SouthmetroConnect

Roe Highway Extension

Public Environmental Review

20 June 2011

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GOVERNMENT OF WESTERN AUSTRALIA

mainroads WESTERN AUSTRALIA

AECOM

Seeking **collaborative solutions** for extending Roe Highway

Project Brief

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South Metro Connect is an integrated project team comprising personnel from Main Roads Western Australia and AECOM. The team was created for the development phase of the Roe Highway Extension project. Its primary objective is to work collaboratively with specialist consultants, stakeholders and regulatory authorities to develop an environmentally, socially and economically acceptable project design in order to obtain relevant statutory approvals.

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Acronyms and Measurements

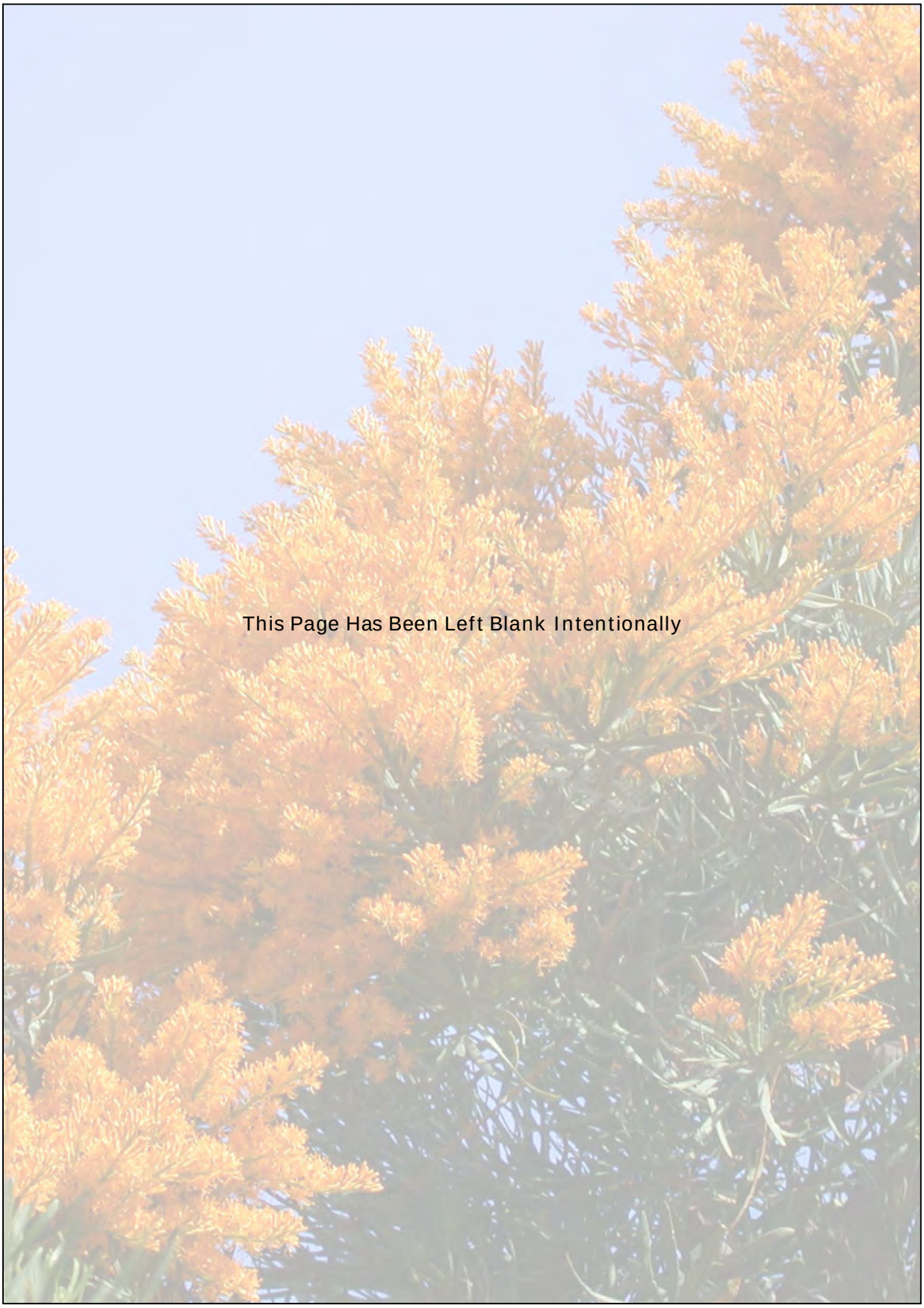
Abbreviation	Expansion
AASS	Actual Acid Sulfate Soils
AH Act	Western Australian *Aboriginal Heritage Act 1972*
AHD	Australian Height Datum
ALCP	Arum Lily Control Programme
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	Average Recurrence Interval
ASS	Acid Sulfate Soils
ASSMP	Acid Sulfate Soils Management Plan
ATSIHP Act	Commonwealth *Aboriginal and Torres Strait Islander Heritage Protection Act 1984*
BAU	Business As Usual
BOD	Biochemical Oxygen Demand
BoM	Bureau of Meteorology
BGPA	Botanical Gardens and Parks Authority
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CALM	Department of Conservation and Land Management (now DEC)
CAMBA	China-Australia Migratory Bird Agreement
CBD	Central Business District
CCW	Conservation Category Wetland
CEMP	Construction Environmental Management Plan
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CoRTN	Calculation of Road Traffic Noise
CPTED	Crime Prevention Through Environmental Design
CS	Conservation Significant
CSD	Contaminated Sites Database
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food Western Australia

Abbreviation	Expansion
DBH	Diameter at Breast Height
DCC	Department of Climate Change
DEC	Western Australian Department of Environment and Conservation (formerly CALM and DoE)
DEP	Department of Environmental Protection
DET	Department of Education and Training
DEWHA	Commonwealth Department of Environment, Water, Heritage and the Arts (now DSEWPaC)
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DIA	Western Australian Department of Indigenous Affairs
DMA	Decision Making Authority
DO	Dissolved Oxygen
DoE	Department of Environment (now DEC)
DOLA	Department of Land Administration
DoP	Western Australian Department of Planning
DoW	Department of Water (formerly WRC)
DPI	Department of Planning and Infrastructure (now DoP)
DRF	Declared Rare Flora
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA)
DSI	Detailed Site Investigation
EL	Ecological Linkage
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EP Act	Western Australian *Environmental Protection Act 1986*
EPA	Western Australian Environmental Protection Authority
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPP	Environment Protection Policy
ERP	Emergency Response Plan
ESA	Environmentally Sensitive Area

Abbreviation	Expansion
ESD	Environmental Scoping Document
EWR	Environmental Water Requirement
FCT	Floristic Community Type
FESA	Fire and Emergency Services Authority of Western Australia
FPA	Fremantle Port Authority
GDE	Groundwater Dependent Ecosystem
GHG	Greenhouse Gas
GSMRP	Graceful Sun-moth Research Proposal
IBRA	Interim Biogeographical Regionalisation of Australia
IPCC	Intergovernmental Panel on Climate Change
ISQG	Interim Sediment Quality Guidelines
ITS	Intelligent Transport System
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
Lakes EPP	*Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*
LCU	Landscape Character Units
LED	Light Emitting Diode
LFA	Land Function Analysis
LIC	Local Impacts Committee
LOR	Limit of Reporting
LOS	Levels of Service
LULUCF	Land Use, Land Use Change and Forestry
MAC	Murdoch Activity Centre
MAH	Monocyclic Aromatic Hydrocarbons
MCA	Multi Criteria Analysis
MRPA	Metropolitan Regional Planning Authority
MRS	Perth Metropolitan Region Scheme
MUSIC	Model for Urban Stormwater Improvement Conceptualisation

Abbreviation	Expansion
MUW	Multiple Use Wetland
NASS	Non Acid Sulfate Soils
Native ARC	Native Animal Rehabilitation Centre
NEPM	National Environment Protection Measure
NES	National Environmental Significance
NGER Act	*National Greenhouse and Energy Reporting Act 2007*
NO_2	Nitrogen Dioxide
NWQMS	National Water Quality Management Strategy
OEPA	Office of the Environmental Protection Authority
OME	Organic Matter Enriched
PAH	Polycyclic Aromatic Hydrocarbons
P&R	Parks and Recreation
PASS	Potential Acid Sulfate Soils
PBN	Perth Bicycle Network
PBP	Perth Biodiversity Project
PEC	Priority Ecological Community
PER	Public Environmental Review
PMR	Perth Metropolitan Region
POS	Public Open Space
PSI	Preliminary Site Investigation
PSP	Principal Shared Path
RAOU	Royal Australasian Ornithological Union
REW	Resource Enhancement Wetland
RHE	Roe Highway Extension
RL	Reduced Level
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
ROM	Regional Operations Model
SAP	Sampling and Analysis Programme

Abbreviation	Expansion
SARGE	System for Accounting and Reporting Government Emissions
SHC	State Housing Commission
SMART	Sustainability Measurement Assessment and Reporting Tool
SMC	South Metro Connect
SPOCAS	Suspended Peroxide Oxidation Combined Acidity and Sulfate
SPP	State Planning Policy
SRE	Short-Range Endemic
SRES	Special Reference Emission Scenario
TDS	Total Dissolved Solids
TEC	Threatened Ecological Community
TN	Total Nitrogen
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbons
TPS	Town Planning Scheme
TSP	Total Suspended Particulate matter
TSS	Total Suspended Solids
UFI	Unique Feature Identifier
VOC	Volatile Organic Compounds
WA	Western Australia
WAEPNR	Western Australian *Environmental Protection (Noise) Regulations 1997*
WAM	Western Australian Museum
WAPC	Western Australian Planning Commission
WC Act	Western Australian *Wildlife Conservation Act 1950*
WRP	Wetland Restoration Plan
ZTV	Zone of Theoretical Visibility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Invitation to Make a Submission

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal. Both electronic and hard copy submissions are most welcome.

Main Roads Western Australia proposes to extend Roe Highway from its current western terminus at Kwinana Freeway in Jandakot to Stock Road in Coolbellup, a distance of approximately five kilometres. The footprint of the proposed project will generally fall within the existing Metropolitan Regional Scheme (MRS), but may extend beyond the MRS boundary (between Kwinana Freeway and North Lake Road) into adjacent government-owned land. A preferred option, which achieves the best environmental and social outcomes, has been determined in collaboration with the community, stakeholders and environmental practitioners.

In accordance with the *Environmental Protection Act 1986* (EP Act), a Public Environmental Review (PER) has been prepared which describes this proposal and its likely effects on the environment. The PER is available for a public review period of 12 weeks from 20th June closing on 12th September in year 2011.

Comments from government agencies and from the public will help the EPA to prepare an assessment report in which it will make recommendations to government.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action— including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence, subject to the requirements of the *Freedom of Information Act 1992* (FOI Act), and may be quoted in full or in part in the EPA's report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining a group interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the PER or the specific proposal. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific elements of the PER:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the PER;
- if you discuss different sections of the PER, keep them distinct and separate, so there is no confusion as to which section you are considering;
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date; and
- whether and the reason why you want your submission to be confidential.

Information in submissions will be deemed public information unless a request for confidentiality of the submission is made in writing and accepted by the EPA. As a result, a copy of each submission will be provided to the proponent but the identity of private individuals will remain confidential to the EPA.

The closing date for submissions is: **12th September 2011**.

The EPA prefers submissions on PER documents to be made electronically using one of the following:

- by email to submissions@epa.wa.gov.au;;
- by email to the officer Gerard.obrien@epa.wa.gov.au.

Alternatively, submissions can be:

- posted to:
  Chairman
  Environmental Protection Authority
  Locked Bag 33
  CLOISTERS SQUARE WA 6850
  Attention: Gerard O'Brien; or
- delivered to:
  The Environmental Protection Authority
  Level 4, The Atrium
  168 St Georges Terrace, Perth
  Attention: Gerard O'Brien; or
- faxed to (08) 6467 5562.

If you have questions on how to make a submission, please ring the EPA assessment officer, Gerard O'Brien on 6467 5459.

Where to review a copy of this document?

A copy of the PER will be available at the following sites during the public comment period:

- **South Metro Connect Website**: www.southmetroconnect.com.au
- **JS Battye (State) Library**
  25 Francis Street, Perth Cultural Centre
  Phone: 9427 3111
- **Spearwood Library**
  9 Coleville Crescent, Spearwood
  Phone: 9411 3800
- **Coolbellup Library**
  90 Cordelia Avenue, Coolbellup
  Phone: 9411 3830
- **Success Library**
  Shop 220, Cockburn Gateway Shopping
  Phone: 9411 3840
- **Melville Civic Square Library**
  10 Almondbury Road, Booragoon
  Phone: 9364 0138
- **Fremantle City Library**
  8 William Street, Fremantle
  Phone 9432 9766

Preface

The purpose of this document is to assess the environmental impacts of extending Roe Highway from Kwinana Freeway in Jandakot to Stock Road in Coolbellup; including modifications to intersecting roads and an extension of Murdoch Drive. The Environmental Scoping Document (SMC 2010) served as the basis for development of the Public Environmental Review (PER).

To facilitate the readers' review of the PER, an executive summary, table of contents, list of figures, list of tables and acronym definitions have been incorporated before the first section of the PER. The Invitation to Make a Submission is also found before the first section on different coloured paper as required by the Environmental Protection Authority (EPA).

The introduction, presented as Section 1, identifies the proponent, outlines the purpose of the PER, describes the key characteristics of the proposed project (preferred option) and details the assessment process and project schedule.

Section 2 presents the project background and justification. Justification for the project is presented in Section 2.2 and explains the need for the proposed project in terms of increased population and urban growth, reduced traffic congestion, improved road safety and other anticipated benefits. This section also presents the no-build scenario and discusses alternative alignment options that have previously been considered.

Section 3 presents a summary of the process undertaken to develop and select the preferred option for a concept design. Land use, tenure and planning constraints on design are outlined in Section 3.3. The preferred option was selected following an extensive community engagement and review process that included various forums for community and stakeholder input, multi-criteria analysis and an iterative design development process that included consideration for environmental factors, described in Section 3.4. The preferred option developed as a result of this process is described in detail in Section 3.5 including a description of the environmental design features of the proposed project. The chapter closes with a proposal to revise the MRS and Beeliar Regional Park boundaries once the proposed project is completed.

Section 4 describes the overarching legislation and other regulatory requirements that pertain to the impact assessment. Section 4 also contains a list of other required approvals for the project; as well as principles of environmental protection and how these principles were considered. This section also identifies relevant decision-making authorities and necessary approvals. Where appropriate, policies and regulations are detailed within Section 5 and Section 6 as they relate to assessment aspects for each factor.

Section 5 describes the existing environment. Results of desktop studies, literature reviews and field investigation are presented within this section in order to define the existing conditions of the project area; as well as to inform the impact assessment and identify constraints for the selection of a preferred option. The summary table presented at the end of this section (Section 5.17) links the Environmental Scoping Document (SMC 2010) with the PER. The table presents the status and key outcomes of the scoped investigations for each factor.

Section 6 presents an assessment of project impacts associated with construction and operation; as well as management and mitigation measures. Impacts have been estimated for each factor based on overlays with the proposed alignment, ancillary components and the construction footprint. Impact avoidance modifications, accomplished during the development of the project design, are presented in the overview to this section (Section 6.1). Proposed mitigation measures are presented within each subsection to describe how impacts will be minimised, reduced or rectified. At the end of each subsection, residual impacts remaining after mitigation has been applied are quantified.

The environmental impact assessment is summarised in Section 7. The summary includes the factor objective, summary of existing conditions, project aspects (activities) or impact pathway, predicted impacts, management/mitigation and residual impacts for key factors affected by the proposed project.

Impacts on Matters of National Environmental Significance (NES) are described in Section 8. A summary table identifies PER sections where each of the Matters of NES are discussed in more detail. This section is provided in response to specific request of DSEWPaC representatives.

An environmental offset package is provided in Section 10. This package is proposed in order to offset the residual impacts remaining following mitigation/management of project impacts.

The PER conclusion (Section 11) presents a synthesis of information that outlines the basis for an environmentally acceptable project. Environmental commitments are presented in Section 9. These commitments in combination with management and mitigation measures (Section 6) will enable Main Roads to meet EPA's objectives (Section 6) and DSEWPaC's objectives (Section 8).

In Section 12, the bibliography lists guidelines, websites and other sources used to develop the PER. The bibliography contains reference material cited within the PER; as well as literature reviewed during its development.

Finally, a set of appendices containing supporting information and the results of investigations are provided electronically in a CD attached to the back cover of the hard copy of the PER.

Executive Summary

Main Roads Western Australia (Main Roads) proposes to extend Roe Highway approximately five kilometres from its current terminus at Kwinana Freeway in Jandakot to Stock Road in Coolbellup. In August 2009, Main Roads (the proponent) and industry partner, AECOM Australia, formed the South Metro Connect (SMC) alliance. The team was created for the development phase of the Roe Highway Extension project (the proposed project). Its primary objective is to work collaboratively with specialist consultants, stakeholders, and regulatory authorities to develop an environmentally, socially and economically acceptable project design in order to obtain relevant statutory approvals.

The proposed project will consist of a dual carriageway with two lanes in each direction; separated by a concrete barrier in place of a median strip. The preferred design was selected following an extensive options analysis and consultative process. During this process, project objectives; as well as specific environmental, social and economic criteria were examined. Once selected, the preferred option was modified to avoid and minimise impacts on several environmental factors.

Environmental principles have been applied throughout the project development process. Findings from surveys, studies, reviews and stakeholder and community engagement were used to inform options analyses and the identification of impacts and mitigations. The engagement programme was designed to encourage input and involvement from community members, stakeholders and interest group representatives through a variety of engagement activities including community information days, design workshops, a project shop front, a telephone hotline, online forums, a project website, email updates and newspaper publications.

Proposal

The proposed project is located approximately 14km south of Perth within the Swan Coastal Plain Bioregion. The project area is contained within the City of Cockburn; however, parts of the design extend northward into the City of Melville along Murdoch Drive and Kwinana Freeway. Generally, the proposed project is orientated east-west largely within a road reserve that was set aside in the Metropolitan Region Scheme in 1963. It aligns between North and Bibra lakes, which are part of the Eastern Chain of the Beeliar Wetlands.

The proposed project includes modifications to Stock Road, Sudlow Road, Coolbellup Avenue, North Lake Road, Progress Drive, Hope Road, Bibra Drive, Murdoch Drive, Pausin Crescent, Kwinana Freeway and Karel Avenue to accommodate the proposed development and anticipated traffic flow. Access from the proposed project will be provided at four major interchanges with Roe Highway – Stock Road, North Lake Road, Murdoch Drive (to and from the Murdoch Activity Centre) and Kwinana Freeway. Other major components of the proposed project include:

- Principal Shared Path along the length of the proposed project;
- Elevated structures over Progress Drive, between North and Bibra lakes and at Roe Swamp;
- Removal and rehabilitation of a section of Hope Road west of the Cockburn Wetlands Education Centre, Native Animal Rehabilitation Centre (ARC) and provision of a recreational car park;
- Bioretention basins to retain and treat runoff from the proposed project, as well as other stormwater basins;
- Pedestrian and fauna underpasses; and
- Replacement of power transmission infrastructure.

Assessment Characteristics

The project area supports environmental values that are relevant to the State Environmental Protection Authority (EPA) and Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC). Accordingly, the proposal was referred to the EPA in March 2009; and DSEWPaC (formerly Department of Environment, Water, Heritage and the Arts) in July 2009.

In 2003, pursuant to Section 16(j) of the *Environmental Protection Act 1986* (*EP Act*), the EPA advised that key environmental values identified as being associated with the construction of the proposed project relate to wetlands, vegetation, fauna, ecological linkages, Aboriginal heritage, residential amenity [noise], recreation and education (EPA 2003). Commonwealth Matters of National Environmental Significance (NES) listed under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* for the project area were initially identified through the DSEWPaC search tool as follows:

- Three Wetlands of International Significance (south of the project area);
- Forest Red-tailed, Baudin's and Carnaby's black cockatoos;
- Graceful Sun-moth;
- Three mammals: Chuditch, Red-tailed Phascogale and Quokka;
- Three plant species: King Spider-orchid, Muchea Bell and Beaked Lepidosperma;
- Migratory terrestrial birds: White-bellied Sea-Eagle and Rainbow Bee-eater;
- Migratory wetland and marine species: Great and Cattle egrets and Fork-tailed Swift.

In November 2009, the proposal was assigned a Public Environmental Review (PER) level of assessment under the provisions of Part IV of the *EP Act.* An Environmental Scoping Document was developed by SMC and approved by the EPA in June 2010.

This PER has been prepared in accordance with the *Guidelines for preparing a Public Environmental Review/Environmental Review & Management Programme* (EPA 2009a) and the *EP Act Environmental Impact Assessment Administrative Procedures 2002* (EPA 2002a). It has been authorised for public release by the EPA and will be released for a 12-week public review period. Hard copies of the PER will be available at the following locations during the comment period (commencing June 2011):

- EPA Library / reading room
- JS Battye Library
- State Library
- City of Cockburn Library
- City of Melville Library
- City of Fremantle Library
- Spearwood Library
- Coolbellup Library
- Success Library

Digital copies can be accessed via the SMC website:
http://www.southmetroconnect.com.au/

The closing date for comment submissions to the EPA is 5th September 2011.

Upon receipt of SMC's response to public comments, the proposal will be assessed by the State EPA and Commonwealth DSEWPaC. The State and Commonwealth Ministers will issue separate decisions.

