground location to be determined and for their final implementation. This will require acquisition, covenants with land owners and possibly rehabilitation. Where possible any remnant vegetation or local natural areas should be retained in their entirety, rather than just the portion of these areas which fall within the mapped 500m wide linkage.

Recommendations

1. This report supports the recommendations and ecological linkages through the ex-pine plantations on State forest proposed by (Brown *et al.* in prep.).
2. The 500m wide ‘Conceptual Linkages’ (blue lines in Figures 2 and 3) will need to be assessed individually to determine the exact on-ground boundaries, based on remnant vegetation, land use and availability for purchase. They will require acquisition, covenants with land owners and generally, rehabilitation.
3. The 500m wide ‘Conceptual Linkages’ (blue lines in Figures 2 and 3) should not be used as definite boundaries where everything that falls outside the line can be considered to be cleared of remnant vegetation.

4. There is a need to initiate an active rehabilitation program within Whiteman Park (GSS Zone 1) and other degraded Bush Forever sites to build up the functionality of the designated linkages and revegetate the degraded patches of land within the 'core' areas and linkages.

5. There is currently a gap in linkages across the eastern side of the GSS study area (GSS Zones 3 and 5) and overall there are very few areas that have the potential to connect the coastal plain with the Darling Range. These linkages are thus seen as of high importance for further planning, refinement and protection.

6. There are great challenges in achieving linkages through existing and future planned urban areas in the City of Wanneroo and the City of Swan (GSS Zones 2, 3 and 4). New ecological linkages are proposed by this study; however these linkages require urgent assessment to determine their exact boundaries and planning protection due to the immanent urban development. This will require input from State planners, the Cities of Wanneroo and Swan and the community.

7. The major north-south ecological linkage through Yellagonga Regional Park, Neerabup National Park and Yanchep National Park needs small additions to the conservation estate to develop it into a continuous bushland and wetland linkage.

8. In the northern third of the GSS study area, north of the Bush Forever study boundary and the Metropolitan Region Scheme area, no detailed study of regionally important bushland has been conducted. The GSS strongly supports the completion of a regional bushland assessment over this area similar to that completed by Bush Forever over the Perth MRS area.

9. The Moore River is one of the most natural estuaries remaining on the Swan Coastal Plain, with the most northern areas of Tuart woodland found along its banks. The protection of remnant vegetation along its banks, and that of the banks of the Gingin Brook, is a major conservation objective.

10. Offsetting or land-swapping towards the implementation of the regional ecological linkage targets outlined in this paper may be required.

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Appendix 1 – Full report on Community Workshops concerning Ecological Linkages in the GSS.

Gnangara Sustainability Strategy

Ecological Linkages Community Workshop Series

Analysis Report

for

Department of Environment and Conservation and Swan Catchment Council

September 2008

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Version	Date	Prepared by	Reviewed by
V1	5th August 2008	Lucy Sands	R Davis, D Witham
V2	8th September 2008	Lucy Sands	

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1. EXECUTIVE SUMMARY

As part of the Ecological Linkages Project, which is contributing to the development of the Gnangara Sustainability Strategy, a series of community workshops were held during June 2008 with the purpose of informing the community of the Project and associated research.

In addition, the Department of Environment and Conservation were interested in obtaining community input into the location of regional ecological linkages and the threats to their long term viability. Participants were also asked to contribute their ideas as to what needs to be done to protect and improve these linkages.

The responses obtained during the workshop sessions indicated that those attending appeared to have a clear understanding of what constitutes a priority regional ecological linkage and the importance of associated wetlands, waterways and bushland.

Many participants felt that the security and long term protection of these ecological linkages were threatened by clearing associated with urbanisation and private land use. Additional threats associated with human activities and proximity to urban areas were also of concern to participants (i.e. feral species, fire, fragmentation, roads and railways).

To address these threats, the majority of participants felt that the community needed to be aware of the benefits (both direct and indirect) provided by these linkages and associated bushland. Revegetation and rehabilitation using endemic species and greater use of understorey species were also a priority for participants, seen as important in improving the health of existing linkages and bushland.

Adequate policy and regulation to protect linkages was considered important in ensuring the long-term security and protection of these assets from clearing associated with urbanisation and private land use.