Purpose of PER

The PER describes the existing environment and outlines potential, predicted and residual impacts arising from the proposed project. It also proposes management and mitigation measures for significant impacts, in line with relevant EPA position and guidance statements. The purpose of this PER document is to:

- Provide sufficient context for the proposed project with regard to its relevance to the planning and development requirements for the State;
- Place the proposal in the context of the local and regional environment;
- Describe the components of the proposal adequately, so that the State and Commonwealth Ministers can consider approval of a well-defined project;
- Define clearly the likely impacts of the project;
- Outline the proposed management measures and commit to management outcomes to ensure that environmental and socio-economic impacts will be minimised;

- Communicate clearly with stakeholders so that the EPA and DSEWPaC can obtain informed comment to assist in providing advice to government; and
- Provide a document that clearly sets out the reasons why the proposed project can be judged to be environmentally acceptable by the EPA, DSEWPaC and their Ministers, as well as by other stakeholders.

Background and Benefits

Roe Highway was originally planned to form part of Perth's strategic ring road network. In 1963, the alignment for the proposed project was set aside as a Controlled Access Highway in the Perth Metropolitan Region Scheme (MRS). The highway was designed to connect Fremantle Port with the Kewdale, Welshpool and Canning Vale industrial areas; as well as major transport corridors including the Great Northern, Great Eastern, Tonkin and Albany Highways. Roe Highway has been constructed in stages from Midland to Kwinana Freeway over the last 29 years, with Stage 1 beginning in 1981.

Roe Highway Stage 7 was completed in 2006 and presently terminates at Kwinana Freeway. Subsequent to the State Government's commitment, the Roe Highway Strategic Review concluded that the proposed project is required to support ongoing development and to ease traffic congestion (GHD and Meyrick 2009). This is consistent with the findings of most related previous studies. The GHD and Meyrick study (2009) supports the MRS alignment and found that the proposed project is required for the following key reasons, among others:

- To increase efficiency of freight movements to and from key generators and the Fremantle Port;
- To reduce air pollution through the removal of stop and start operations at traffic signals and by reducing travel times;
- To increase safety of the road network through the reduction of heavy vehicles on interactive streets (streets with multiple access points and residential and retail developments); and
- To reduce traffic volume along the already congested Leach Highway and South Street.

Justification

The proposed project is being developed to accommodate Perth's forecast urban and industrial growth to 2031. Within a local context, the City of Cockburn population is predicted to increase by 44 percent by year 2031; while the number of dwellings is forecast to increase by 53 percent. The population of the Perth Metropolitan and Peel regions is expected to grow by approximately 35 percent to reach more than 2.2 million by 2031.

The project area is located within a region identified for key growth over the next 20 years. In the short term, the proposed project will support a growing number of freight vehicles utilising the Fremantle Inner Harbour and other local industrial areas. In the long term, it will provide the necessary infrastructure for businesses to operate effectively, which is crucial for stimulating and supporting economic growth of the Perth southern metropolitan region.

Present and proposed development in the region is expected to provide thousands of employment opportunities. Several ongoing and planned development areas for the southern metropolitan region include:

- Kwinana Industrial Area;
- Australian Marine Complex;
- Latitude 32 Industrial Area;
- Fremantle Outer Harbour (Kwinana Quay); and
- James Point Private Port.

The Murdoch Activity Centre (MAC) further underscores the need for the proposed project. It will be an important centre for growth in the area, which is anticipated to employ thousands of people. The MAC will include developments such as the Fiona Stanley Hospital and supporting commercial development, education providers and office space. At present, there is no access to MAC from north bound traffic on the Kwinana Freeway, except via South Street, which is already heavily congested. Connection with the proposed project would improve traffic efficiency, reduce congestion on South Street and provide efficient access to the MAC.

The proposed project is expected to convey an average of 60,000 vehicles per day by 2031, which would otherwise be using local roads. The proposed project will provide a route designed for the safe and efficient movement of more than 6,000 heavy vehicles a day. Without the proposed project these vehicles would have to be accommodated elsewhere in the network along less desirable routes.

Justification for the proposed project has been reviewed in numerous reports, the majority of which conclude that the proposed project is required to ease congestion. The strategic rationale for constructing the proposed project determined that managing the existing network without the proposed project (the no-build option) would not adequately satisfy key freight requirements, thereby jeopardising safety, local air amenity and efficiency.

Several previous studies have investigated alternative routes, albeit few in the context of a completed Roe Highway Stage 7. Those that have been prepared since completion of Roe Highway Stage 7 generally work on the assumption that Roe Highway will not be constructed beyond Kwinana Freeway, but do not recommend viable alternatives to address forecast traffic volumes and anticipated traffic congestion.

A road network assessment that considers the forecast performance of the surrounding road network in 2021 (SMC 2011) concluded that the no-build scenario would have a significant impact on network performance, and a southern link to the Murdoch Activity Centre would be required to overcome these issues to some extent.

Impact Avoidance during Project Planning and Development

Environmental, social, economic and governance constraints were identified through extensive and detailed consultation and studies of biophysical and landscape condition. Design options for the proposed project were selected based on avoidance and minimisation of environmental and social impacts on key values; as well as budgetary considerations. The proposed project is designed to avoid the resumption of private property. Bridges, retaining walls, construction methodology, horizontal and vertical alignment and reconfiguration and relocation of interchanges were incorporated into the project design to avoid and minimise impacts on environmental and heritage values. These values include the following key environmental factors:

- Intact native vegetation;
- Significant fauna habitat;
- Ecological linkages; and
- Wetlands.

Environmental Assessment

The Environmental Scoping Document outlined studies and investigations that were required to assess impacts of the proposed project. It has been determined that environmental impacts on many of the environmental factors will be managed and mitigated to eliminate or reduce the potential impact. However, four key environmental factors will require offsets to mitigate effectively. The environmental assessment includes factors that are relevant to both the State and Commonwealth governments.

Key Environmental Factors

A review of Bulletin 1088 (EPA 2003), development of the ESD (SMC 2010) and evaluation of environmental study results has established and confirmed that there are several key environmental biophysical factors requiring assessment and management: flora/vegetation, Conservation Category wetlands (CCW), conservation significant fauna and ecological linkages. Specific impacts on these key issues are presented below.

Wetlands including groundwater dependent ecosystems

The proposed project will have an impact on CCWs and minor impacts on Lakes Environment Protection Policy (EPP). The identified areas of mapped wetland affected by the proposed project include:

- Bibra Lake –1.0ha out of 138ha total mapped Lakes EPP wetland;
- Horse Paddock Swamp – 0.2ha out of 3.2ha total mapped CCW boundary; and
- Roe Swamp – 5.6ha (temporary and permanent clearing) out of 53.7ha total mapped CCW boundary.

Although approximately 1.0ha of the proposed development is within the Bibra Lake EPP boundary, the mapped wetland in this area is shown to have limited ecological value. The intersection of the proposed project with the EPP boundary is immediately adjacent to the existing Hope Road. Vegetation in the area has been assessed as 'Completely Degraded'. Likewise, Horse Paddock Swamp also currently has limited ecological value as it is predominantly devoid of native vegetation and is assessed as 'Completely Degraded'. There is no anticipated loss or reduction in current wetland value or function of Horse Paddock Swamp due to the proposed project. Works towards the restoration of Horse Paddock Swamp are planned as an offset.

The attributes, functionality and values exhibited by Roe Swamp and surrounding sumplands (i.e. Lower, Melaleuca and Roe swamps) are assessed as being commensurate with those of a CCW. An area of approximately 5.1ha of the mapped CCW of Roe Swamp will be occupied by the proposed project. With the relocation of Murdoch Drain, Roe Swamp CCW will incur a temporary impact of approximately 0.5ha. The inclusion of a 50m buffer (i.e. Environmentally Sensitive Area) around Roe Swamp includes unvegetated areas that are developed and/or contain degraded habitat on the east side of Roe Swamp and vegetation in good condition on the west.

Roe Swamp is an integral part of the linked hydrological, geomorphic and ecological systems within the eastern low hollows of the Bassendean Dunes that drains towards North and Bibra lakes. Roe Swamp has demonstrated resilience to existing pressures as evidenced by the ongoing functionality of the swamp despite fragmentation caused by Farrington Road, Hope Road and the power transmission line. As it is a pre-requisite for development of an east-west corridor, the proposal is to cross a section of the wetland. However, the proposed project avoids the main swampland of Roe Swamp, which is located in the south-east portion of the larger Roe Swamp and, in doing so, also avoids intersection of known good quality black cockatoo foraging habitat.

The maintenance of the water cycle is essential to the continued long-term function of Roe Swamp. This will be achieved by the provision of a bridge that spans a significant extent of very good condition vegetation within Roe Swamp to avoid the impedance of surface and near surface water conveyance along the topographic low point of the catchment. The relocation of a shallow replication of the existing Murdoch Drain will also assist in the regard.

Of a total of 79ha of native vegetation to be cleared, approximately 13ha of groundwater dependent ecosystem (GDE) sub communities will be cleared for the proposed project. This represents approximately five percent of the area covered by GDE sub communities within the GDE study area.

A combination of bioretention and infiltration basins will be used through the project area. Where the basins are located close to wetlands, the basins incorporate a bioretention section within the infiltration basins. A large bioretention basin (1.7ha) is proposed east of Horse Paddock Swamp at Hope Road. The Hope Road basin will be planted with native wetland species and existing vegetation along with a natural filter medium, which will filter the water prior to its entry into the superficial aquifer. Although localised water mounding will occur below the basins, it will not disrupt regional groundwater regimes, relative to inter-annual and typical seasonal effects. The bioretention basin will ultimately take the form of a natural wetland system functioning to improve water quality and provide wetland habitat. These basins are presented as part of the mitigation package for impacts on wetland values.

It is further proposed that impacts on Roe Swamp CCW are mitigated through the allocation of funding for the restoration of Horse Paddock Swamp, which is assessed as having 'completely degraded' vegetation condition rating. Coordination with DEC will be required due to Horse Paddock Swamp's status as a CCW and Lakes EPP wetland. Adjacent uplands ('completely degraded' condition) are also proposed for restoration with appropriate native vegetation to create an upland/wetland interface that will serve as habitat for resident fauna.

Flora and Vegetation

Project construction will require the removal of up to 79.3ha of remnant native vegetation, of which approximately 38ha can be rehabilitated at completion of construction. Approximately 37.5ha of the native vegetation due for removal (47%) has been identified as in 'degraded to good' condition or better (i.e., considered to be intact remnant native vegetation). The remaining 41.8ha consists of areas that have been previously cleared or are void (or almost so) of native vegetation.

Seven hectares of Bush Forever Site 244 occurs within the construction footprint of the proposed project. Clearing of this area will include the removal of 4ha of intact native vegetation within the Bush Forever Site.

A total of 15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants will be impacted by the proposed clearing. Most of the recorded Priority Flora plants within the proposed clearing footprint are *Dampiera triloba* (Priority 1), a small herb species that is locally abundant.

Potential impacts associated with vegetation loss include increased stress on the local biodiversity and reduced availability of terrestrial fauna habitat.

Minimal vegetation impacts due to fragmentation, edge effects and associated weed invasion, shading and altered hydrology are predicted, with the first three effect pathways already existing widely across the project area. If managed appropriately, these impacts will be reduced to low levels or totally eliminated. The risk of fire and introduction of dieback disease to the project area will be managed through the development and implementation of a Construction Environmental Management Plan to impose conditions on the movement and operation of plant and machinery.

Fauna

Clearing of vegetation and the installation of drainage basins will result in the loss of up to 112ha of fauna habitat. This includes 40ha (36 percent) of *Eucalyptus*/*Banksia* woodland, 26ha (23 percent) of *Eucalyptus*/*Xanthorrhoea* woodland and 13ha (12 percent) of other native remnant vegetation. The clearing includes 20ha (17 percent) of various other woodland types, rehabilitated vegetation, parklands and roadside verges that provide fauna habitat. The remaining clearing is of areas that hold little value for fauna, in particular 13ha (12 percent) of 'degraded' condition vegetation with low value habitat.

Habitat for three recorded Commonwealth and State conservation significant fauna species will be removed within the project area: Carnaby's Black Cockatoo; Forest Red-tailed Black Cockatoo; and Graceful Sun-moth. Additionally, habitat for two recorded State conservation significant species is expected to be removed within the project area: Southern Brown Bandicoot and Perth Lined Lerista. Habitat for the Black-striped Snake will also be removed; however, this species was not recorded during recent project surveys, but may potentially occur within the project area.

Approximately 78ha and 73ha of foraging habitat for the Carnaby's and Forest Red-tailed Black Cockatoos, respectively, will be affected by the proposed project. Also, 249 significant trees (which have a diameter at breast height greater than 500mm) will be removed; 20 of which contain hollows that could potentially be used for nesting by black cockatoos and other bird species. Neither actual cockatoo nesting nor roosting sites are known to occur within the project area.

In addition to the impacts that were avoided during the development of the project design, the following mitigation measures will be implemented:

- Install artificial nesting hollows to replace lost potential nesting hollows for wetland birds; and
- Rehabilitate cleared areas on completion of works with appropriate foraging food species, including Marri, Jarrah and *Banksia* species, where possible.

Graceful Sun-moth habitat has been categorised into confirmed – where adults have been collected; suitable – where its host plant, *Lomandra hermaphrodita* has been recorded; and potential – vegetation communities that are known to contain *L. hermaphrodita*.

Of the 8.7ha of confirmed Graceful Sun-moth habitat, 5.6ha (64 percent) will be affected by the proposed project. The removal of approximately 1,100 recorded individual plants (34 percent of those recorded) will result in the loss of suitable habitat. Approximately 60.5ha (48 percent) of potential habitat will be removed, excluding the confirmed habitat above (8.7ha). Confirmed Graceful Sun-moth habitat was based on the collection of six adults in 2010 and five adults in a March 2011 survey.

Besides the Graceful Sun-moth, six out of eight additional conservation significant invertebrates identified during database searches could potentially occur within the project area, as suitable habitat exists for these species. The six potentially occurring species include a scorpion fly, two native bees, a butterfly and two crickets. The scale of habitat loss within the project area is expected to be higher for:

- *Leioproctus contrarius*;
- *Throscodectes xiphos*; and
- *Vanessa itea*.

One SRE species recorded in the project area, an unidentified sucking millipede (*Siphonotidae sp.*), may be of conservation significance. However, further taxonomic review of this species is required. A single specimen was collected from *Eucalyptus/Banksia* habitat in the north-east quadrant of the Stock Road/Forrest Road intersection. Vegetation clearing will result in the removal of habitat from its only known location within the project area. Positive identification of this species is underway, so its specific habitat requirements are unclear. Consequently, the extent of habitat loss cannot be calculated at this time; and the scale of impact by the proposed project has yet to be determined.

With the exception of the unidentified *Siphonotidae sp.*, project impacts of habitat loss and fragmentation on invertebrates are negligible to minor.

Habitat loss and fragmentation pose the most significant risks to the Southern Brown Bandicoot by the proposed project. Key habitat within the project area is represented by *Eucalyptus/Xanthorrhoea* woodland, *Eucalyptus/Banksia* woodland and *Eucalyptus/Melaleuca* woodland. Vegetation clearing will result in a loss of approximately 73ha of available Southern Brown Bandicoot habitat.

The risk of Southern Brown Bandicoot deaths as a result of construction activities and highway traffic will be minimised through the installation of fencing within habitable areas and the implementation of a trapping and relocation programme prior to commencement of clearing activities.

Southern Brown Bandicoot habitat fragmentation can lead to isolation of populations and reduction in population viability. Movement between sub-populations within the study area appears limited; therefore, impacts of the proposed project are likely to be localised.

The Perth Lined Lerista is a skink recorded within and adjacent to the project area during project and previous surveys. Suitable habitat for this species exists throughout the project area, except for areas with peaty silt soils in and around Roe Swamp, Horse Paddock Swamp and Murdoch Drain. Habitat loss and fragmentation pose the highest risks to the Perth Lined Lerista by the proposed project. Within the project area, vegetation clearing will result in a loss of approximately 91ha of available habitat for this species.

The Black-striped Snake was not recorded in the project area but may occur as potential habitat exists and individuals have been previously recorded at nearby Jandakot Airport (Bamford *et al.* 2002). The Black-striped Snake may potentially utilise *Banksia* woodland associated with pale sandy soils. Approximately 43ha of potential habitat will be affected by the proposed project.

Revegetation of 52ha of fauna habitat, including rehabilitation of 38ha of cleared native vegetation and restoration of an additional 14ha of currently degraded land, will replace some of the lost habitat. Other general management and mitigation measures that will be undertaken to minimise impacts on habitat loss for fauna includes:

- Replacing ground habitat features, such as fallen logs, top soil and leaf where habitat loss or degradation occurs;
- Rehabilitating cleared areas on completion of works where possible;
- Delineating the extent of clearing through the installation of fencing at the boundaries of the construction zone and tagging specific trees for retention;
- Avoiding clearing or disturbance outside the defined project footprint boundaries;
- Minimising damage to surrounding wetland habitats (shoreline) outside the project footprint during construction, by fencing or clearly delineating construction site boundaries; and
- Revegetating available parts of Horse Paddock Swamp and Roe Swamp disturbed by the project.

Other At-Risk Species

Although not considered State or Commonwealth conservation significant, these species (birds, reptiles and one mammal) contribute to the biodiversity of the project area. Ten regionally significant bird species defined in Bush Forever and recorded within the study area are considered to be at risk.

Fairy-wrens and thornbills are two groups of concern that have previously declined in various locations across the Perth metropolitan region. Among other bird species, the Splendid Fairy-wren, White-browed Scrubwren, Western Thornbill and Grey Shrikethrush have been identified as some of the sedentary (resident), insectivorous species that are declining on the Swan Coastal Plain. The Western Thornbill, in particular, is considered a habitat specialist and is limited in resources, dispersal, area and process within the Swan Coastal Plain. Additional at-risk species include the Common Brushtail Possum, South-western Crevice Skink, Western Bearded Dragon, West Coast Ctenotus and other small fossorial reptiles.

Ecological Linkages

Historical fragmentation associated with urban encroachment (i.e. housing and roads) has already resulted in the fragmentation of the existing environment of the project area. The project design has been developed to ensure connectivity between the north and south sides of the proposed project is maintained through the inclusion of bridges and fauna underpasses in areas not already severed by existing infrastructure. Linkages either side of North Lake Road, Sudlow Road/Coolbellup Drive and Stock Road will be improved through the grade separation of the proposed project and inclusion of apertures under these roads for fauna movement.

Most plant species do not critically depend on physical linkages with other habitat patches in the short term (Bennett and Mulongoy 2006). Rather, their long-term survival depends more upon having the opportunity to move progeny, via pollen and seed dispersal, to other habitat patches in response to flooding, fire or other periodic natural disturbances. Therefore, ecological linkages are considered largely in the context of fauna connectivity.

Six regional and local ecological linkages were identified within the project area. After the consideration of historical fragmentation and the incorporation of project design elements, the proposed project will partly affect one regional and two local ecological linkages: EL1, EL5 and EL6.

EL1 is located at a 'squeeze' point where the proposed project intersects Sudlow Road, Coolbellup Avenue and Forest Road. These existing roads already affect this east-west fauna connection, and the grade separation of these roads and alignment of Roe Highway underneath them will enable connectivity to be re-established between habitats on either side.

The proposed project will cause an intermittent fragmentation to local linkages EL5 and EL6. Proposed bridges will mitigate the main conveyance portions of these linkages and fauna underpasses and culverts will provide north-south passageways for a range of ground-dwelling and aquatic species. The continuance of north-south linkage for EL5 and EL6 equates to maintenance of processes for local connectivity. EL4, as a regional linkage that is already heavily fragmented by roads such as Farrington Road, Hope Road and Bibra Drive, is not considered to be significantly impacted by the proposed project.

Other Environmental Factors

In addition to the key factors, environmental impact assessment has been conducted for the following factors and impact mechanisms:

- Acid Sulfate Soils;
- Sources of Potential Contaminants;
- Aboriginal Heritage;
- Noise;
- Recreation and Education;
- Air Quality;
- Visual Amenity; and
- Greenhouse Gases.

Impacts on these matters will be mitigated or managed to a reduced level within the project area in compliance with applicable legislation as shown in Section 4.

Matters of National Environmental Significance

Discussions of Matters of National Environmental Significance (NES) have been integrated with environmental factors relevant to the State and are presented above. The controlling provisions under the *EPBC Act* are listed threatened species and listed migratory species. No other matter of NES applies to this impact assessment. The closest Ramsar site (i.e. Thomsons Lake) is located 7km south of the project area.

Section 8 of this PER has been developed for DSEWPaC and stakeholder review. It contains a complete summary of the existing environment and impact assessment for Matters of NES that were initially identified by an *EPBC Act* Protected Matters Report. As discussed above, the following Matters of NES will be affected by the proposed project:

- Carnaby's Black Cockatoo – endangered;
- Forest Red-tailed Black Cockatoo – vulnerable; and
- Graceful Sun-moth – endangered.

Several migratory and wetland birds will potentially be subject to impacts by the proposed project. These include Rainbow Bee-eater, Glossy Ibis, Eastern Osprey, Eastern Great Egret and Cattle Egret.

The majority of management strategies available are adequate to manage risks and mitigate the impacts of the proposed project on Wetlands and Groundwater Dependent Ecosystems. For detail, see Section 6.2 and Section 7.

Table i describes residual impacts where management and mitigations are not sufficient to reduce or remove a predicted impact. Also outlined are commitments to environmental outcomes. Offsets are proposed for project impacts that do not achieve a satisfactory outcome.

Table i: Summary of Environmental Factors, Residual Impacts and Management Outcomes

Factor	Objective	Residual Impacts	Commitments to Outcomes	Offsets
Wetlands	To maintain existing ecological functions and environmental values	Aerial extent of GDE communities within project area reduced by 13.3ha Area of intact native vegetation within Roe Swamp CCW boundary reduced by 5.6ha Filling of a portion of a CCW Reduced connectivity of Roe Swamp A reduction in amenity and aesthetics Alteration in vegetation community species composition in 0.4ha under proposed bridge Drainage basins improve water quality delivered to wetland areas	Maintain wetland ecological connectivity either side of the proposed road where it crosses Roe Swamp Minimise ground compaction areas in Roe Swamp that would otherwise have occurred as a result of traditional construction methods Maintain ground and surface water conveyance through Roe Swamp Hydrological function associated with Murdoch drain will be retained Maintain existing groundwater levels between Bibra Lake and Horse Paddock Swamp Contain and treat road runoff to remove potential contaminants to baseline levels Prevent the spread of dieback through project construction activities Prevent the release of sediment into wetlands Prevent the release of pollutants from Acid Sulfate Soils into wetlands Minimise the risk of contaminants being released into the wetland system will be minimised	Direct: Following the implementation of a weed control programme, transfer of MRS reserve into Beeliar Regional Park for DEC management Creation of wetland values within Hope Road bio retention basin Restoration of wetland values at Horse Paddock Swamp Rehabilitation of degraded wetland fringes at North Lake and the Spectacles Implementation of a weed control programme at Roe Swamp and Thomsons Lake

Factor	Objective	Residual Impacts	Commitments to Outcomes	Offsets
Vegetation and Flora	To maintain abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge	Loss of 38ha intact native flora and vegetation including 7ha of GDE sub-communities Loss of 2.1ha of BahS vegetation community type from project area Loss of 7ha of Bush Forever, including 4ha of intact native vegetation Loss of 15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants (most of which are of one small herb species that is locally abundant)	A maximum of 79ha of remnant native vegetation will be removed Successful rehabilitation of disturbed areas to specified criteria will occur Ecological linkages between the northern and southern sides of Hope Road will be improved The risk of importing fill contaminated with pollutants, *Phytophthora* and/or weeds will be minimised Ensure adherence to site environmental management procedures	Rehabilitation and restoration of degraded areas within or adjacent to the project area Rehabilitation of degraded wetland fringes and Horse Paddock Swamp Offset for impacts on black cockatoo habitat will also contribute towards offsetting of native vegetation loss Removal and Rehabilitation of Hope Road west of proposed cul-du-sac Transferral of unused Roe Highway road reserve into Beeliar Regional Park
Fauna	To maintain abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge	78 ha loss of foraging habitat for Carnaby's Black Cockatoo 73ha loss of foraging habitat Forest Red-tailed Black Cockatoo 2.5ha (249 significant trees) loss of potential black cockatoo nesting habitat 73ha loss of habitat loss for Southern Brown Bandicoot 91ha loss of habitat for Perth Lined Lerista Lowered rates of movement of ground dwelling animals such as the Southern Brown Bandicoot and reptiles between north to south during road operations Loss of confirmed (non-viable) GSM	Protect fauna from contact with construction operations and highway traffic Contribute funding toward Graceful Sun-moth research Minimise the impact on potential black cockatoo nesting habitat	Purchase and covenanting of foraging habitat at a ratio of 6:1 as close to the project area as possible Purchase and covenanting of potential nesting habitat at a ratio of 10:1 as close to the project area as possible Funding towards improved habitat and species management at known Graceful Sun-moth locations Funding toward research into the biology of Graceful Sun-moth species and habitat Funding towards management

Factor	Objective	Residual Impacts	Commitments to Outcomes	Offsets
		population Reduction in potential habitat for future GSM populations Low rates of vehicle strike on flying birds Limited fauna displacement		and improvements to wetland migratory bird habitats
Noise	To protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards	Noise and vibration may be temporarily encountered during the construction phase through different parts of the project area Several recreational areas adjacent to the proposed transport corridor will potentially be affected by the proposed project during operations Twenty nine receivers adjacent to the new road are predicted to marginally exceed the noise target criterion (by up to 2 dB(A)) at the ground level in 2031	Noise limit criteria will be achieved at all residences affected by the proposed new highway Minimise the effects of construction noise	No offsets are proposed for impacts on Noise emissions
Greenhouse Gases	Minimise emissions of greenhouse gases during construction	Construction and operation GHG emissions	Provide a benchmark carbon emissions value against which to drive improvements in efficiencies for the proposed and future projects Report on actual carbon emissions	GHG emissions will be offset through a more efficient road network during operations
Ecological Linkages	To maintain abundance and diversity of flora species and allow for long-term genetic conveyance along continuous regional corridors that link many different vegetation complexes	A temporary impact on fauna linkages that require vegetative cover and leaf litter for movement (e.g. Lerista and Southern Brown Bandicoot) A temporary impact on fauna movement during the time earthworks is being	Maintain connectivity between flora populations and vegetation communities Maintain connectivity of local ecological linkages within the project area	Whilst there are no offsets proposed for residual impacts on ecological linkages, the restoration of Horse Paddock Swamp, which is proposed as an offset against impacts on Roe Swamp, will also serve to

Factor	Objective	Residual Impacts	Commitments to Outcomes	Offsets
	To maintain abundance and diversity of fauna species and allow for fauna movement along continuous regional corridors that link different habitat types	conducted Partial fragmentation of north-south EL5 and EL6 linkages Reduction in width of the east-west EL1 linkage		enhance connectivity between Bibra Lake and North Lake
Aboriginal Heritage	To ensure that changes to the biophysical environment do not adversely affect historical and cultural associations and comply with relevant heritage legislation	Loss of 73ha of Forest Red-tailed Black Cockatoo foraging habitat Loss of less than 41 individual *Nuytsia* trees There will be some residual impact on mythological values associated with hydrology	During construction and clearing activities, subject to agreement with the Traditional custodian, Main Roads will relocate/plant a selection of prominent mature *Nuytsia floribunda* for use as entry statements and for the possible punctuation of interpretive trails	No offsets are proposed for impacts on Aboriginal Values
Visual Amenity	To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape to as low as reasonably practicable	Limited views from parklands and private residences of activity within the construction footprint adjacent to wetland landscapes Views from parklands and private residences of infrastructure and traffic adjacent to wetland landscapes and bushland landscapes will persist Loss of intact native vegetation Although noise walls will provide some screening benefits (i.e. reduced visibility of traffic and road), they will also block some existing views of the natural landscape Express local identity (focusing on cultural and natural heritage) and visually enhance the road environment Light spill and sky glow	Minimise impacts on key view across Bibra Lake, from North Lake, for users of local schools and for residents living in close proximity to the proposal Minimise impacts on visual amenity and landscape values of Beeliar Regional Park Express local identity (focusing on cultural and natural heritage) and visually enhance the road environment	No offsets are proposed for impacts on Visual Amenity

Factor	Objective	Residual Impacts	Commitments to Outcomes	Offsets
Recreation and Education	To ensure existing and planned recreational uses are not compromised	A minor reduction in natural experience will occur at locations in close proximity to the proposed project Improved access to recreation facilities in the vicinity of the project area for regional visitors Improved westward flow from the existing Roe Highway PSP Improved standard of local pathways Improved access to wetlands for Blue Gum Montessori School Alteration of educational access routes	Maintain connectivity for pedestrians and Regional Park users between either side of the proposed alignment	No offsets are proposed for impacts on Recreation and Education

1. Introduction

On behalf of the State government, Main Roads Western Australia proposes to extend Roe Highway from its current terminus at Kwinana Freeway in Jandakot to Stock Road in Coolbellup. This will complete a strategic link in Perth's road network, and provide access to the forthcoming Murdoch Activity Centre, which includes the Fiona Stanley Hospital.

The project area is illustrated in Figure 1.2-1. The project area boundary generally follows the existing Metropolitan Region Scheme (MRS) Primary Regional Roads boundary. However, it extends slightly beyond this area between Kwinana Freeway and North Lake Road into adjacent government-owned land. This reflects the need to explore an alignment outside the MRS regional roads boundary to minimise potential environmental impacts.

In August 2009, Main Roads Western Australia and industry partner, AECOM, formed the South Metro Connect (SMC) alliance. The team was created for the development phase of the Roe Highway Extension project. Its primary objective was to work collaboratively with stakeholders and community, specialist consultants and regulatory authorities to develop an environmentally, socially and economically acceptable concept design in order to obtain relevant statutory approvals.

This Public Environmental Review (PER) document forms the environmental assessment documentation for the proposed Roe Highway Extension. This section identifies the proponent and provides an explanation of the purpose of this PER. It also presents a summary of the key characteristics of the proposed project and concludes with a description of the assessment process and schedule.

1.1. Proponent Identification

Main Roads Western Australia (hereafter referred to as 'Main Roads') is the proponent for the proposed Roe Highway Extension (hereafter referred to as the 'proposed project'). Main Roads is Western Australia's state road authority, managing a network of over 18,000km of state roads and providing access to one of the world's most geographically spread-out road networks. The role of Main Roads includes:

- Management of planning, design and construction of major new roads;
- Upgrading major roads and associated structures; and
- Operation and maintenance of the road network.

Official details for the project proponent and key contact:

Proponent: Commissioner of Main Roads

Main Roads Western Australia

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Key contact: Jamie Shaw

Project Environment Manager

South Metro Connect

C/O AECOM

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Jamie.Shaw@Southmetroconnect.com.au

Ph: (08) 6430 2199

Correspondence or enquiries regarding the project should be addressed to the Project Environment Manager.

1.2. Purpose of the Public Environmental Review

The purpose of this PER is to provide details of the proposed project and to present an environmental impact assessment in accordance with the administrative requirements of the Environmental Protection Authority of Western Australia (EPA), as set out in *Guidelines for Preparing a Public Environmental Review/Environmental Review and Management Plan* (EPA 2009a) and the *Environmental Protection Act Environmental Impact Assessment Administrative Procedures 2002* (EPA 2002a). The Environmental Scoping Document (ESD) for the PER was approved by the EPA in June 2010. The PER is subject to a 12-week public review period.

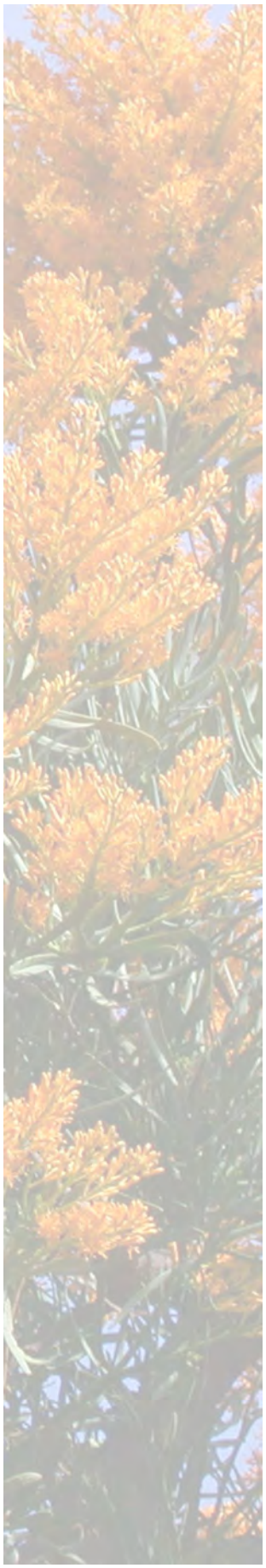
This document enables the coordinated assessment of the proposal by the EPA pursuant to Part IV of the *Environmental Protection Act 1986* (*EP Act*) and the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). This coordinated assessment will occur in accordance with Section 45 of the *EPBC Act*, which enables the establishment of a Bilateral Agreement between the commonwealth and the state. The agreement allows the proponent to provide environmental assessment documentation to the EPA, which then liaises with DSEWPaC. However, both organisations will make separate and independent project approval decisions.

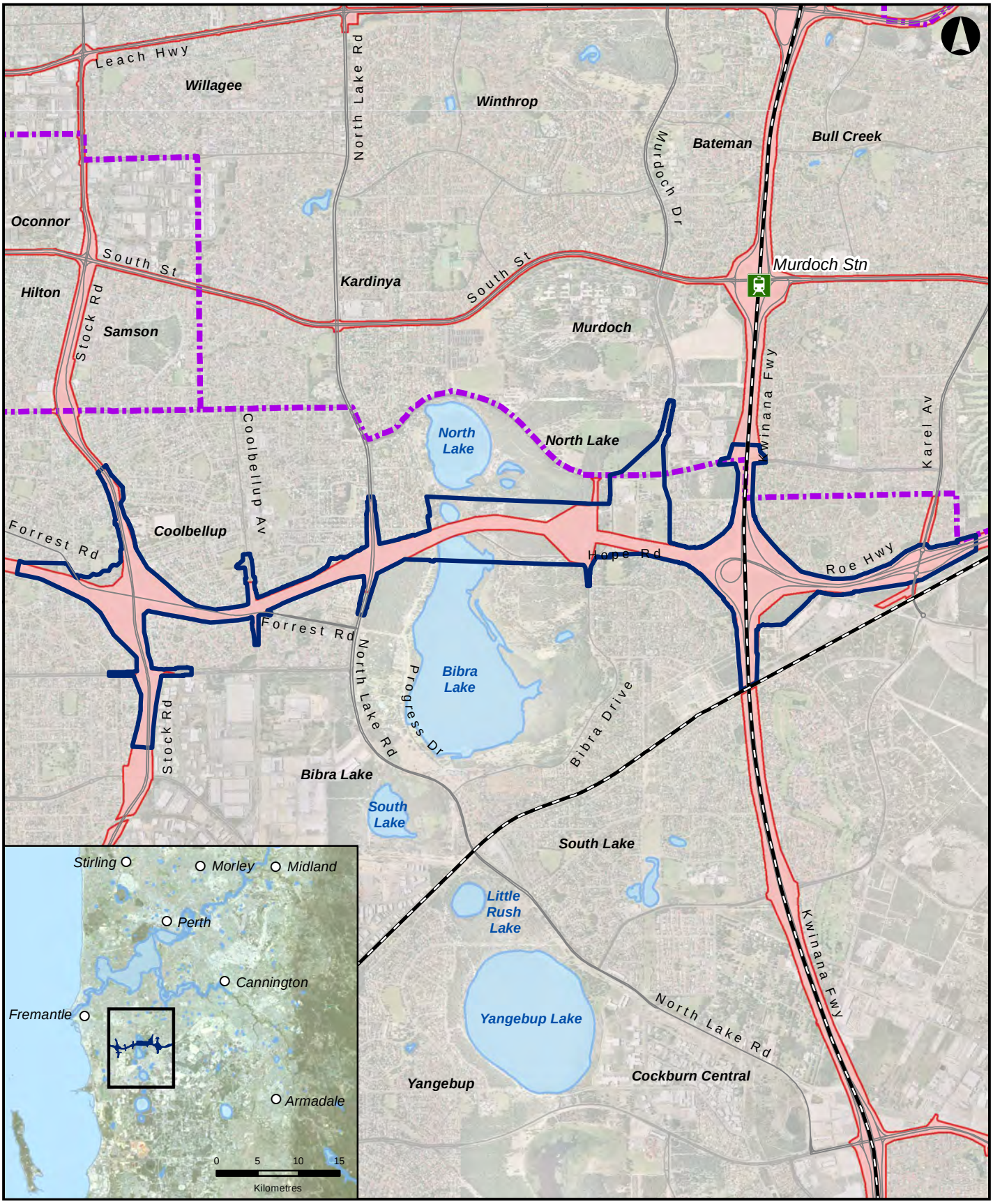
The PER describes the existing environment and outlines the likely impacts arising from the proposed project. It proposes management and mitigation measures for significant impacts, in line with relevant EPA position and guidance statements. Specifically, the purpose of this PER document is to:

- Provide sufficient context for the proposed project with regard to its relevance to the planning and development requirements for the state;
- Place the proposal in the context of the local and regional environment;
- Adequately describe the components of the proposal , so that the state and commonwealth ministers can consider approval of a well-defined project;
- Clearly define the likely impacts of the project;

- Outline the proposed management measures and commit to management outcomes to ensure that environmental and socio-economic impacts will be minimised;
- Communicate clearly with stakeholders so that the EPA and DSEWPaC can obtain informed comment to assist in providing advice to government; and
- Provide a document that clearly sets out the reasons why the proposed project must be judged to be environmentally acceptable by the EPA, DSEWPaC and their ministers, as well as other stakeholders.

The document has been reviewed in accordance with the EPA Checklist for documents submitted for Environmental Impact Assessment (EIA) on marine and terrestrial biodiversity, attached as Appendix A.





Project Area

South Metro Connect

Figure 1.2-1

0 0.5 1 1.5
Kilometres
1:42,000 (A4)
Datum: GDA94 Projection: MGA z50

Project Area
LGA Boundaries
MRS - Primary Regional Roads
Railway

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SouthmetroConnect

1.3. Background to Project Design

The EPA, in its advice provided in Bulletin 1088 (EPA 2003), identified the following key factors of concern (detailed in Section 6.1.1) as a result of the proposed project as it existed at that time:

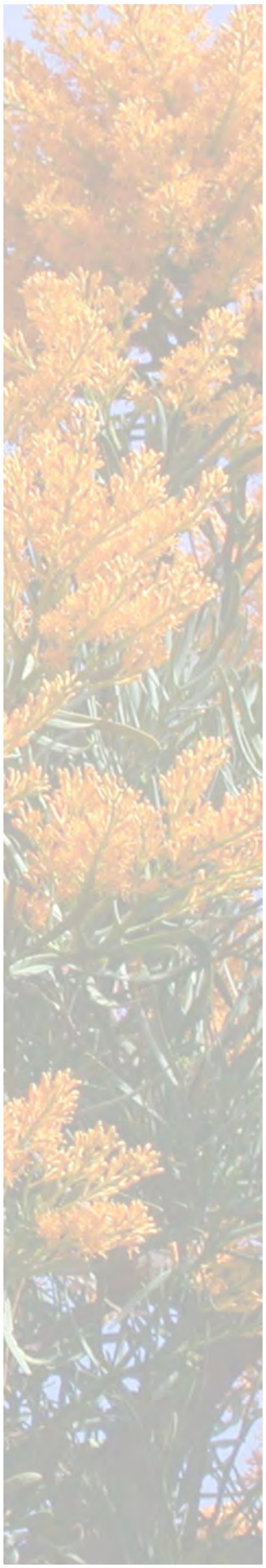
- Protection of wetland values, particularly those of protected wetlands;
- Loss of remnant native vegetation;
- Protection of significant fauna values;
- Maintaining ecological linkages between and within the Beeliar Regional Park;
- Recognising Aboriginal heritage values of the Beeliar Wetlands;
- Protection of residential amenity; and
- Maintaining recreational and educational values of the area.

Since commencing planning for the proposed project, Main Roads has consulted extensively with key stakeholders and the broader community. Community concerns have been broad ranging. A detailed description of the outcomes of SMC's community engagement programme is provided in Appendix B. Around 1,300 comments were recorded during public consultation sessions, covering topics such as:

- Economic management;
- Social, environmental and Aboriginal heritage values;
- Concerns regarding the consultation and project development process; and
- Suggestions for design and alignment solutions.

In summary, the most common environmental factors raised by the community during these sessions included:

- Minimise the footprint on wetlands;
- Minimise clearing and retain native vegetation;
- Maintain fauna connectivity;
- Preserve good value habitat;
- Preserve habitat for black cockatoos, Graceful Sun-moths and Southern Brown Bandicoots;
- Avoid lakes and wetlands;
- Protect groundwater quality;
- Manage stormwater and road run-off quality before discharging it to the environment;
- Use stormwater to recharge lakes and manage water levels;
- Noise;
- Air pollution; and
- Light spill.



The community provided suggestions on how the above concerns could be addressed. A selection of these included:

- Avoid ground disturbance and maintain connectivity through the construction of an elevated highway;
- Install bridges at wetlands;
- Select an alternative alignment;
- Align along the Western Power maintenance track;
- Close Hope Road and install facilities such as parking and a Principal Shared Path (PSP), and rehabilitate redundant sections;
- Enhance the environment through the rehabilitation and restoration of wetland and bushland areas and weed control;
- Eradicate foxes and rabbits; and
- Control midges and mosquitoes.

The preferred concept design is the culmination of a substantial stakeholder consultation and community engagement programme (detailed in Appendix B and summarised in Section 3.4) and is considered to be the least impacting and balanced option that can deliver the required traffic solution.

1.4. Modifications to the Original Proposal

Since submitting the ESD (SMC 2010), there have been several minor changes to the project extent, as forecast in Section 2.1 of the ESD where it was noted that: 'The project may also include minor alterations to other intersections within the affected road network.' When making these changes, SMC ensured that the investigations outlined in the ESD either already encompassed the extended project areas, or extended the scope of the investigations to include the extended areas.

These changes are illustrated in Figure 1.4-1, which indicates the original project area boundary (in black) and the revised project area boundary (in red). A description of each change is provided below, with reference to the numerical annotation shown on Figure 1.4-1.

Figure 1.4-1: Changes to the Proposed Project

SouthmetroConnect

1) Widening of Stock Road to three through lanes, with additional turning lanes at and to the south of the Phoenix Road Intersection. This is required to accommodate the increased traffic through the location as a result of the proposal. This was not evident until detailed traffic modelling was undertaken during project development.