The information obtained from the community workshops will be considered and incorporated into the Ecological Linkages Project. Additional community consultation may be required as part of this project, which is likely to be restricted to community stakeholders.

2. WORKSHOP METHODOLOGY

An invitation to attend the workshops was circulated to interested community members through established email networks. Three workshops were held in the northern suburbs, located at;

- Chittering (17th June 2008)
- Midland (19th June 2008)
- Wanneroo (24th June 2008)

The format of each workshop was identical. A copy of the agenda may be found in Appendix 1. At the commencement of each workshop, two presentations were made to provide participants with background information to assist them in providing informed decisions as part of the workshop session.

The first presentation included an overview of the Gnangara Sustainability Strategy and the Ecological Linkages Project. This included background information on the purpose and extent of the proposed Gnangara Park and general information on regional ecological linkages.

Following this, Dr. Rob Davis from the University of Western Australia presented his findings from recent research on ecological linkage requirements for birds and guidelines for ecological linkages.

Following the presentations, participants were asked to contribute information in a workshop session. The facilitated workshop session required attendees to prioritise regional ecological linkages in their area. This was initially performed on individual maps which could be cross referenced with aerial photography. Then participants confirmed their top three linkages on one map placed at the front of the room. The priority north-south and east-west linkages were identified by the facilitator.

Once the priority regional ecological linkages for the area were identified, participants were asked to respond to two focus questions;

- What are the issues surrounding these ecological linkages?; and
- What needs to be done to improve or maintain these ecological linkages?

Participants considered their responses individually and placed them on sticky notes which they then placed under each question at the front of the room. These responses were discussed by the facilitator and are presented in Section 3 of this report.

Following the workshop session, participants were informed that the information they provided would be analysed and used to incorporate community opinions into the Ecological Linkages Project. It was mentioned that an additional round of stakeholder consultation may be undertaken as part of this project.

3. WORKSHOP RESULTS

The following results provide a description of the priority regional ecological linkages identified by the community at each workshop and a summary of the responses to the focus questions, which have been briefly interpreted in Section 4. There were 49 people who attended the workshops. A list of participants may be found in Appendix 2. A list of participant's comments and suggestions for each workshop may be found in Appendix 3.

3.1 PRIORITY REGIONAL ECOLOGICAL LINKAGES

The following linkages were identified as being the most important to workshop participants;

Chittering

East-West

1. Gingin Brook
2. Corridor connecting remnant vegetation north of Neaves Road with Darling Scarp vegetation

North-South

1. Corridor following the Great Northern Highway and Brand Highway to Gingin Brook
2. Corridor following the Great Northern Highway and Brand Highway and then branching off in a North-East direction through remnant vegetation with >60% cover
3. Corridor connecting Bindoon down to the Darling Scarp

Midland

East-West

1. Corridor connecting Swan River to Lake Jandabup (through Whiteman Park and the western edge of the pine plantation
2. Corridor connecting Walyunga National Park with Lake Jandabup (through the pine plantation along Warbrook Road)

North-South

1. Corridor connecting Swan River to Neaves Road

Wanneroo

East-West

1. Corridor connecting Lake Jandabup with Burns Beach (crossing Lake Joondalup)
2. Corridor through Yanchep National Park (connecting Wanneroo Road with coastline)

North-South

1. Corridor following Yellagonga National Park to Wilbinga
2. Corridor following the coastline

3.2 ISSUES IMPACTING ECOLOGICAL LINKAGES

Table 1 outlines the issues that participants believe adversely impact on regional ecological linkages. There were 99 issues listed by participants from all three workshops, with most participants choosing to list more than one issue.

Urbanisation was the most commonly listed issue, listed 21 times. Some participants chose to elaborate on this issue, indicating that developers were seeking to develop environmentally constrained land in the absence of easily developable land and that developers and the Department of Planning and Infrastructure did not appreciate the indirect services provided by biodiversity (i.e. air quality, water quality and recreation).

Feral species (including flora and fauna), was the second highest ranked issue, listed nine times. This was followed by private land ownership, which was mentioned at the Chittering and Wanneroo workshops only. Participants felt that private land ownership was a significant issue (related to land development) and suggested that private ownership compromises the long term viability of many of these corridors.