2) Widening of Stock Road extends beyond the original project area to the north to ensure adequate tie-in with the existing lanes on Stock Road. Additional slip lanes into Ralston Street and Counsel Road are included at the request of the community.

3) The loop connecting the proposed highway and Stock Road extends slightly outside of the existing MRS primary regional road reserve into Hamilton Senior High School land. The road geometry is driven by design standards and road safety requirements, which hadn't been fully assessed until concept design development. This occurred after submission of the ESD. The location of the loop is constrained as a result of the south-east corner of the road reserve having been released previously for development.

4) Improvements and upgrades to various local roads are required west of Stock Road to accommodate the impacts from the closure of Forrest Road. These alterations are required to ensure the appropriate level of access and road safety is maintained at this location.

5) There is some minor tie-in work required to provide safe access to the proposed roundabout between Forrest Road and Sudlow Road.

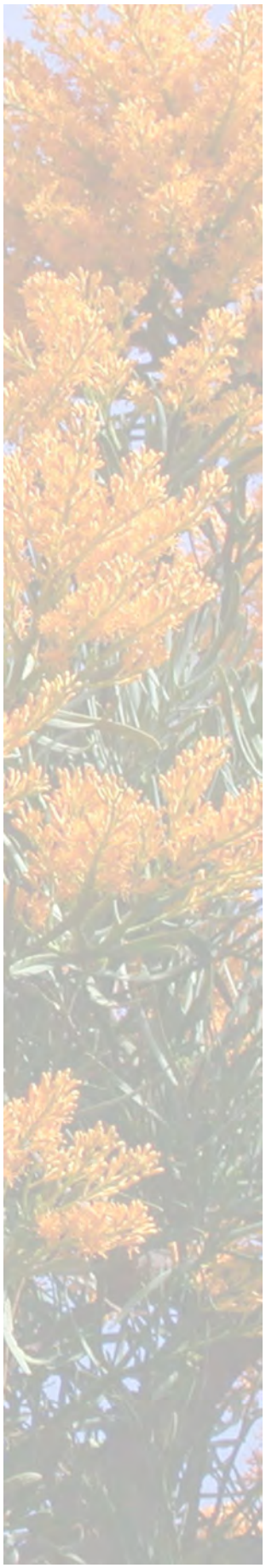
6) The grade separation of Sudlow Road/Coolbellup Avenue and Roe Highway means that the realigned Coolbellup Avenue is higher than the current alignment. This will result in the closure of the access point to Belarius Street. This access will be relocated to a point along Coolbellup Avenue adjacent to Ferdinand Crescent at the suggestion of City of Cockburn officers.

7) There will be minor earthworks required to tie-in North Lake Road to accommodate widening through the proposed North Lake Road Interchange.

8) The design work that sits outside the original project area is required to tie-in the proposed realignment and southern extension of Murdoch Drive. This preferred alignment was developed in consultation with the directly impacted community and stakeholders and is a result of relocating the interchange away from Roe Swamp to minimise environmental impacts.

9) The project area extends north of the original proposal extent to enable tie-in of the Roe Highway off-ramps to Kwinana Freeway north-bound. The extent required to accommodate these works could only be determined once traffic modelling and the Roe Highway/Kwinana Freeway interchange concept were completed. The work as indicated ties in with the proposed widening of Kwinana Freeway between Leach Highway and Roe Highway, which will be completed prior to implementation of this proposal.

10) The project area extends south of the original proposal extent to enable tie-in of the Roe Highway on and off-ramps to the south of the Kwinana Freeway interchange. The extent required to accommodate these works could only be determined once traffic modelling and the Roe Highway/Kwinana Freeway interchange concept were completed. The work as indicated ties in with the proposed widening of Kwinana Freeway between Roe Highway and Armadale Road, which is currently in planning and is likely to be constructed prior to implementation of this proposal.



The proposed project is to extend Roe Highway from its current southern end point at Kwinana Freeway to Stock Road.

11) The project area extends east of the original proposal extent to ensure the Roe Highway/Kwinana Freeway interchange concept design operates effectively. The extension is the result of more detailed interchange design that determined that alteration to the existing infrastructure east of the project area is required to safely permit the required traffic movements at the interchange.

1.5. The Proposed Project

The proposed project is to extend Roe Highway from its current southern end point at Kwinana Freeway in Jandakot to Stock Road in Coolbellup. The road will be constructed almost entirely within government-owned land; however a short section will be constructed outside the Metropolitan Region Scheme (MRS) Primary Regional Roads boundary in order to accommodate an alignment that minimises environmental impacts. There will be no acquisition of privately owned residential land.

Construction of the proposed project will require the following key activities:

- Clearing of up to 112ha of land ranging in condition from 'Completed Degraded' to 'Good to Very Good';
- Removal and stockpiling of topsoil;
- Construction of:
  - Road formation;
  - Road drainage basins;
  - Principal Shared Paths (pedestrian and cycle paths);
  - Retaining walls;
  - Fauna underpasses and culverts;
  - Bridges and overpasses;
  - Noise attenuation walls;
- Installation of street and PSP lighting;
- Realignment of a short section of Murdoch Drain; and
- Rehabilitation of areas disturbed for construction.

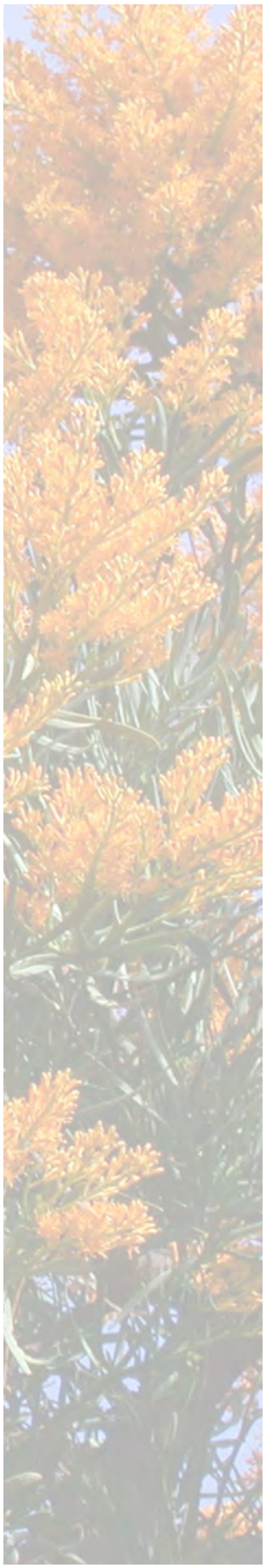
Operation of the proposed project will result in the following key activities:

- Freight transport;
- Private and commercial vehicle movements;
- Operation of street lighting; and
- Maintenance.

In order to accommodate the proposed works where they will occur outside the existing MRS road reserve, a scheme amendment will be required and will be prepared following the Part IV impact assessment process. The key characteristics of the proposed project are outlined in Table 1.5-1.

Table 1.5-1: Key Characteristics of Proposed Project

Elements	Description
Length of highway extension between Kwinana Freeway and Stock Road	Approximately 6.8km from the interchange between Karel Avenue and Roe Highway to the western edge of the Stock Road on-ramp
Murdoch Drive Extension	Full access via an extended Murdoch Drive into and out of the Murdoch Activity Centre from both directions of travel on Roe Highway
Bridge at Roe Swamp	A bridge will span the topographic low point at Roe Swamp.
Bridge located between North and Bibra lakes	A bridge will be constructed between North and Bibra Lakes
Rehabilitation of Forrest Road	Approximately 1.0ha of redundant sections of Forrest Road will be rehabilitated
Cut and fill areas (subject to final design)	~1,123,000m^3 of fill ~1,172,000m^3 of cut
Retaining walls (subject to final design)	~1,360m full height ~420m half height
Water supply (source, hourly requirement during construction)	An estimated 140,000kL of water will be needed for the highway construction, including dust suppression. Water will be sourced from outside the project area and will not result in drawdown on wetlands. Sources and volumes will be determined during detailed design once a contractor is able to confirm requirements
Stormwater basins	Basins will be located adjacent to the proposed project; however, arrangements with the City of Cockburn may be undertaken to use existing basins. Presently, the proposed basins are as follows: • Standard stormwater retention basins to be located at Stock Road Interchange, Kwinana Freeway Interchange, North Lake Road Interchange; Progress Drive Overpass, Murdoch Drive Extension Interchange and various locations along the proposed highway • Stormwater bioretention basin to be located east of Horse Paddock Swamp and south-west of Lower Swamp
Access/haul roads	• Haulage and access will be via the construction corridor, Hope Road, Forrest Road and other existing infrastructure or existing cleared areas • No additional clearing will be required
Total clearing footprint (biological footprint)	• Up to 112ha (inclusive of temporary clearing)
Construction contingency	• Up to an additional 15ha of land outside the current proposed construction footprint to facilitate construction requirements where necessary

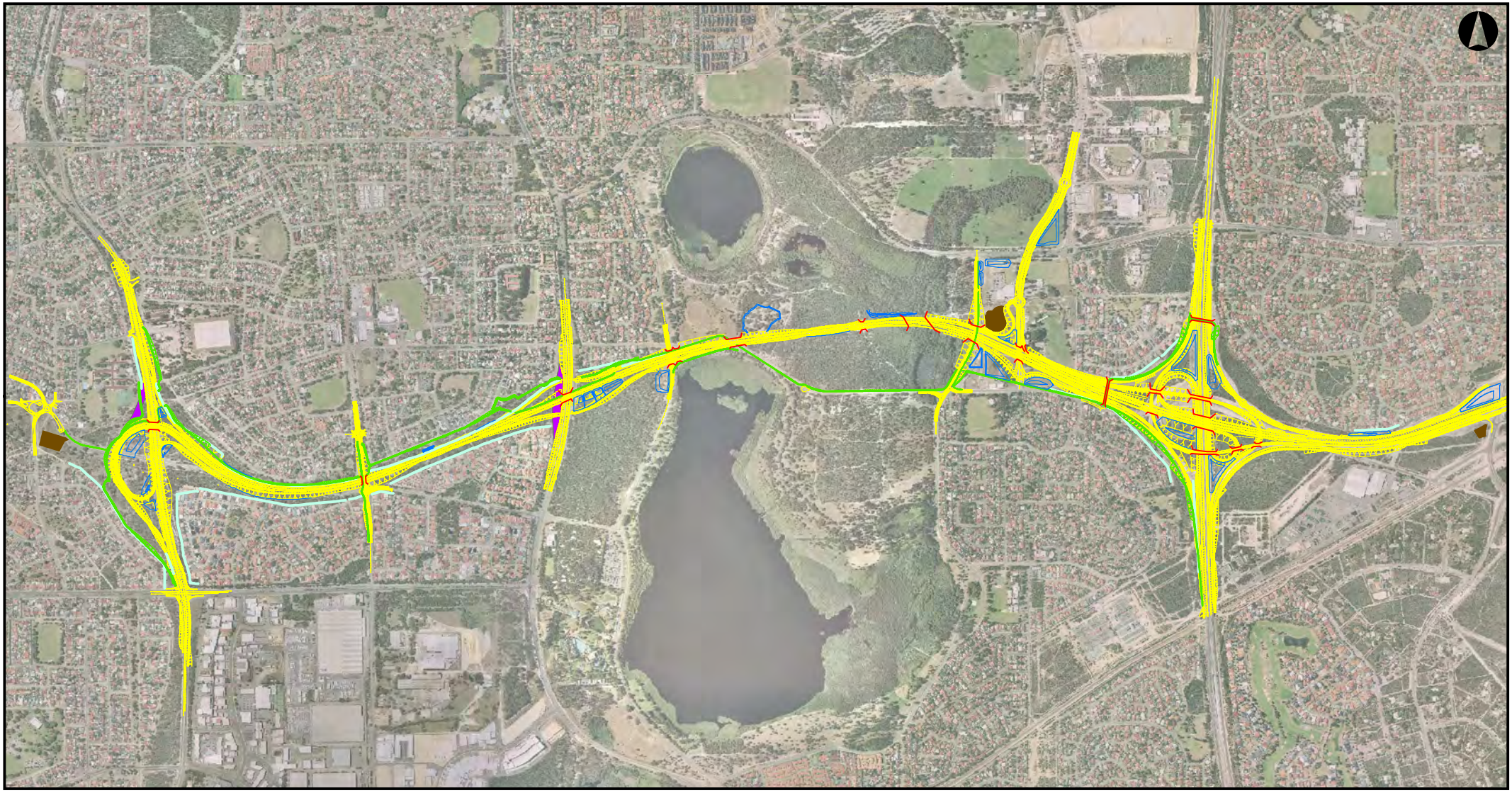


Elements	Description
Area of cleared native vegetation to be rehabilitated	• Up to 38ha
Total clearing of wetland areas (temporary and permanent)*	• Up to 5.80ha of Conservation Category Wetland • Up to 0.95ha of Environmental Protection Policy Lakes • These areas are included in the total clearing footprint

*values are not exclusive of each other and do not include wetland buffers

The total clearing footprint identified represents a 'biological footprint', which is defined as clearing of any area of land that has some form of biological value. In addition to intact native vegetation, the biological footprint includes vegetation ranging between 'Completely Degraded' to 'Degraded' and land currently subject to rehabilitation, landscaping or open grasslands (fields), all of which perform some sort of function as either habitat or linkage. Accordingly, the 'biological footprint' differs in extent to the vegetation clearing area.

The spatial extent of the proposed project is displayed in Figure 1.5-1, with a detailed series of strip maps provided in Section 3.5. Digital spatial data has been provided to Office of EPA (OEPA) upon submission of this PER, in accordance with *Draft Environmental Assessment Guideline No.1 Defining a Proposal* (EPA 2009b).



The Preferred Alignment

South Metro Connect

Figure 1.5-1

0 250 500 750 1,000

Metres

1:25,000 (A4)

- Road Formation
- Bridge Abutment
- Basins
- Principal Shared Paths
- Indicative Noise Walls Design
- Temporary Bypasses
- Laydown Areas

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1.6. Assessment Process and Project Schedule

The proposed project was referred to the State EPA and Commonwealth DSEWPaC in 2009, at which time a PER level of assessment was set and the Bilateral Agreement was enacted.

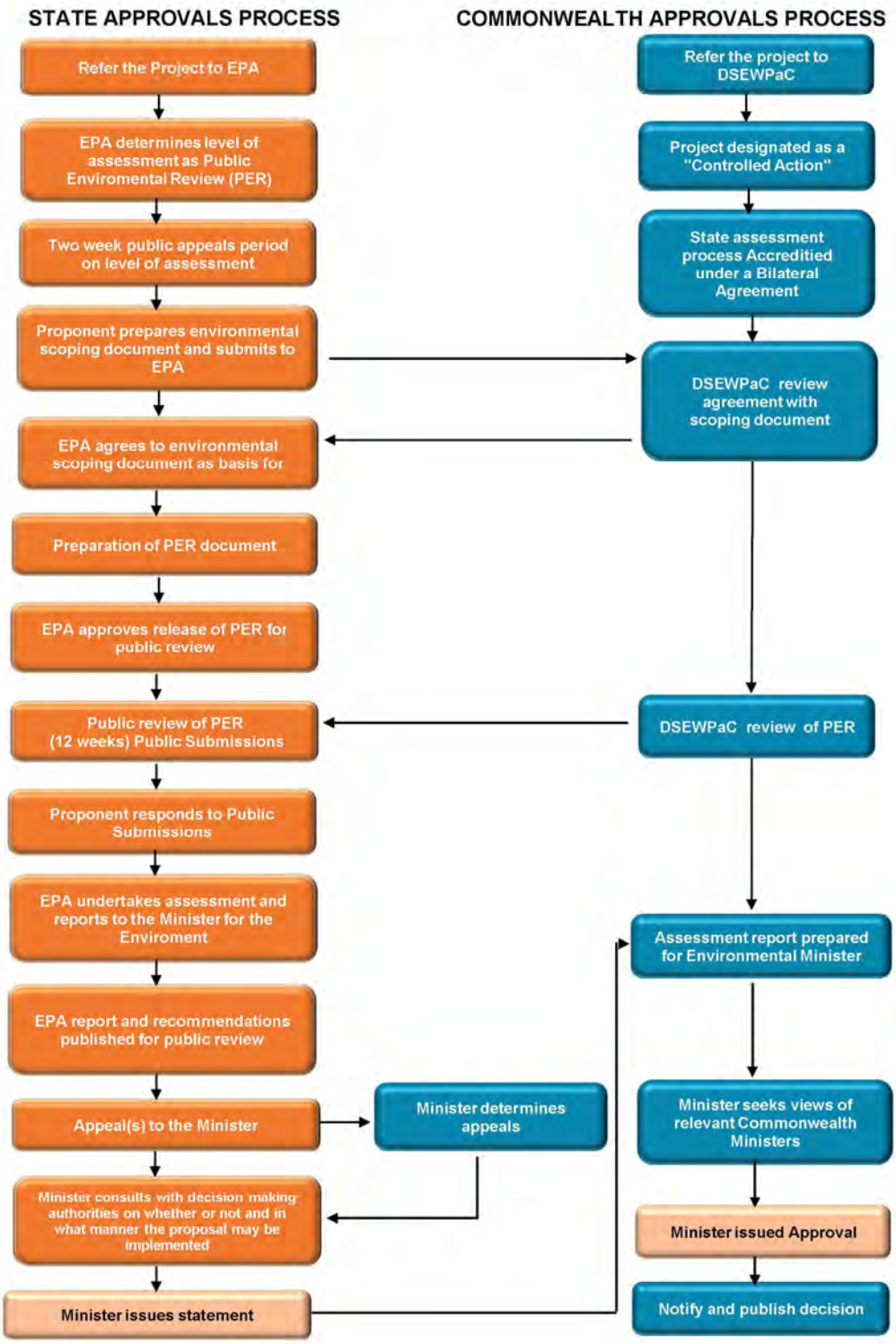
The PER will be subject to a 12-week public review period, after which the EPA will provide a summary and copies of the public submissions to SMC. SMC will prepare a response to the key issues and matters raised in public submissions and provided to the EPA.

After review of the PER, the OEPA will submit an assessment report to the Minister for the Environment. After consideration, the Minister will publish and circulate the assessment report. A 14-day public appeal process will follow the publication of the report. Table 1.6-1 provides the schedule for the environmental assessment for the proposed project. A summary of the bilateral assessment process is presented in Figure 1.6-1.

Table 1.6-1: Project Schedule

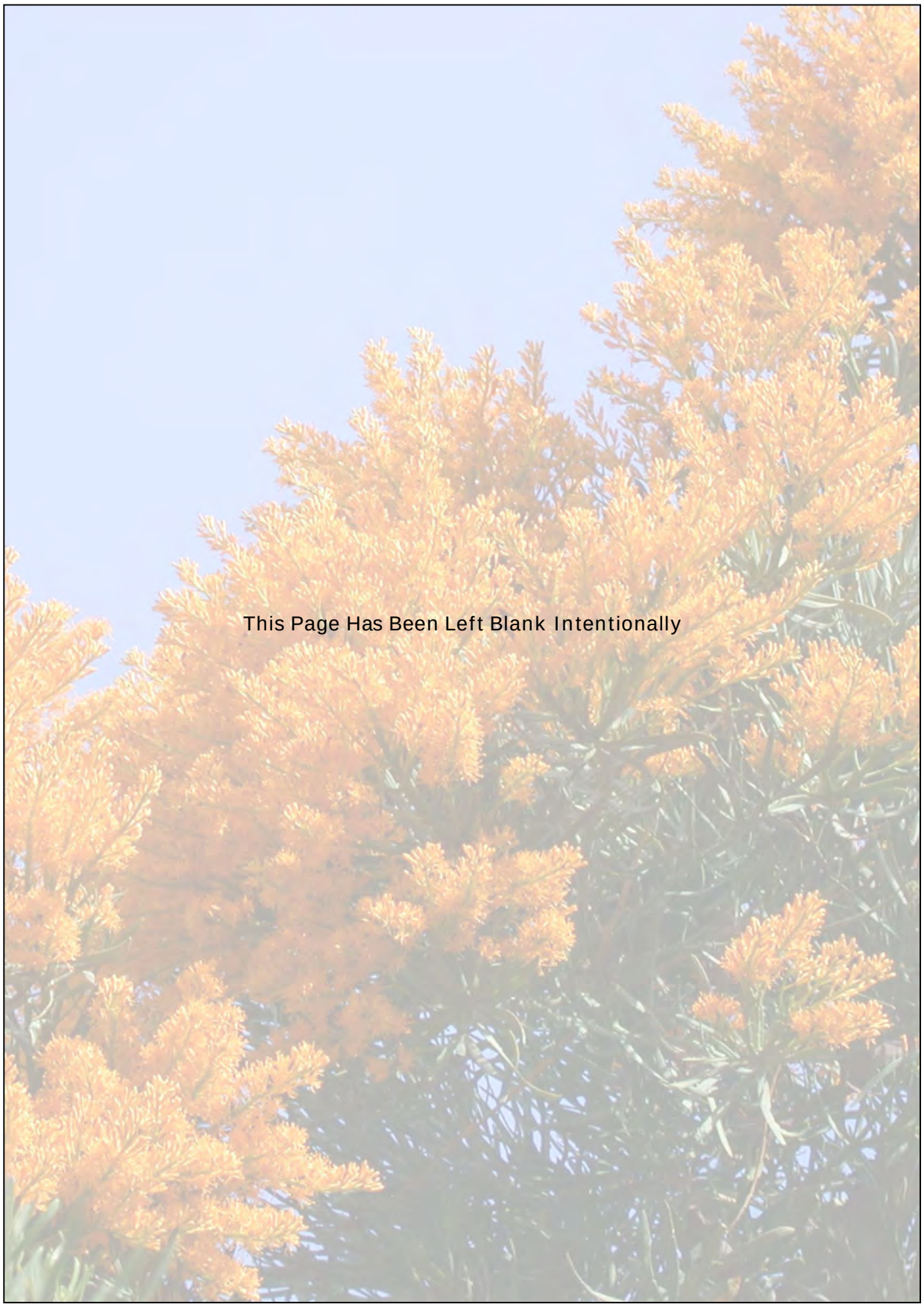
Activity	Date
Approvals	
Proposal referred to the EPA	March 2009
Proposal referred to the DSEWPaC	July 2009
Approval of ESD by OEPA	June 2010
Submission of draft PER to EPA	6 December 2010
Commencement of DSEWPaC review of PER	6 December 2010
Submission of PER (final iteration) to EPA	18 May 2011
Commencement of PER public review period (12 weeks)	20 June 2011
End of public review period	12 September 2011
SMC commences response to public submissions	3 October 2011
Release of EPA report	3 February 2012
Public appeals on conditions	5 February 2012

The construction phase may involve construction of the entire project (as defined in this PER document) or alternatively may involve construction of portions of the project under a staged approach. The decision on whether the proposed project will be staged and the nature and timing of stages will be made by government in consideration of the available funding and other relevant factors.



Source: Adapted from EPA 2007a; DSEWPaC 2011

Figure 1.6-1: Bilateral Assessment Process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2. Project Background and Justification

This section presents the outcome of an extensive community engagement and design development process. This process aimed to develop a solution that addresses current transport needs, as well as considering the environmental and social constraints associated with the project area. This section details the need for the proposed project and discusses alternatives considered previously.

2.1. Project Background

Roe Highway was originally planned to form part of Perth's strategic ring road network. In 1963, the alignment for the proposed project was set aside as a Controlled Access Highway in the Perth Metropolitan Region Scheme (MRS). The highway was designed to connect Fremantle Port with the Kewdale, Welshpool and Canning Vale industrial areas and major transport corridors, including the Great Northern, Great Eastern, Tonkin and Albany highways. Roe Highway from Midland to Kwinana Freeway has been constructed in stages over the last 29 years, with Stage 1 commencing in 1981.

Roe Highway was initially designed to connect to Fremantle Port via a section of road passing through South Fremantle and along Marine Terrace. This section of the highway was deleted from the MRS in 1991. Subsequently, it was planned that Roe Highway would link to the port via the Fremantle Eastern Bypass, which was a section of road planned between Healy Road in Hamilton Hill (close to Stock Road) and High Street in Fremantle.

After 1963, several reports reviewed future transport requirements and strategies with regards to an alignment within MRS boundaries. Generally, the studies identified the need to build Roe Highway from Island Street in Fremantle to the Kwinana Freeway by 1979 (Department of Transport n.d., GHD and Meyrick 2009, HGM 2001, Main Roads 1996, Road Reserve Review (WA) 1991).

In 1988, a study was undertaken for the review of the MRS alignment through North and Bibra lakes (Sinclair Knight & Partners 1988). The study recommended further review to ensure limited impact on the lakes.

During the 1990s, additional studies were undertaken by Main Roads, the Western Australian Planning Commission (WAPC), Fremantle Port Authority (FPA) and the Department of Planning and Infrastructure (DPI, now the Department of Planning (DoP) and the Department of Transport (DoT)) to determine the transport needs and strategy for the project area. Generally, these studies identified a requirement for the completion of Roe Highway (to Fremantle Port) as a strategic freight route. Conversely, one study (*South West Metropolitan Region Transport Strategy*) recommended deleting Roe Highway west of Stock Road and the Fremantle Eastern Bypass from the MRS. The report indicated that building Roe Highway to the west of Stock Road would go against the philosophy of demand management and the aim of reducing car dependency (Travers Morgan Pty Ltd 1992). The land reserved for the Fremantle Eastern Bypass was deleted from the MRS in April 2004 and portions of the available land within the reserve were re-zoned and sold for urban use.

Various studies have identified a requirement for the completion of Roe Hwy as a strategic freight route

Between 2001 and 2002, the Metropolitan Freight Network Review was conducted to review and suggest improvements for freight movement in the Perth metropolitan region. This review incorporated a high level of community and stakeholder involvement (DPI 2002).

In 2004, the Metropolitan Freight Network Review working group for the Freight Network Master Plan conducted a multi-criteria analysis process to consider Roe Highway Stage 7 (South Street to Kwinana Freeway), the current Roe Highway Extension (the proposed project) and other alternatives. Selected route options were assessed against economic, social and environmental criteria.

The highest ranked option was to construct Stage 7 (South Street to Kwinana Freeway), coupled with a major upgrading of Stock Road. While the options for the proposed project ranked low, an option to upgrade Leach Highway west of the Kwinana Freeway ranked highly (GHD and Meyrick 2009), recognising the need for additional east-west road capacity in the area. The Metropolitan Freight Network Review recommended a Six-Point Plan to improve the current freight network, summarised below:

- Extend Roe Highway to the Kwinana Freeway (Stage 7);
- Increase the quantities of freight transported by rail;
- Build a container terminal at Kewdale to minimise unnecessary truck movements;
- Improve road use by freight traffic to reduce unnecessary truck movements;
- Extend Outer Harbour; and
- Improve existing roads.

Following the Metropolitan Freight Network Review, various studies were completed that did not identify the proposed project as a solution and which supported the Freight Network Strategy. One study conducted within this time period suggested that intersection improvements and congestion management solutions, along routes such as Leach Highway and South Street, would ease traffic congestion in the region (Freight Network Review Second Congress 2002).

In August 2002, the then Minister for Planning and Infrastructure established the Local Impacts Committee (LIC) to identify ways of managing traffic within the south-west metropolitan region (DPI 2005a). The LIC undertook technical investigations, in conjunction with community consultation, to identify problem areas within the network and to recommend appropriate solutions in line with the recommendations of the Metropolitan Freight Network Strategy (DPI 2005a). The key recommendations made by the LIC included:

- Develop plans for sections of Leach Highway, High Street, South Street and Stock Road with the aim of reducing congestion, social and environmental problems associated with the road network;
- Implement a broad and comprehensive road congestion management strategy for the south-east metropolitan region;
- Develop a road network enhancement strategy, which would involve retro-fitting existing road infrastructure to ensure environmental and social improvements for local communities;

- Pursue further vibration studies by the DoP and Main Roads to improve the understanding of the relationship between technical analysis and community perceptions of noise along roads with heavy traffic; and
- Provide advice to various government agencies in relation to identified problems with the freight network, as well as the assessment techniques used by the LIC (DPI 2005b).

Roe Highway Stage 7 was completed in 2006 and presently terminates at Kwinana Freeway. The State Government made a commitment to extend Roe Highway west from the Kwinana Freeway in the lead up to the last Western Australian State Election. The Roe Highway Strategic Review (GHD and Meyrick 2009) concluded that the proposed project is now required, due to inadequate existing transport infrastructure to support present and future development and to ease congestion. This is consistent with the findings of most related previous studies. The study supports the MRS alignment and found that the proposed project is required for the following reasons:

- To increase efficiency of freight movements to and from key industrial areas, in particular Fremantle Port and major intermodal and freight warehousing precincts including, but not limited to, Welshpool, Cannington and Kewdale;
- To reduce air pollution through the removal of stop and start operations at traffic signals and by reducing travel times;
- To increase safety of the road network through the reduction of heavy vehicles on parallel east-west interactive streets (streets with multiple access points and residential and retail developments); and
- To reduce traffic volume along the already congested Leach Highway and South Street.

In August 2009, the Minister for Transport announced the creation of the South Metro Connect (SMC) project team to manage the environmental and other approvals, concept design and community engagement processes for the proposed project. The Minister emphasised that the State Government recognised the value of the natural environment in the vicinity of the proposed project and that the project team would strive to meet the highest possible environmental and community engagement standards.

In 2009, the proposal was referred to the Environmental Protection Authority of Western Australia (EPA) and the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC, the then Department of Water, Heritage and the Arts (DEWHA)); thereafter the Bilateral Agreement was enacted. The EPA set the level of assessment for the proposed project at Public Environmental Review (PER). DSEWPaC has classified the project as a 'controlled action' pursuant to the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*), requiring approval by the Minister for Sustainability, Environment, Water, Population and Communities.

The State Government recognises the value of the natural environment.

The Minister for Transport committed the project team to strive to meet the highest possible environmental standards

An Environmental Scoping Document (ESD) was prepared by SMC, in consultation with the community and other stakeholders, to provide a scope of works for the PER for the assessment of the proposed project. Interested stakeholders and the wider community were given the opportunity to provide input for the ESD at targeted focus group sessions and a community information day. The preliminary ESD was then provided to interested stakeholders and publicised on the SMC website for a four-week period, to enable the public to review and comment on the document. The ESD defined critical issues and outlined additional studies necessary to make an informed assessment of environmental and social impacts of the proposed project, in compliance with Section 45 of the *EPBC Act* and Section 38 of the *Environmental Protection Act 1986* (*EP Act*).

A draft ESD was submitted to the Office of the Environmental Protection Authority (OEPA) in November 2009 and distributed to key stakeholders for review and comment. These comments were considered and the ESD revised accordingly. The revised ESD was submitted to the OEPA on 22 April 2010. It was approved by the OEPA on 15 June 2010 as guidelines for the preparation of this PER.

2.2. Project Justification

The proposed project is justified within the context of Perth's forecast urban and industrial growth to 2031 and within the overarching strategic plan for accommodating this growth. This section provides an analysis of Perth's transport needs that highlights the importance of transport infrastructure in facilitating continued growth.

2.2.1. Forecast Growth

Three key factors are likely to contribute towards increasing pressure on Perth's south-west metropolitan road network (GHD and Merrick, 2009):

- Population growth;
- Growing freight task; and
- New development.

Table 2.2-1 shows the projected growth in population for the cities of Cockburn, Melville and Fremantle by 2031. The population of the Perth metropolitan and Peel regions (the region) is expected to grow by approximately 35 percent, to reach more than 2.2 million by 2031. To accommodate this level of growth, it is estimated that another 328,000 houses and 353,000 jobs will be required (WAPC 2010).

Table 2.2-1: Projected Population Growth for Relevant Local Government Authorities

	Population				Occupied Dwellings		
	2010	2031	Total Growth	Average Annual Growth Rate	2010	2031	Total Growth
City of Cockburn	88,599	127,888	44.3%	1.76%	34,249	52,519	53%
City of Melville	99,485	109,194	9.8%	0.44%	40,299	46,156	14.5%
City of Fremantle	28,498	37,632	32%	1.4%	11,850	14,190	19.7%

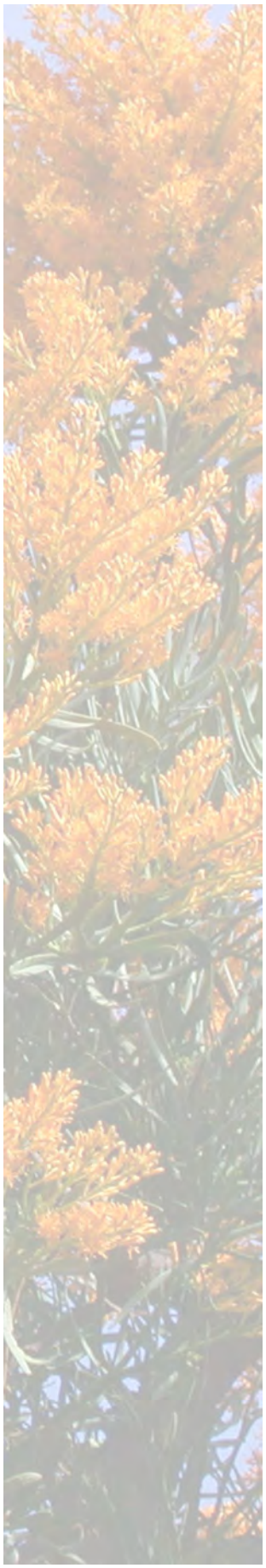
Source: Australian Bureau of Statistics Census 2006

By 2031, Perth's south-east metropolitan area is expected to grow by 34 percent to 228,000 people. The population of Perth's south-west metropolitan area, which includes the project area, is predicted to increase by 34 percent to 278,000 (WAPC 2010). Current urban growth areas of significance include the suburbs of Southern River, Forrestdale and Armadale. Planned urban growth areas include the Murdoch Activity Centre (MAC), Port Coogee and the Western Trade Coast, incorporating the Latitude 32 and Henderson industrial areas. Significant residential growth is expected to occur in locations adjacent to the Kwinana Freeway, such as Aubin Grove-Banjup, Hammond Park-Wattleup and further south, associated with the Town of Kwinana Eastern Residential Intensification Concept. The growth expected for the region will significantly increase traffic levels on the road network, particularly during peak periods.

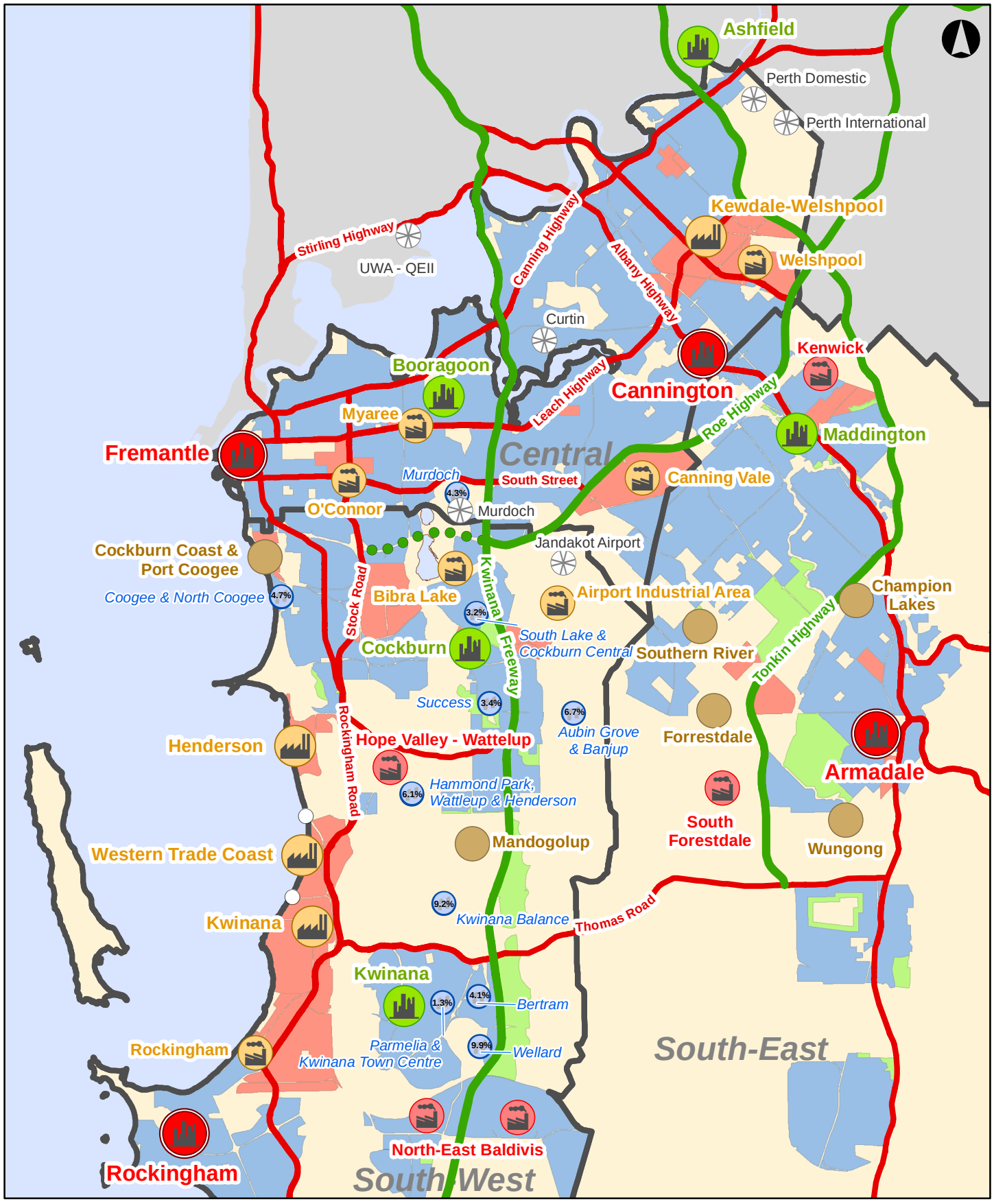
Maddington-Kenwick and South Forrestdale are at varying stages of investigation for their suitability for industrial uses, as they are connected to intermodal freight facilities and are ideally located to develop synergies with major export-oriented industrial centres, such as Latitude 32 (WAPC 2009a). Figure 2.2-1 depicts the current and planned spatial distribution of urban growth and industrial centres in the south-east.

Altogether, the south-west metropolitan area has nine industrial locations and an aggregate area of 6,400 hectares (ha) of land, of which 2,450ha are currently yet to be developed for industrial, residential or commercial uses (GHD and Merrick 2009).

Over the next 20 years, the total quantity of imported and exported international freight in Perth is anticipated to double, which will be reflected in a growth of road freight on the Perth Urban Corridor of between two and four percent per year between now and 2025.



Inter and intrastate freight currently accounts for the greatest proportion of freight movements by road, with 80 percent of road movements made by small to medium-sized trucks. Much of the freight task utilising the Perth Urban Corridor is not port-related and travels relatively short distances in the metropolitan area to highly dispersed origins and destinations. Therefore, although rail freight targets aim for 30 percent of port-related traffic to be moved by rail, it is unlikely that rail will carry more than a minor proportion of the metropolitan freight task (GHD and Merrick 2009), leaving the majority of the freight transportation task to the road network.



Regional Development Centres

South Metro Connect

Figure 2.2-1

0 1 2 3 4 5

Kilometres

1:200,000(A4)

- Strategic Metropolitan Centre
- Secondary Centre
- Strategic Industrial Centre
- Other Industrial Centre
- Priority Industrial
- Future Residential
- Strategic Specialised Centre
- Freeway/ Controlled Access Highway
- Major Road
- Sub-Region Boundary
- Proposed Project
- Industrial
- Urban
- Urban Deferred

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SouthmetroConnect

2.2.2. Planning for Growth

Directions 2031 builds on many of the aspirational themes of *Network City*, the superseded blueprint for Perth's future growth that interlinked transport and land use, including environmental protection (WAPC 2004). *Directions 2031* identifies a hierarchy and spatial distribution of core growth centres that are the focus of planning and the provision of housing, commercial development, infrastructure and services that are necessary to accommodate the expected growth (WAPC 2010). The development of activity centres is intended to lead to a reduction in the length of individual trips and reliance on motor vehicles.

As Perth city grows, the amount of freight to be transported and the increasing distances required for distribution will place significant pressure on transport infrastructure. Perth's radial transport network provides access to the central business area, but it draws a high proportion of daily trips through the centre to other destinations. This results in increased network congestion. The use of Kwinana Freeway between Roe Highway and Leach Highway as a major freight route for vehicles travelling between Kewdale and Fremantle is an example of this type of inefficiency. Building better connections between activity centres is intended to moderate pressure on the central area transport network.

The implementation of *Directions 2031* seeks to enhance the efficiency of the freight transport system. It recognises that freight transport facilities and routes must be protected and that measures are needed to address problems on existing transport corridors. Presently, various roads that are identified as urban corridors also function as freight routes, such as the section of South Street west of the Kwinana Freeway. As urban corridors are developed to create commercial and residential precincts, the freight network will need to be restructured to eliminate non-local road freight.

In the financial year 2008-09, Fremantle Port handled approximately 550,000TEU (20 foot (container) equivalent units). At its peak, 18 percent of this freight was transported by rail and the remainder by road. The volume of freight transported by rail has since reduced. The capacity of this rail track is limited because:

- A single track connects the port to the main railway line;
- Sections of the track are shared with the urban passenger rail line, resulting in morning and afternoon peak hour curfews (up to three hours each) to allow the passenger lines to meet their capacity requirements;
- Sections of the track are located in predominantly residential areas in South Fremantle and Cockburn. To minimise the impact on residents, the FPA has minimised rail movement along the line between 10:00pm and 5:00am; and
- At Cockburn, the track joins the main railway line connecting Perth's major industrial areas of Forrestfield and Kwinana. This track is currently well-utilised and will be more so in the future with the transportation of iron ore to the Kwinana Bulk Port.

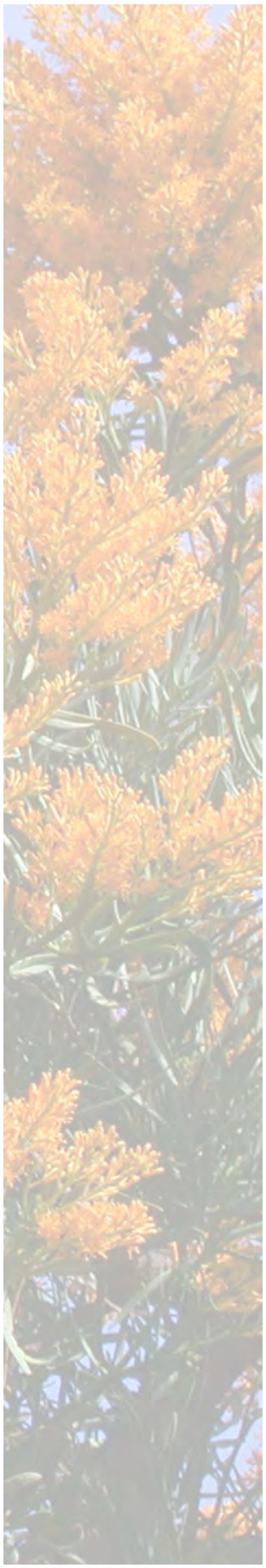
The port activity is predicted to expand to 1.2 million TEU per year. In order to accommodate 33 percent of this throughput (400,000TEU), the rail line will require upgrading by construction of a second track, together with night time running and double stacking of containers. An additional increase in freight movement by rail will require further upgrades. However, this will increase the cost of the rail, which may reduce its economic viability. Even if this stretched target is met, road freight will still be required to accommodate up to 600,000TEU, which is substantially more than at present.