Table 1. Issues participants listed as impacting on regional ecological linkages

Issue	Chittering (n=34)	Midland (n=35)	Wanneroo (n=30)	Total (n=99)
Urbanisation/land development	10	3	8	21
Feral species	1	5	3	9
Private land ownership	4		4	8
Long term management and viability	4	2	1	7
Fire	3	3		6
Fragmentation	1	1	4	6
Roads/railway	2	3		5
Recreation		5		5
Water quality and quantity	1	1	3	5
Vegetation condition	4	1		5
Lack of community understanding			3	3
Inadequate legislative protection	1		2	3
Lack of long term funding	1	1	1	3
Rubbish dumping		2		2
Dieback and disease		2		2
Width of linkages		2		2
Lack of indigenous involvement in planning		2		2
Land degradation (i.e. erosion, salinity, acid sulfate soils)		2		2
Industry impacts	1			1
Number of linkages	1			1
Edge effects			1	1

3.3 SUGGESTED ACTIONS TO IMPROVE LINKAGES

Participants were asked to suggest what needs to be done to improve or maintain these ecological linkages. There were 98 suggestions provided by participants from all three workshops, with most participants listing more than one suggestion.

The most commonly made suggestion was for the responsible agencies to undertake community education and awareness, so that the broader community were aware of the direct and indirect benefits of linkages. Participants suggested involving friends of groups to care for the linkage in conjunction with youth groups, schools and other community associations.

Restoration and revegetation was ranked equally with adequate policy and legislation (with the aim of ensuring long-term protection), receiving 14 comments. In regards to restoration and revegetation, there were suggestions to improve vegetation cover to achieve a minimum of 60% cover by undertaking infill plantings, using endemic species. There were also calls for greater use of understorey species in revegetation projects. Participants were eager to see native species planted soon after the pines were harvested so the area could provide biodiversity values.

Participants felt strongly about the use of policies and legislation to ensure protection of linkages. It was suggested that government should introduced a tiered planning framework where ecological linkages and reserves were protected by Statements of Planning Policy (SPPs) down to local planning policies at local government level. A policy on tracks and trails was also suggested to ensure adverse impacts were minimised by activities in these areas.

Table 2. Actions suggested by participants to improve regional ecological linkages

Action	Chittering (n=30)	Midland (n=25)	Wanneroo (n=42)	Total (n=97)
Community education and awareness	5	4	13	22
Restoration and revegetation	4	4	6	14
Develop adequate policy and legislation to ensure long-term protection	4	6	4	14
Feral species control	4	2	3	9
Secure long-term funding		3	5	8
Improved consultation and collaboration with stakeholders	6			6
Manage access	2	3	1	6
Undertake detailed resource assessments and provide information and data to stakeholders			4	4
Water resource management			4	4
Fire management	2			2
Introduce program that secures conservation of land in private ownership (i.e. Wetland Watch, covenants)		1	1	2
Control vandals	1			1
Maintain land productivity	1			1
Ensure linkages connect nature reserves that offer long term protection	1			1

Encourage innovations to provide safe travel for fauna (i.e. underpasses)			1	1
Fauna management		1		1
Heritage listing		1		1

4. INTERPRETATION OF RESULTS

Participants appeared to have a clear understanding of what constitutes a priority regional ecological linkage, with many selecting existing linkages that traversed wetlands and waterways. Many also had a desire for linkages to connect bushland that had greater than 60% remnant vegetation cover, possibly influenced by the information presented to participants that emphasised the importance of this criteria.

A considerable number of participants were from local friends groups, so in some instances prioritisation reflected a desire to 'protect their own patch'. However, it is likely that these friends groups would have an interest in maintaining these linkages, which must be considered when determining the most appropriate linkages to retain.

Urbanisation was the highest rated issue and consequently, participants rated adequate policy and legislation as a high priority action to ensure the protection from urbanisation and land clearing.

Similarly, private land tenure was seen as a potential threat due to the unsecured nature of some linkages. However, participants were generally unsure of how to address this potential threat. Those that did provided informed recommendations, such as the use of covenants or adapting programs such as Wetland Watch, which aims to conserve wetlands and bushland through a more collaborative approach with land holders.