Historic improvements in the efficiency of Perth's freight network, such as the completion of Roe Highway Stage 7, have come at the expense of a gradual reduction in levels of service on Kwinana Freeway, Leach Highway and South Street. This trend of declining level of service is likely to continue. Recent traffic modelling indicated that the existing road network cannot support the anticipated population growth and the expected industrial, residential and commercial development in the south-west metropolitan area (GHD and Meyrick 2009).

To successfully plan for the extent of residential, commercial and industrial growth predicted for the region, managing the region's transport network is considered a high priority. In implementing the strategic plan for the region, there is an assumption that the development of transport infrastructure will match forecast growth levels for the planning period.

Strategic land-use planning for the region recognises that development and growth can often conflict with the protection of the natural environment (WAPC 2010). For Roe Highway, the challenge is to deliver safe and reliable transport solutions that provide travel choice, whilst protecting and maintaining the surrounding natural environment.

The proposed project facilitates direct freight movement between Perth Airport, Kewdale-Welshpool and Fremantle Inner Harbour via Stock Road; as well as to Latitude 32, Fremantle Outer Harbour, James Point Port and industrial areas associated with the Australian Maritime Complex and Kwinana (Figure 2.2-2). The proposed project and associated road improvements merits consideration as a required component for the implementation of the region's strategic plan.



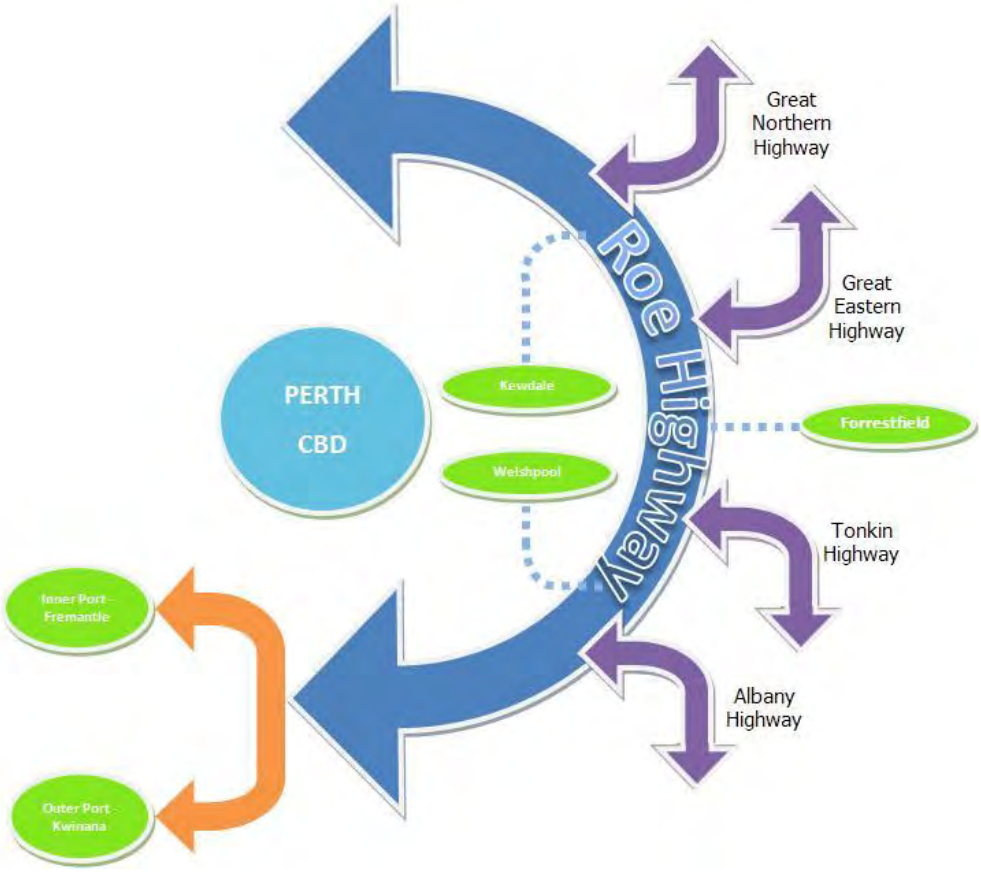


Figure 2.2-2: Roe Highway as an Orbital Route

2.2.3. Transport Needs

In 1955, a planning strategy for Perth, *Plan for the Metropolitan Region* (Stephenson and Hepburn 1955), identified Roe Highway as a strategic orbital route around Perth, connecting Fremantle Port with the eastern suburb of Midland. This extension is required to meet the transport needs of the southern Perth metropolitan area by:

- Providing a new east-west link;
- Reducing congestion on existing east-west links;
- Supporting economic development; and
- Providing access into the MAC via an extension of Murdoch Drive.

2.2.3.1. A New East-West Link

Primarily, the proposed project will provide a vital east to west road link from Kwinana Freeway to Stock Road. This east-west link is a continuation of the existing freight network and is required to improve the efficiency of the thousands of freight movements to and from the growing industrial areas in the region. The proposed project will ultimately provide the increased volume in freight movements, as well as everyday motorists, with a more direct route to various destinations. This will reduce time spent on the road by improving the efficiency of the southern metropolitan road network.

Regional traffic modelling forecasts an increase in daily traffic by up to 85,000 from 2006 to 2021 in traffic moving between Kwinana Freeway and Stock Road, from Canning Highway in the north to Anketell Road in the south. The majority of this increase is predicted to occur north of the Forrestfield to Kwinana freight railway line. Presently, Leach Highway and South Street are used extensively by freight and industry to transport goods to and from the Fremantle Inner Harbour. While these roads are currently the primary access routes used by industry, neither road is designed for the daily heavy vehicle movements that they experience. Both roads feature a number of large signal-controlled intersections and numerous uncontrolled access points to adjacent residential and commercial properties. These features increase friction between light and heavy vehicles, causing increased delays and raising safety concerns for motorists, pedestrians and nearby residents.

Between Kwinana Fwy and Stock Rd, traffic modelling forecasts a daily increase by up to 85,000 from 2006-2021

2.2.3.2. Supporting Economic Development

The project area is located within a region identified for significant growth over the next 20 years. In the short term, the proposed project will support the growing number of freight vehicles utilising the Fremantle Inner Harbour and other local industrial areas. In the long term, it will provide the necessary infrastructure for businesses to operate effectively, which is crucial for stimulating and supporting the economic growth of the Perth southern metropolitan region. Present and proposed development is expected to provide thousands of employment opportunities. There is a need for improved infrastructure in the area with regional development areas such as those listed below (and illustrated in Figure 2.2-1):

- Kwinana Industrial Area;
- Australian Marine Complex;
- Latitude 32 Industrial Area;
- Fremantle Outer Harbour (Kwinana Quay); and
- James Point Private Port.

2.2.3.3. Murdoch Activity Centre

The MAC is one of Perth's planned urban growth areas. It will include the Fiona Stanley Hospital and a number of health and educational institutions, producing one of the largest concentrations of employment (35,000 jobs) outside the central business district (WAPC 2010). Traffic modelling shows that the MAC is expected to generate a significant increase in traffic in the area, contributing to additional demand on the currently stressed accesses along South Street. In particular, the Murdoch Drive/South Street intersection and the Kwinana Freeway/South Street interchange are expected to struggle to cope with the additional demand from the MAC, with primary access only provided by the Murdoch Drive/South Street intersection.

In order to accommodate expected increases in traffic demand due to employment and visitors to the MAC, a new southern access is required by an extension of Murdoch Drive south of the Farrington Road Intersection. Traffic is best delivered to this access point via the proposed project, as it accommodates efficient traffic movement to the site from the south (via the Kwinana Freeway), as well as from the east via Roe Highway. If access to the MAC is provided from the west, via the proposed project, traffic efficiency would considerably improve. Connection with the proposed project would reduce congestion on South Street and provide efficient access to the MAC (including the Fiona Stanley Hospital).

2.2.4. No-build Option

Since 1955, the justification for the proposed project has been reviewed in numerous reports, the majority of which conclude that the proposed project is required to ease congestion. The strategic rationale for constructing the proposed project was confirmed and documented by Main Roads in 2001 (HGM 2001). This study determined that managing the existing network without the proposed project would not adequately satisfy key freight desire lines, thereby jeopardising safety, local air amenity and efficiency (HGM 2001 from GHD and Merrick 2009).

Following the 2001 study, the 2002 Metropolitan Freight Network Strategy was developed by the then Department of Planning and Infrastructure in consultation with all relevant state government agencies, and was strongly based upon a congestion management philosophy. One outcome of the Strategy was to limit the extension of Roe Highway as far as the Kwinana Freeway. Alternative methods of congestion management were then investigated and outlined in the *Local Impacts Committee Report* (DPI 2005b). Even with the successful implementation of a congestion management strategy, the technical findings of the LIC report imply that forecast traffic volumes on major east-west corridors will still create unacceptable congestion at intersections and driveways by 2031, for which there are no low-cost solutions (GHD and Merrick 2009).

Subsequent studies detail the road widening and road extension projects that are required to relieve the areas subject to 'unacceptable congestion' by 2031. The proposed project is one of the extension projects aimed at minimising the total vehicle travel time and kilometres travelled (ARRB 2007 from GHD and Merrick 2009).

Levels of Service are represented graphically in Figure 2.2-3. Level of Service (LOS) A represents optimum conditions and LOS F represents the worst. The impacts of forecast traffic growth upon major roads in the south-west metropolitan region without the inclusion of the proposed project are shown in Figure 2.2-4 and Figure 2.2-5 (the then Department for Planning and Infrastructure WA and SKM 2005, as cited in GHD and Merrick 2009).

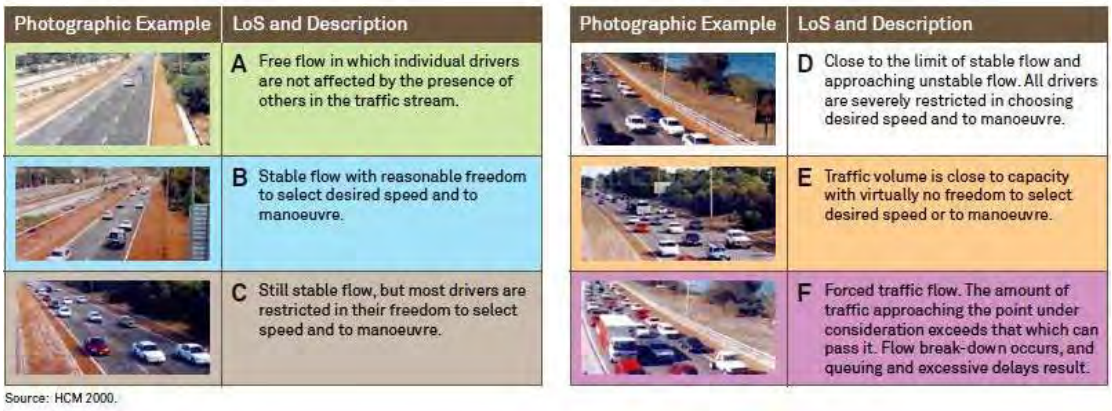


Figure 2.2-3: Level of Service (LOS) Descriptions

Of the 11 mid-block locations measured (i.e. at locations approximately half-way between intersections – see Figure 2.2-4), nine are forecast to exhibit worsened or unimproved level 'F' congested conditions by 2031 without the introduction of the proposed project. Of the 17 intersections measured (Figure 2.2-5), ten locations are forecast to exhibit worsened or unimproved level 'F' congested conditions by 2031 without the introduction of the proposed project.

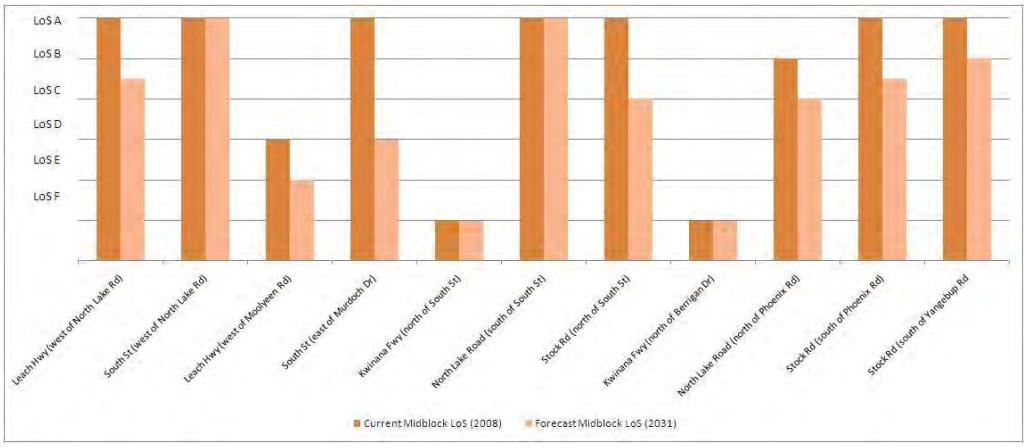


Figure 2.2-4: Predicted Midblock LoS on the Existing Road Network without Roe Highway

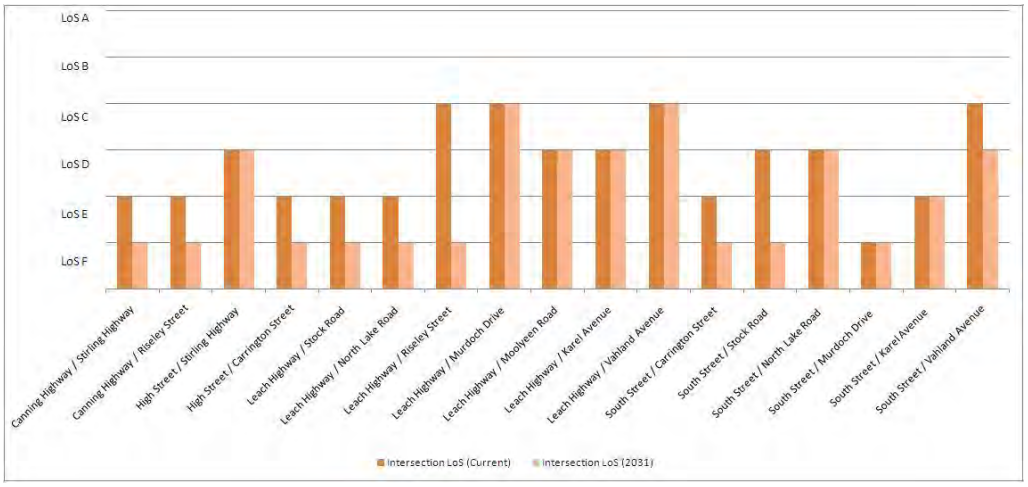


Figure 2.2-5: PM Peak Hour Levels of Service at Intersections in the Existing Road Network without Roe Highway

The proposed project is forecast to reduce the number of vehicles, particularly heavy vehicles, along Leach Highway, South Street, Farrington Road and North Lake Road. The graphs shown in Figure 2.2-6 illustrate the predicted reduction in traffic (at positions approximately half-way between Kwinana Freeway and Stock Road) as a result of the implementation of the proposed project.

A reduction in vehicle numbers, particularly heavy vehicles, is forecast along Leach Hwy, South St, Farrington Rd and North Lake Rd

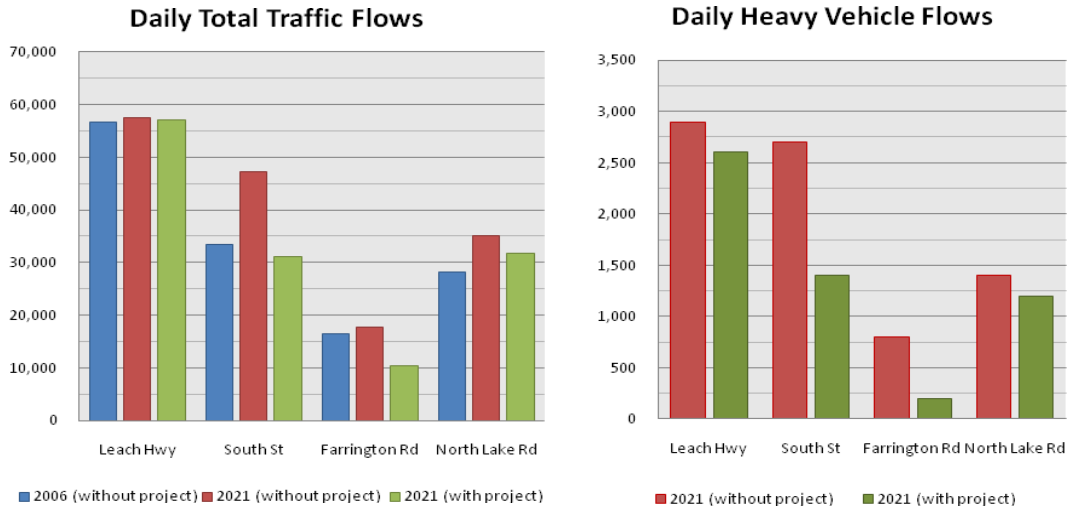


Figure 2.2-6: Daily Traffic Flows on the Surrounding Road Network

Figure 2.2-6 shows that the traffic is forecast to increase noticeably on roads surrounding the proposed project from 2006 to 2021. The proposed project is forecast to reduce the combined total traffic in 2021 across these roads to a lower level than the combined total in 2006. The reductions in traffic volumes mean that the LOS along Leach Highway, South Street, Farrington Road and North Lake Road will improve with the implementation of the proposed project.

Figure 2.2-7 shows the difference in the LOS at certain mid-block and intersection locations on these roads with and without the proposed project, by 2021. The improvements in LOS on the local road network would enable congestion management measures to be successfully implemented. Leach Highway and South Street will approach or exceed the limits for stable flow at the depicted intersections. Without the proposed project, this is forecast to deteriorate to a forced flow condition in 2021. Generally, the depicted road segments and intersections are expected to be relieved as a result of the proposed project. This is most noticeable on South Street.

The forecast deterioration of LOS on Stock Road is explained by the diversion of traffic to Stock Road via the proposed project. Stock Road is planned to be upgraded to a freeway to carry high volumes of traffic, including high volumes of freight. The LOS estimates have been based on the current road capacity rather than the planning freeway capacity values. The LOS values depicted in Figure 2.2-7 demonstrate that the construction of the proposed project accelerates the need for the proposed future upgrade of Stock Road.

The proposed project is expected to carry on average 60,000 vehicles per day by 2031, which would otherwise be using local roads in the area. The proposed project will provide a route designed for the safe and efficient movement of heavy vehicles, which is anticipated to be in excess of 6,000 vehicles a day. Without the proposed project, these vehicles would have to be accommodated elsewhere in the network, most likely along less desirable routes.

Metropolitan Perth has a high car dependency and relatively low population density. Successful implementation of a long-term congestion management plan must also include significant travel behaviour change. According to Directions 2031, current private car use accounts for 57 percent of daily trips. If the move towards greater use of public transport and non-motorised transport modes continues along its current trend, private car use is expected to reduce from 57 to 50 percent of daily trips by 2031. Despite the proportional reduction, there will still be an overall increase in total vehicle trips associated with the expansion of the metropolitan population. These vehicles will require management through the introduction of appropriate infrastructure and technology, as well as support from education initiatives, mode choice opportunities and strategic land use planning.