A lack of community understanding of ecological linkages was mentioned as an issue at the Wanneroo workshop, but interestingly it did not rate highly compared to other issues. However, community education and awareness was the highest priority action. It could be assumed that participants felt the lack of community understanding was the underlying reason for many of the other issues, such as feral species, fire, disease and rubbish dumping.

Restoration and revegetation was a high priority action, with participants commenting that existing linkages should be retained and improved to ensure they supported greater than 60% remnant vegetation cover. There was a desire to involve and inform community groups of this work, which could partially achieve the suggested action of improved stakeholder consultation and collaboration, which rated highly at the Midland workshop.

In summary, the security of these linkages was an overwhelming concern to participants. In general, participants felt that if the linkages could be secured and protected from clearing then they would be more viable and attract funding for collaborative projects for improvement and maintenance.

Appendix 1 Workshop Agenda

Ecological Linkages Project

Community Workshop Series

Agenda

Purpose: The workshop aims to;

- update and inform as this is the first round of consultation with the community on the ecological linkages project
- identify landscapes with 60% vegetation in the Ellen Brook Catchment
- prioritise the key regional ecological linkages (in their local area)
- identify key actions to enable ecological linkages to be maintained or improved

Facilitator

Lucy Sands, BlueSands Environmental

4:00 – 4:15pm	**Registration and light supper**
4:15pm	**Welcome and introduction**
4:20pm	**Presentations** • Gnangara Sustainability Strategy, Gnangara Park and regional ecological linkages, Mr Paul Brown (DEC) • Ecological linkages for birds, Dr Robert Davis (University of Western Australia)
5:00pm	**Workshop session** Participants will be presented with maps showing key regional ecological linkages in their local area and will be asked to prioritise them. Following this, participants will be asked to consider the following focus questions: • What are the issues surrounding these ecological linkages (i.e. land tenure, recreational use) • What needs to be done to improve or maintain these ecological linkages?
6:00pm	**Group discussion**
6:25pm	**Conclusion**

Outcomes: The community workshops will assist in:

- developing achievable actions for the community and Government that will result in improvements to regional ecological linkages
- incorporate the information into the Gnangara Sustainability Strategy decision making process

Appendix 2 List of workshop participants

Chittering workshop participants

Azar Awang	Shire of Chittering
Keith Burgemeister	Shire of Chittering
Doreen Mackie	Shire of Chittering
Alison Nannup	South West Aboriginal Land & Sea Council
Phillipa Schmuker	South West Aboriginal Land & Sea Council
Andrew Del Marco	Ironbark Environmental
Kevin Smith	Community - Upper Swan
Judith Bell	Community - Bullsbrook NLC
Val Pate	Community - Chittering Landcare
Sandy Pate	Community - Chittering Landcare
Ann Graham	Community - Chittering Landcare
Steve Valance	Community - Chittering Landcare
Robert Hawes	Community - Chittering Landcare, EBIC, Wannamal LCDC
Karen Warner	Community - Chittering Landcare
Peta Rakela	Community - Chittering Landcare
Sue Tough	Community - Chittering Landcare
Phillip Surtees	WA Farmers Federation
Laurie Bush	WA Farmers Federation / Gingin Property Rights
Renae Thorpe	Chittering Landcare Centre
Rosanna Hindmarsh	Chittering Landcare Centre
Katerina Neve	Chittering Landcare Centre
Amy Salmon	Chittering Landcare Centre
Paul Brown	DEC
Janine Kinloch	DEC
Rob Davis	UWA
Danielle Witham	SCC

Midland workshop participants

Rod Henderson	Community
John Williams	Community
Sue Hurt	Community
John Sutherland	Community
Cheryl Anne McCann	SCC
Donald Yates	Bassendean Preservation Group
Kelly Norris	City of Swan
Frank Alban	Community
Hazel Dempster	Community

Tracy Sonneman	DEC
Rob Davis	UWA
Danielle Witham	SCC

Wanneroo workshop participants

Phil Thompson	City of Wanneroo
Jacqueline Giles	City of Wanneroo
Nicola Hoey	City of Wanneroo
Marilyn Zakrevsky	Community
Ken Zakrevsky	Community
John Corbellini	City of Wanneroo
Peter Bombak	Yellagonga Community Advisory Committee
John Boonzaier	Environmental Advisory Committee
Kathy Peek	Two Rocks
Barbara Bennett	Two Rocks
Martina Thomas	Community
Lara O'Neill	City of Wanneroo
David Goodall	Edith Cowan University
Geoffrey Curtis	Environmental Advisory Committee
Robert Susac	Environmental Advisory Committee
Rae Kolb	Community
Rhonda Hardy	City of Joondalup
Janine Kinloch	DEC
Tracy Sonneman	DEC
Rob Davis	UWA
Danielle Witham	SCC

Appendix 3 Participants comments and suggestions

Chittering Workshop

Question: What are the issues surrounding these ecological linkages?

Issue	Comments
Development	• Population growth will increase the pressure to clear land for subdivision • Need to select locations of ecological linkages according to future planning for housing development • Developers do not respect the environment and should be required to reserve land for linkages
Vegetation condition	• Vegetation condition and quality is uncertain along linkages • Degradation of remnant vegetation reduces linkage effectiveness • Dieback and disease
Fire	• Inappropriate fire regimes
Roads/railway	• Rail and highway access • Increased traffic
Private land	• Present private land use • Conflict with private property owners over restrictions associated with linkages • Rural pursuits (grazing, cropping) can be poorly managed
Industry	• Extractive industry (basic raw materials) taking precedence
Feral animals	
Fragmentation	• Isolating animals e.g. Kangaroos
Access to water	• Access to water all year round

Question: What needs to be done to improve or maintain these ecological linkages?

Suggestions for improvements or maintenance	Comments
Consultation and collaboration	• Require consultation between land care experts, scientists, shire and developers (knowledge of subdivisions, main roads, public open spaces) • Aboriginal consultation with South West Aboriginal Land and Sea Council • Maintain ecological linkages by working with the Caring for Country Projects (Australian Government) • Define early the responsibility for maintenance
Education and awareness	• Require better community understanding of linkages • Advice, financial assistance, fencing • Identify benefits to landowners, planners and ecotourists
Restoration/ revegetation	• Identification of flora and fauna already present • Maintenance of species distribution • Infill plantings • To gain 60% cover of vegetation through ecological linkages carry out endemic seed collection (locally sourced)

Suggestions for improvements or maintenance	Comments
Feral species control	• Control weeds and vermin movement • Define early the responsibility for weed control
Policy and Legislation	• Requires statutory backing to ensure conservation/protection of corridors • Local planning policies to integrate linkages • Policy on tracks and trails
Fire management	• Strategic burning • Fire protection of surrounding farm land
Access control	• Limited vehicle access
Control of vandals	
Maintain land productivity	
Connect nature reserves, parks with the corridors	

Midland Workshop

Question: What are the issues surrounding these ecological linkages?

Issue	Comments
Recreation (especially off road vehicles)	• Illegal access by 4WD and trail bikes • Managed recreation – trail bikes, horse riding links, tracks and trails • Limit access of vehicles. Causes damage to soil crust.
Weeds	• Arum lilly, swan plant
Fire	
Development /Urbanisation	
Roads/ Railway	• North/south road structures isolating Whiteman Park from the hills i.e. Perth to Darwin Hwy, Henley Brook Avenue, Great Northern Hwy, West Swan Road and Train Route. No viable method available to cross these.
Rubbish dumping	
Dieback	
Width of corridors	
Aboriginal involvement	• Cultural issues, planning management • Integration of aboriginal sites into corridors • Integration of aboriginal cultural knowledge into corridor positioning
Feral animals	• Urban corridor development impact from domestic pets and released exotic birds
Land degradation	• erosion • acid sulfate soils • salinity

Issue	Comments
Fragmented land tenure	
Funding issues	
Long term viability	• Access to water and remove all contaminants • Contingencies for native vegetation on private property
Fauna species management	• Cull Caversham Airbase, Black Glove Wallabies.
Water – reduction of groundwater levels	

Question: What needs to be done to improve or maintain these ecological linkages?