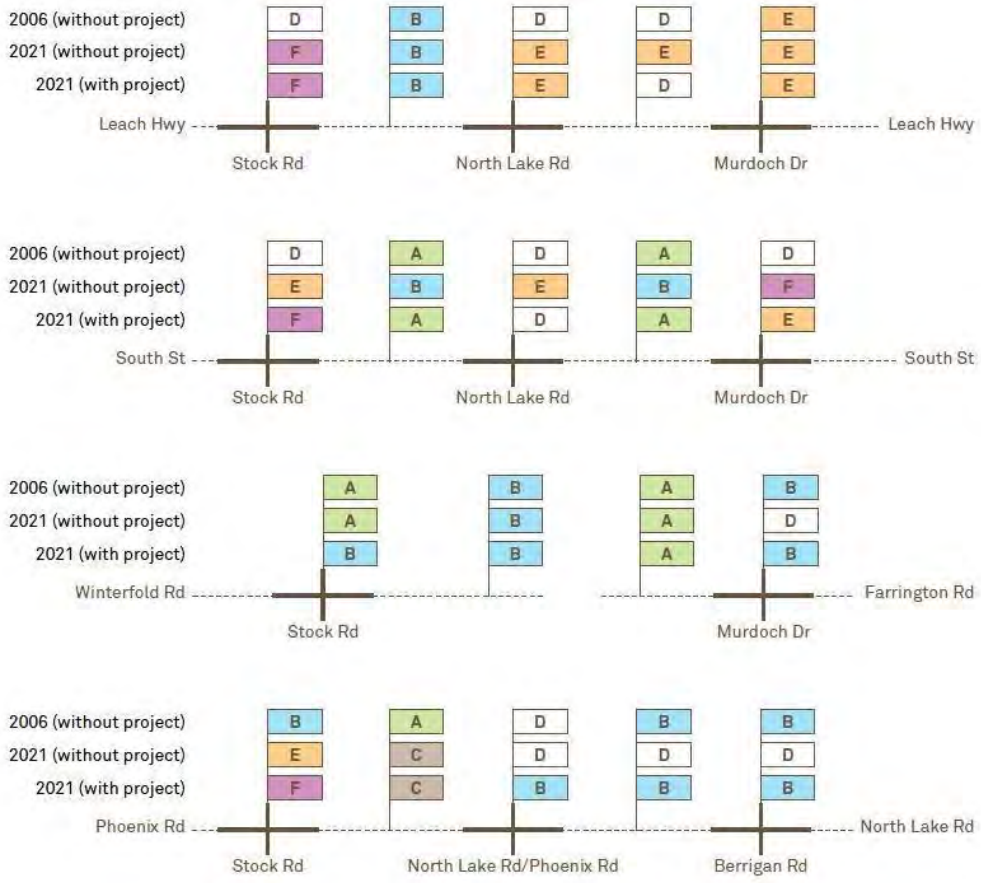


Figure 2.2-7: Forecast Levels of Service on the Surrounding Road Network

2.2.5. Alternatives Considered

Since the inclusion of the Roe Highway reserve in the MRS in 1963, urban development has resulted in very little land suitable for a transport corridor being available. Whilst investigation of alternative alignments was beyond the scope of SMC, several previous studies have investigated alternative routes, albeit few in the context of a completed Roe Highway Stage 7 (e.g. WAPC 2004; SKM 1988; WAPC 2009a). Those that have been prepared since completion of Roe Highway Stage 7 generally work on the assumption that Roe Highway will not be constructed beyond Kwinana Freeway, but do not recommend viable alternatives to address the traffic congestion detailed in Section 2.2.4.

An investigation of traffic issues in the south west Perth metropolitan area (DPI 2005a) recommended intersection improvements and congestion management solutions, working on the theory that building new infrastructure only solves congestion in the short term.

The option of realigning Roe Highway extension to the existing Forrestfield to Kwinana freight railway line was investigated in 2002 (DPI 2002). This option has been proposed as an alternative to the proposed project on several occasions at stakeholder workshops and meetings. A railway alignment option built to the same standard as the proposed Roe Highway Extension is deficient when compared to the MRS alignment (proposed project) for the following reasons:

- It involves significant resumption of land and residential properties, therefore having enormous social impacts that were not envisaged in the original planning for this road;
- Because of its orientation further to the south, the railway alignment does not attract traffic that currently uses Leach Highway or South Street and does not improve access to the inner harbour to the same extent;
- As a result of the construction of Roe Highway Stage 7 and the current location of the Kwinana Freeway interchange, an extension that follows the freight railway is no longer viable; and
- The railway alignment does not allow for improved access from the south to the rapidly expanding MAC area, which the MRS alignment (proposed project) would provide.

During design development for the proposed project, several alternative solutions for traversing the wetland section (i.e. between Bibra Drive and Progress Drive) within the specified project area were investigated. A Multi Criteria Analysis (MCA) was undertaken for a selection of the more viable options. This process is discussed in Section 3.4. In addition to the four options presented in Section 3.4, the design team investigated the options of building a bridge over the entire section, or a tunnel using either a cut and cover construction method or a boring method.

The bridge option, which included consideration for features such as the creation of an elevated tunnel to prevent bird strike, minimise noise impacts and contain air emissions, was rejected on a combination of environmental and cost factors. From an environmental perspective, many of the perceived advantages of including a conventional bridge that crosses the entire wetland would not be realised when a detailed consideration of construction requirements was made. These include:

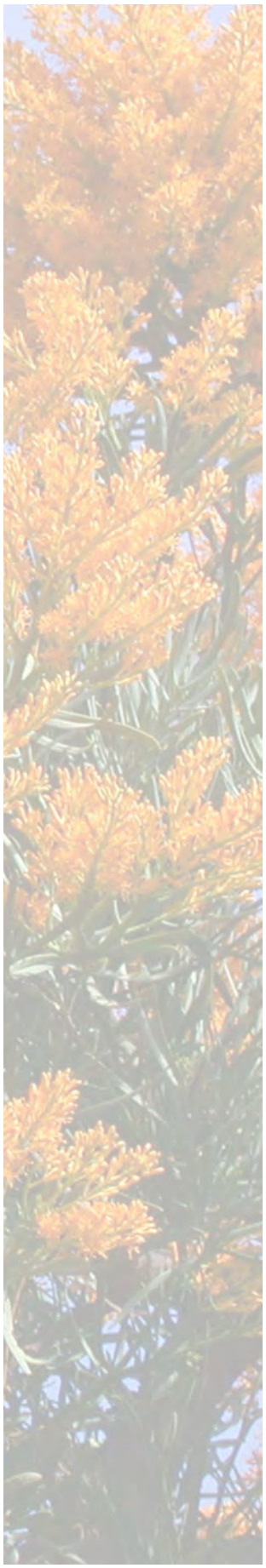
- Full clearing under the structure would be required along its entire length to allow construction access, making it difficult to regrow vegetation and re-establish ecological linkages;
- The weight of the structure would require significant piling or spread footings to be constructed, increasing the depth of impact below ground level; and
- The size of the structure would result in a much greater level of visual impact.

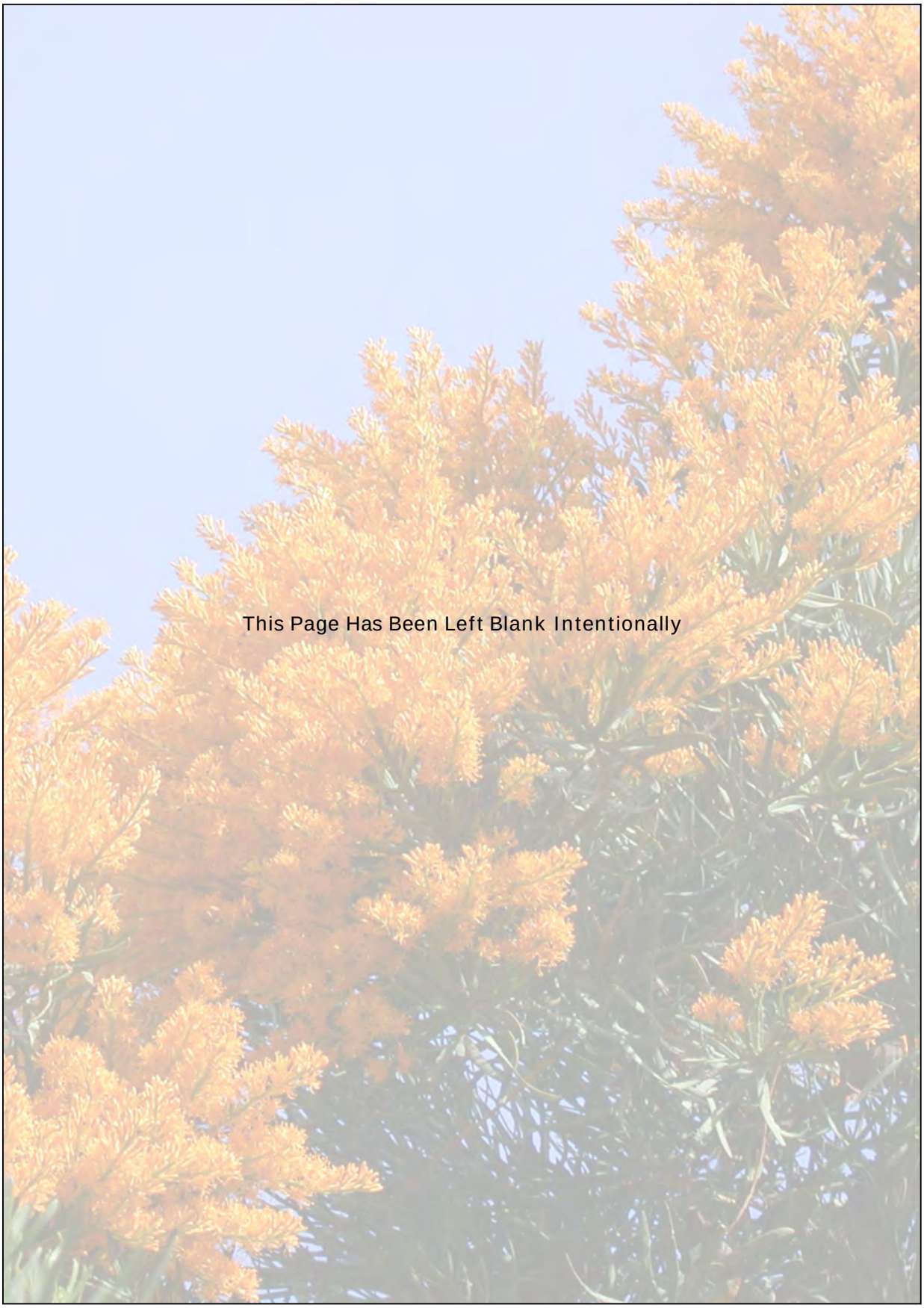
Despite discounting the bridge option during design development, the environmental benefits were considered sufficient to revisit the option during the MCA process, as discussed in Section 3.4.

The two tunnelling options were considered in detail in a study undertaken in 2001 (HGM 2001). This study, which was revisited during design development for this project, considered the issues surrounding the construction of a bored and a cut and cover tunnel.

Cut and cover construction would result in a significant amount of clearing through the wetlands – similar to that required for the option presented within this PER. Both methods would result in the creation of an impervious barrier to groundwater movement up to 12m deep, as well as significant dewatering during construction and possible ongoing dewatering during operation. This would result in long-term effects on groundwater levels.

In addition to the environmental effects of these options, both have significantly higher capital costs than the bridge option, which in itself was considered prohibitively expensive. Tunnelling would also have a significant impact on the ability of the proposal to meet its operational requirements, resulting in lower speed limits for safety considerations, height restrictions, exclusion of certain placarded loads, as well as an increased risk and consequence of fire. As a result, the tunnelling option was considered unviable and was rejected.

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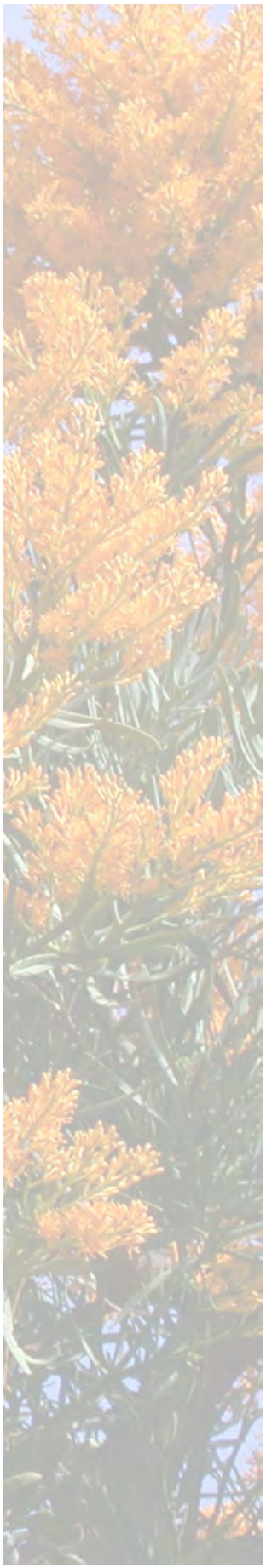
3. Preferred Option Development

This section presents a summary of the process undertaken to select a preferred option for the concept design. Selection of the preferred option was based on a sustainable decision-making framework, described in Section 3.2. The selection process also involved a collaborative community and stakeholder engagement programme (refer to Section 3.4). Land use and tenure constraints influenced option development and are identified in Section 3.3. This section of the document concludes with a description of the preferred option (Section 3.5) as well as some of the land tenure amendments that will be required as a result of the proposed project (Section 0).



3.1. Project Objectives

The purpose of the preferred option selection process was to identify a sustainable road transport solution, with specific emphasis on meeting the highest possible environmental and community engagement standards. Whilst particular consideration is given to Main Roads' environmental principles (2004), the project objectives (Table 3.1-1) align with the Strategic Plan (2K12) (Main Roads 2010). Main Roads' 2012 strategic framework aims to ensure the effective development, maintenance and operation of one of the largest and advanced road networks in the world, with the ability to support our future and present generation needs.

Table 3.1-1: South Metro Connect Project Objectives

Key Result Area	Objectives
Environment	Deliver an outstanding solution to road design in environmentally sensitive areas
	Net environmental benefit
	Minimal impact on the environment
Social	Lasting positive legacies and relationships
	Operational road safety – towards the state government's 'Vision zero' (zero deaths and serious injuries on WA roads)
	Exceed expectations of community, stakeholders and Main Roads
Economic	Value for money
	Transport efficiency
Governance	Safe, positive and fulfilling team experience
	Construction to commence in 2012
	Share gained knowledge and development of capabilities (between team and stakeholders)
	New benchmarks for collaboration, innovation and sustainability in project development

A series of collaborative engagement processes were held with community members, stakeholders and specialists to develop the most sustainable concept design option for the proposed project. Engagement processes were led by the South Metro Connect (SMC) multi-disciplined team, and included project meetings, internal workshops, external community and stakeholder design and option selection workshops, stakeholder liaison, and Aboriginal heritage consultation. Running concurrently with the environmental studies, the engagement process sought to clarify constraints and establish initial ideas for design options. Engagement processes and environmental studies conducted during the options selection process are presented chronologically in the key event timeline in Appendix C. A more detailed description of the community and stakeholder engagement process and outcomes is provided in Appendix B.

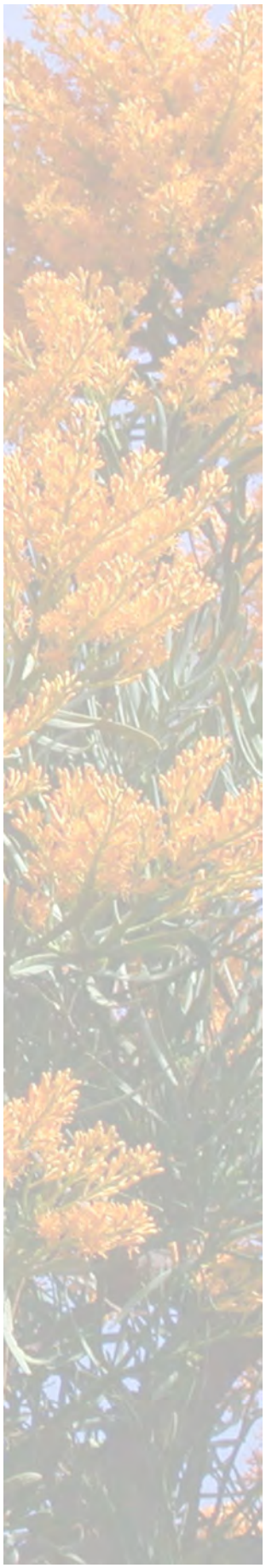
3.2. Developing a Sustainable Outcome

A sustainable decision-making framework was adopted as the basis for the options analysis process (Figure 3.2-1). The framework was based on the project objectives (Table 3.1-1) and sustainability criteria developed in conjunction with community and stakeholders. It formed the basis of decision-making during the project and was applied during key events for the analysis and evaluation of design options and day-to-day design activities.

Responsibility for ensuring sustainable decision-making was embedded within the development phase of the proposed project through reinforcement by every member of the management team.

Figure 3.2-1: South Metro Connect Sustainable Decision Making Framework

This accountability was supported by a dedicated team focused on the collaborative identification, consideration and evaluation of innovative ideas for options development and selection and achieving sustainable outcomes. Ideas were sought from the community during all public forums, workshops, project and stakeholder meetings, and through feedback received from the project website (via discussion forums and emails). All contributions were tracked on a Sustainability and Innovation Register.



3.2.1. Sustainability and Innovation Register

Innovative ideas that promoted sustainable outcomes for the proposed project were recorded on the Sustainability and Innovation Register and then investigated for their feasibility and applicability. Ideas on the register were progressed through the innovation and sustainability process, which is outlined in Figure 3.2-2. Ideas determined to be unfeasible, based on an initial screening process, were given a 'parked' status. However, they remain on the register and are available to be re-evaluated and/or re-considered during the construction and operation phases of the proposed project. The Sustainability Measurement Assessment and Reporting Tool (SMART) was used to rate ideas against a set of sustainability criteria that are weighted according to the project's objectives. The SMART process is outlined in Section 3.2.2.

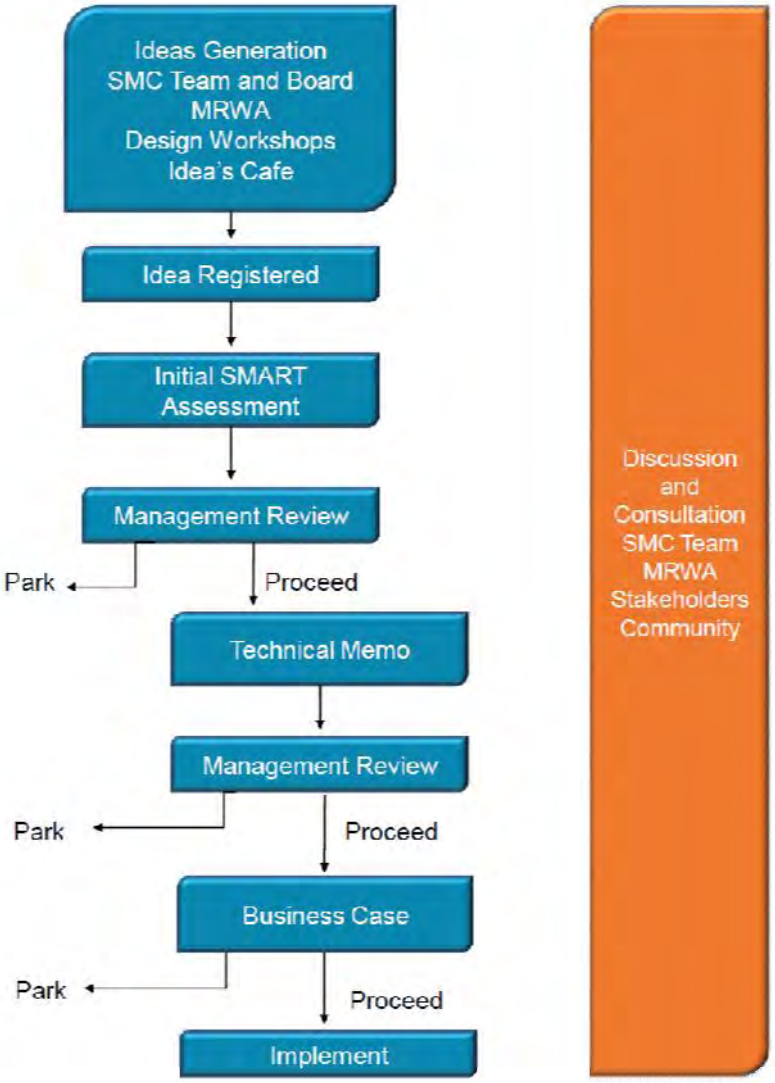


Figure 3.2-2: South Metro Connect's Ideas Innovation and Sustainability Process

3.2.2. Sustainability Measurement Assessment and Reporting Tool

SMART is central to the sustainability activities implemented during the development phase of the proposed project. It was adapted from the tool developed originally by Team Savannah for use on the Great Northern Highway section upgrades in the Kimberley. This tool was used in conjunction with the Multi-Criteria Analysis (MCA) undertaken with the community and stakeholders, outlined in Appendix C.

SMART is designed to assess the viability of ideas on a quantitative basis. It is a Microsoft Excel-based tool that aids the consideration of complex factors by using sustainability principles weighted for the proposed project. Ideas from the register were assessed against the criteria that reflected the project objectives and the themes of the proposed Australian Green Infrastructure Council's rating tool.

SMART generates a circular graph with wedges representing the weighted performance of the idea for each of the criteria, as shown in Figure 3.2-3. The idea was assessed against a business-as-usual (BAU) rating (shown as the red circle). As shown in Figure 3.2-4, a graph was also developed for assessing ideas against project objectives. Outputs of the two graphs reflect the differing levels of importance of the criteria used to assess the idea. By analysing both the BAU and project objectives assessment graphs, the project team was able to evaluate the relative performance of the proposed idea in terms of its holistic performance across environmental, social, economic and governance elements.