Suggestions for improvements or maintenance	Comments
Community education and involvement	• Education at all levels. Mass media communication • Develop 'Friends of' groups for each link • Integrate aboriginal environmental knowledge when planning and managing ecological linkages
Restoration/ revegetation	• Provenance species • Replant vegetation specific to corridor • Maintain buffer to max 500 meters
Policy and legislation	• Legislation to protect areas such as Draft Perth Hills Planning Bill • Establish workable management arrangements • Significant funding is required and longevity of funding • Management Plans to remain viable
Roads and access management	• Less north south roads -consolidate them and manage the issues • Closure of some access to prevent further damage • Need to fence some areas
Control feral species	• Control domestic animals – introduce curfews etc. • Displacement of kangaroos
Heritage listing of strategic environmental locations	• E.g. Bells Rapids.
Acquire key linkages on private land	

Wanneroo Workshop

Question: What are the issues surrounding these ecological linkages?

Issue	Comments
Development and planning	• Development of fragile land (i.e. karst – Yanchep caves). • New buildings should be positively redirected away from ecologically sensitive areas • Future land zoning under MRS • The difference between local/ regional and urban/rural linkages need to be recognised and planned for appropriately • DPI ignore DEC. Planners don't value bush and cannot see it is needed for air quality, passive recreation and biodiversity • Require new developments to landscape with local native plants • In existing suburbs try to link open areas, parks, lakes etc.
Long-term management	• Will they remain ecological linkages forever? • How can these linkages be sustained over a 100 year period? • Linkages may not provide for all life history requirements. • Long-term commitment to the protection of natural areas within the linkage
Private land holders	• Land tenure • Competing property uses • Private property development and clearing
Public perception	• Public perception of what linkages are/what they do • Lack of majority community interest • How do you educate the politicians, developers and general public that linkages are important?
Feral species	• Mobile predators • Weed invasion • Ridding the weeds and plant local indigenous species
Water quality and quantity	• Upper catchment contamination/interception • Water quality of wetlands • Drying climate, decreasing water
Fragmentation	• Safe travel for fauna between habitats • Support migration – birds, raptors, mammals, reptiles etc. • Lack of habitat • Fragmented habitat – lack of sufficient connections to other habitat
Legislation	• Legislation needed to ensure the priority 'bush forever/ecological linkages' cannot be usurped by agencies and developers • Legislation inadequate and not enforced
Funding	
Edge effects	

Question: What needs to be done to improve or maintain these ecological linkages?

Suggestions for improvements or maintenance	Comments
Community education and involvement	• Community education and awareness of the benefits and values of linkages • Continue long-term funding for local nature spot program (not just one year) • Development of a specific on-ground urban linkage program to reconnect people to the environment

Suggestions for improvements or maintenance	**Comments**
	• Involve youth, schools, church, associations etc. • Immigrants don't understand the native vegetation • A network of people to keep watch on having healthy linkages • Instil a spirit of custodianship • Get landholders involved in maintaining ecological linkages • Get councillors to act responsibly • Provisions for consultation with communities must be addressed and acted on and not just noted and never referred to again • Publicise goals achieved
Restoration/ revegetation	• Increase funding to revegetation programs • Restore understorey to remnant vegetation areas • Increase vegetation in major roads • Establish native bush throughout pine plantations as quickly as possible after harvest
Funding for ongoing maintenance	• Sufficient funding for ongoing maintenance and protection e.g. fencing to keep out vehicles • Consistent approach to maintenance by government agencies
Feral species control	• Feral animal control • Pet curfews • Weed control strategies
Policy and legislation	• Adequate legislative protection • Have areas gazetted for protection • Development of a tiered planning framework supported by all levels of government so that it can be implemented effectively
Information and assessment	• Detailed map – local government areas, private, state remnant vegetation areas • Biological inventory • Geotechnical and speleological assessments • Monitoring process required to publicise goals and percentages achieved by
Water resource management	• Regulations to improve water quality and community education • Water restrictions and innovations • Regular construction of water features – dams, ponds etc.
Innovations to improve safe travel for fauna (underpass retrofits etc.)	
Develop key guidelines for proponents	
Land covenants	
Access control	