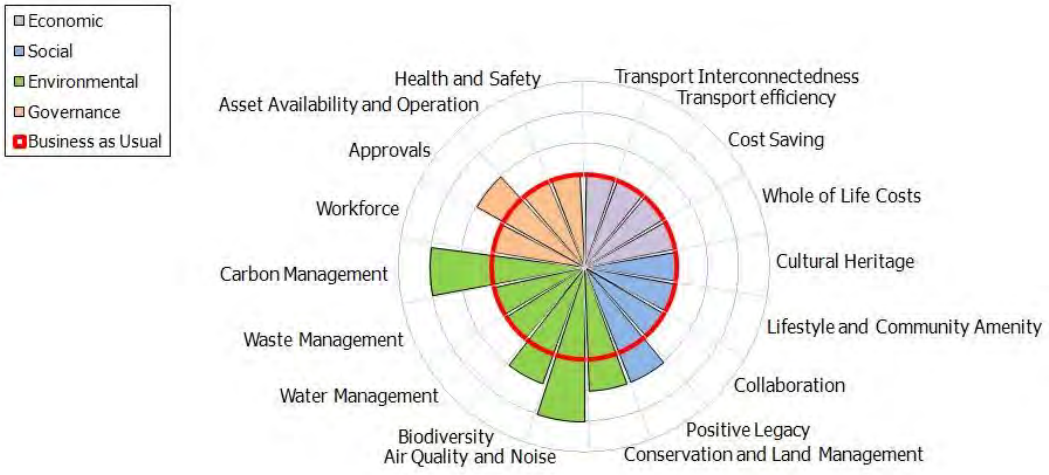


Figure 3.2-3: SMART – Assessment of an Idea versus Business-as-Usual

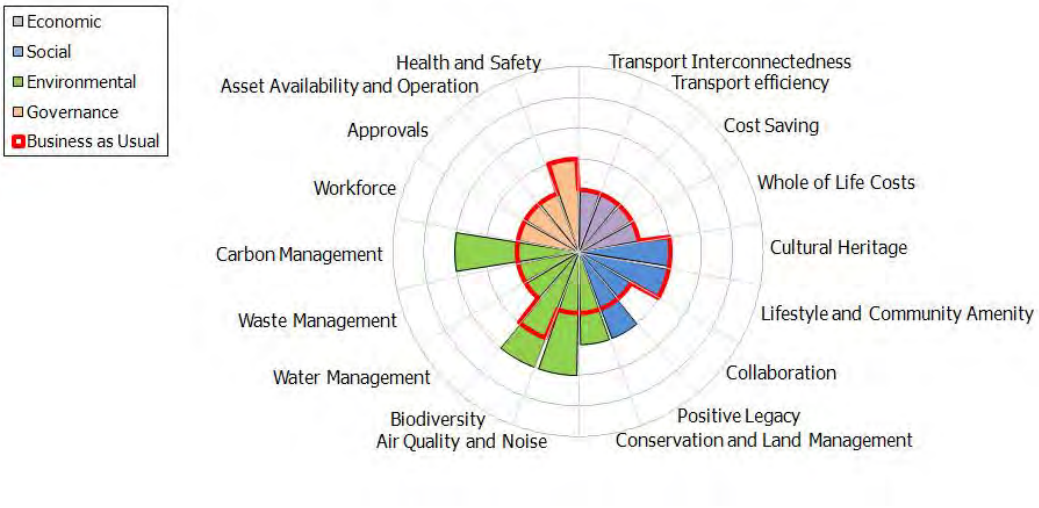


Figure 3.2-4: SMART – Assessment of an Idea versus Importance of South Metro Connect Project Objectives

3.3. Land Use, Tenure and Management Constraints on Design

In developing the preferred option, several design constraints were recognised. Principally, land use, tenure and management constraints significantly guided the design process. Understanding these constraints within and adjacent to the project area was important to the provision of appropriate context with regard to the planning requirements for the proposed project.

3.3.1. Land Tenure and Management

Land adjacent to the Metropolitan Regional Scheme (MRS) road reserve is predominantly zoned for urban uses. Other large areas are reserved for parks and recreation. Zoning and land use within and around the project area are shown in Figure 3.3-1 and Figure 3.3-2. Land reserved under the MRS is designated as a regional reserve within the City of Cockburn Town Planning Scheme (TPS), in accordance with the *Planning and Development Act 2005*.

Much of the land within the project area reserved for parks and recreation corresponds with portions of Beeliar Regional Park and Bush Forever Site 244. While the road reserve does not form part of the regional park, it is included within the boundary of Bush Forever Site 244. Table 3.3-1 presents details of land ownership, reservation, zoning and management within, and adjacent to, the project area.

Table 3.3-1: Land Tenure, Ownership and Zoning within and Adjacent to the Road Reserve

Section	Tenure (Ownership)	MRS Reservation/Zoning	TPS Zoning
Kwinana Freeway to Bibra Drive	Freehold (WAPC, MRPA, Main Roads, SHC, private) Crown Land (Murdoch University)	Urban Parks and Recreation Public Purpose	Residential
Bibra Drive to Progress Drive	Freehold (MRPA, WAPC) Crown Reserve	Parks and Recreation	None
Progress Drive to North Lake Road	Freehold (WAPC, private) Crown Reserve	Urban Parks and Recreation	Residential Parks and Recreation
North Lake Road to Stock Road	Freehold (Water Corporation) Crown Reserve	Urban Public Purpose	Residential Parks and Recreation

MRPA – Metropolitan Regional Planning Authority
SHC – State Housing Commission
WAPC – Western Australian Planning Commission

Land within the Beeliar Regional Park to the north of the MRS road reserve is held freehold by the Western Australian Planning Commission (WAPC). Land to the south has a mixture of ownership that includes the City of Cockburn and WAPC. Freehold land within the Beeliar Regional Park that is owned by WAPC is intended to be converted into reserves under the *Land Administration Act 1997* and vested in the Conservation Commission of Western Australia or the relevant local government authority. This land is managed in accordance with the Beeliar Regional Park Management Plan.

Land to the north of the proposed Roe Highway road reserve generally corresponds with Plan Areas 10 and 11 of the Beeliar Regional Park Management Plan. Land to the south of the road reserve generally corresponds with Plan Areas 12 and 14. Table 3.3-2 presents the details of these management zones and future tenure arrangements.

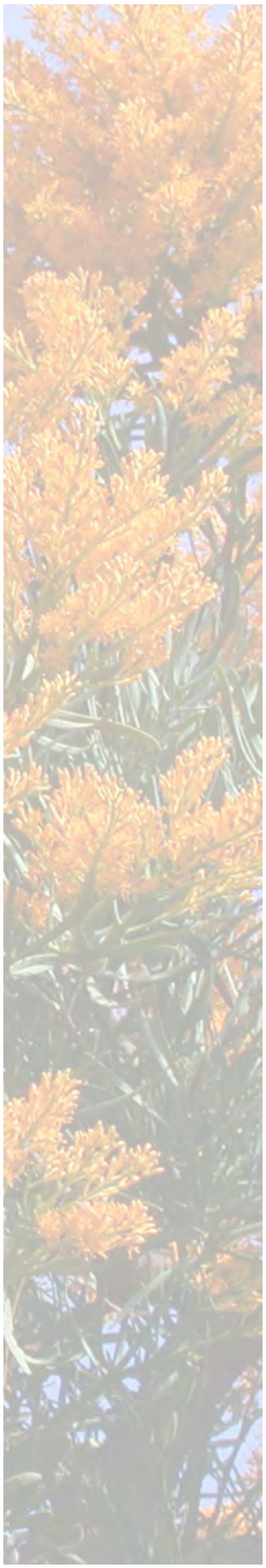


Table 3.3-2: Management Zones and Future Tenure Arrangements

Management Zones			Future Tenure Arrangements	
Management Zone	Plan Area	Management Agency	Reserve Purpose	Vested Authority
Conservation and Protection	10	DEC Regional Parks	Conservation Park	Conservation Commission of Western Australia
	12	City of Cockburn	Recreation Recreation and Education*	Cockburn City Council
	14	City of Cockburn	Pioneer Park Recreation and Education*	Cockburn City Council
Natural Environment Use	9	DEC Regional Parks	Conservation Park	Conservation Commission of Western Australia
Sport and Recreation	11	City of Cockburn	Recreation	Cockburn City Council

Adapted from Thompson Palmer 2006.

*More than one reserve currently comprises the Plan Area.

DEC – Department of Environment and Conservation.

The Beeliar Regional Park Management Plan (Thompson Palmer 2006) identifies the possibility of future changes to the park boundary as a result of infrastructure projects and other development. Changes to park boundaries are intended to be consistent with the Parks and Recreation reservation in the MRS. Therefore, future boundary changes can only be made within the overall extent of land reserved for Parks and Recreation and would not include areas already reserved within the MRS for other purposes such as roads.

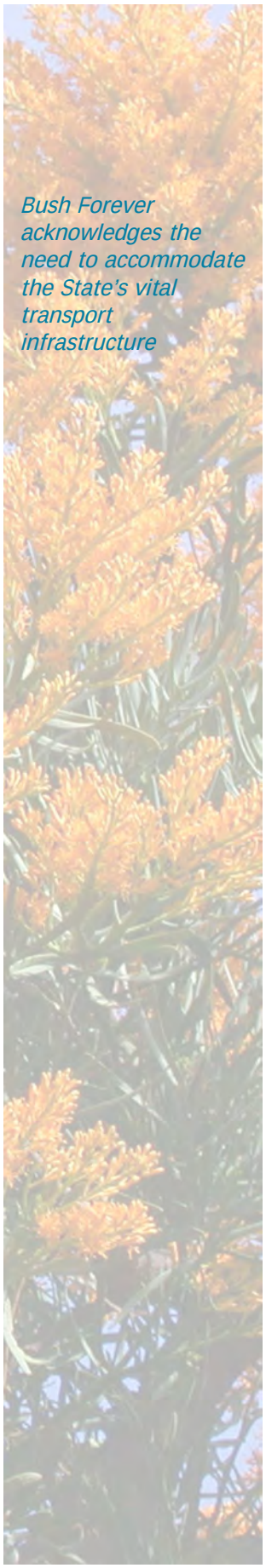
3.3.2. Bush Forever and Road Reserve

In Western Australia, Bush Forever provides the basis for biodiversity conservation by clearly identifying regionally significant bushland. Through effective protection planning, Bush Forever is intended to guide the location and design of development, to minimise effects on adjoining natural areas, rather than to prevent development. It identifies 51,200ha of regionally significant bushland for protection, comprising 26 vegetation complexes and excluding local conservation reserves. This amounts to 18 percent of the original vegetation on the Swan Coastal Plain portion of the Perth metropolitan region, nearly two-thirds of which is already under some form of protection. About 17,800 hectares is unprotected, the majority of which (75%) is under some form of government ownership.

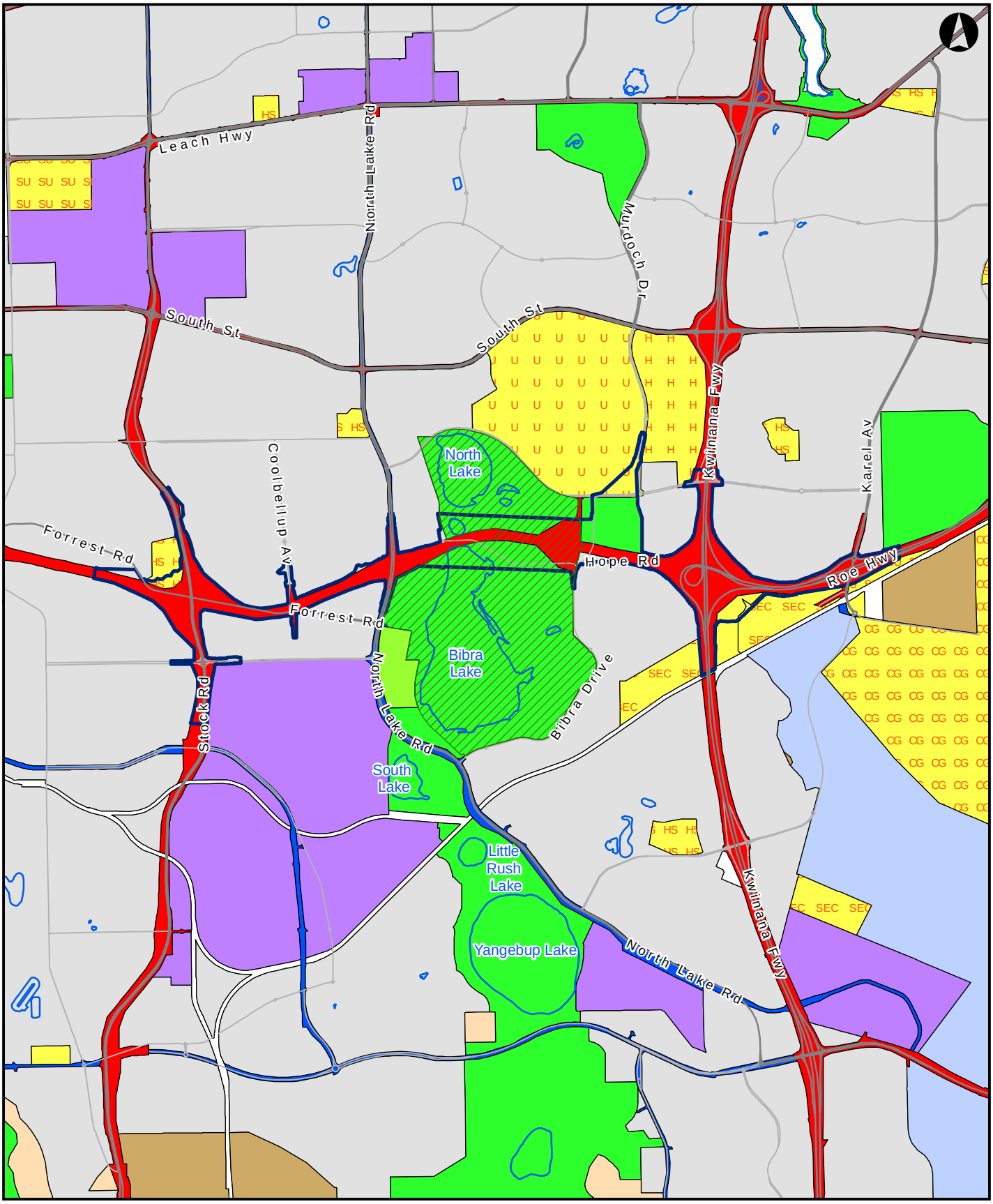
Bush Forever is the primary mechanism for implementing the state's policy to protect regionally significant bushland. It replaces the System 6 recommendations for the Swan Coastal Plain portion of the Perth metropolitan region that assisted the early identification of areas of conservation significance. In the context of North Lake, Bibra Lake and surrounding wetlands, it recommends that the proposed project be modified to reduce impact on wetland areas.

Various Bush Forever sites include land that is identified within regional road reserves. Achieving the Bush Forever objectives for these areas is constrained to varying degrees, depending on the stage to which planning and implementation has proceeded.

A portion of Bush Forever Site 244 is within the MRS road reserve. The policy objective in relation to this is to encourage protection of bushland and corridor values, and to give due consideration to protecting bushland in conjunction with future development. Bush Forever Practice Note 18 recognises that the primary purpose of road and railway reserves is to accommodate the state's vital transport infrastructure. Subject to other required approvals or permits, the construction authority has the right to undertake the necessary works for transport.



Bush Forever acknowledges the need to accommodate the State's vital transport infrastructure



Metropolitan Region Scheme

South Metro Connect

Figure 3.3-1

0 0.5 1 1.5

Kilometres

1:50,000 (A4)

Datum: GDA94 Projection: MGA z50

- Parks and Recreation
- Railways
- Primary Regional Roads
- Other Regional Roads
- Important Regional Roads
- CG Public Purposes (Commonwealth Govt)
- HS Public Purposes (High School)
- H Public Purposes (Hospital)
- Public Purposes (No definition)
- SEC Public Purposes (SECWA)
- SU Public Purposes (Special Uses)
- U Public Purposes (University)
- Rural
- Private Recreation
- Industrial
- Rural - Water Protection
- Urban
- Urban Deferred
- Bush Forever Site 244
- Project Area

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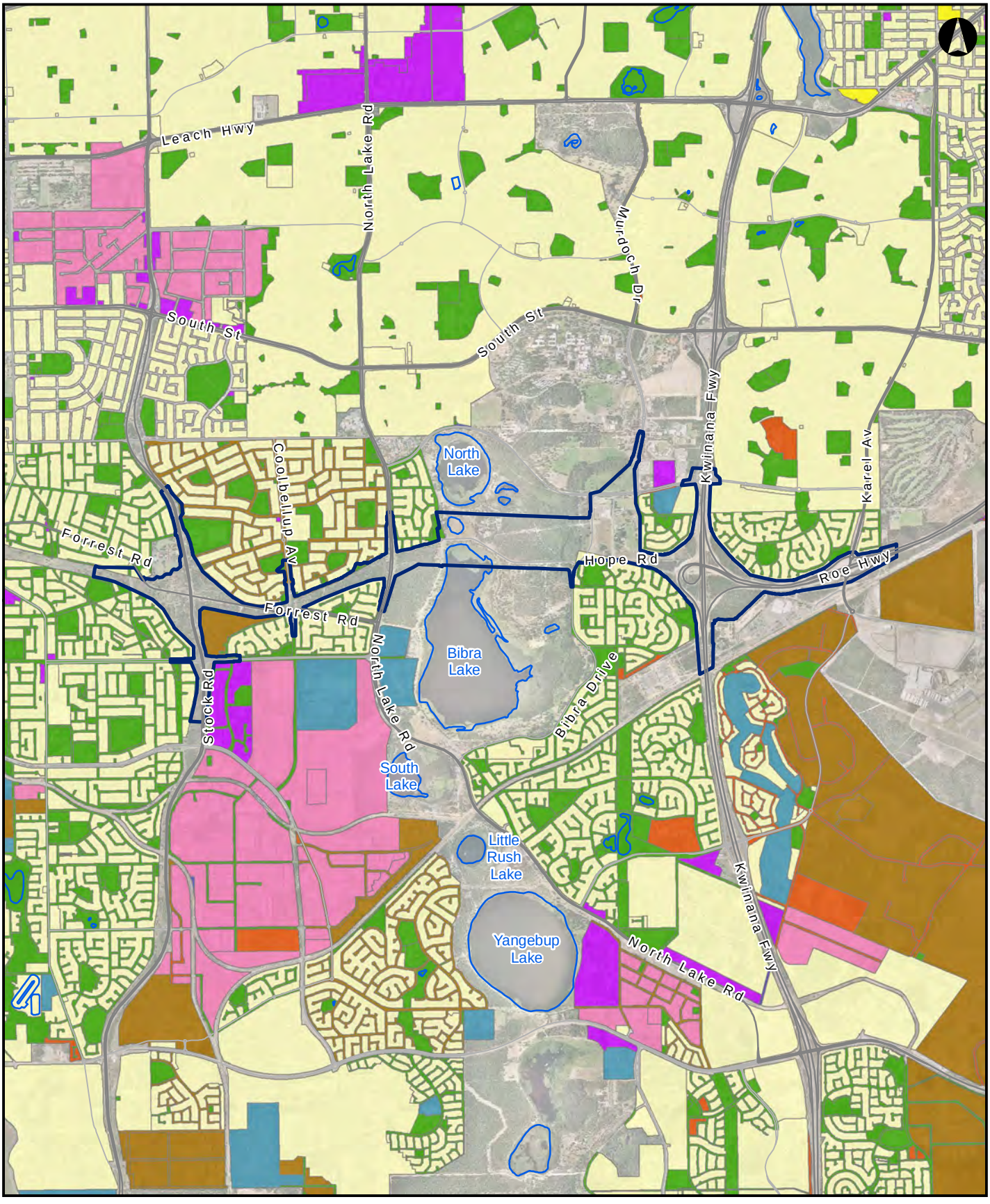
SouthmetroConnect



Town Planning Scheme Zoning

South Metro Connect

Figure 3.3-2

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Kilometres

1:50,000 (A4)

Datum: GDA94 Projection: MGA z50

- Industrial Zones
- Retail/Business
- Institutional/Public Uses
- Rural
- Local Authority Reserves
- Special Zones
- No Zone
- Unknown
- Residential
- Project Area

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Importantly, where regional road reserves exist in the MRS, and no feasible alternative exists for a review of the alignment, the implementation of Bush Forever objectives will be largely for the purpose of design and management, and, where practicable, to retain and protect the bushland values. For Bush Forever Site 244, the policy implementation recommendation is the endorsement of its care, control and management for conservation purposes within Beeliar Regional Park. In practical terms, this means that Site 244 should be managed in accordance with the principles, strategies and priorities of the Beeliar Regional Park Management Plan. Bush Forever Site 244 is described in Section 5.8.4.2.4 and assessed in Section 6.6.

Most of the proposed project lies within the MRS road reserve. However, a small portion, which is located to the west of the proposed Murdoch Drive interchange, extends outside the road reserve into an area reserved in the MRS for Parks and Recreation (P&R).

The majority of the proposed footprint in this area has already been cleared and comprises an existing access track surrounded by degraded vegetation. Bush Forever Practice Note 14 recognises that existing P&R may not be in optimum locations from the perspective of conservation and planning, and further information on the condition of vegetation or representation of vegetation communities may suggest alternative areas that give better outcomes for vegetation representation and urban development.

Bush Forever Practice Note 14 also provides for case-by-case reviews of P&R reserves in the MRS, which achieve wider conservation, planning and community outcomes, subject to other planning and environmental considerations.

A small area of the portion that is situated outside of the MRS road reserve lies within a Conservation Category Wetland (CCW). Bush Forever Practice Note 21 states that such areas are constrained for development purposes, subject to necessary on-site verification of their presence, condition and boundaries. The protection of wetlands is discussed in more detail in Section 5.2.1.

3.3.3. Protecting Wetlands

The environmental values of Bibra Lake, North Lake, Lower Swamp and Horse Paddock Swamp are protected under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* (Lakes EPP). A wetland is identified under the Lakes EPP if it contained an area of standing water of more than 1,000m^2 at 1 December 1991. The Lakes EPP prohibits activities that would result in the destruction and degradation of these wetlands, such as: filling, excavation, the discharge or disposal of effluent and the construction or alteration of associated drainage systems. These activities are prohibited unless otherwise authorised by an approval granted under the *Environmental Protection Act 1986* (*EP Act*).

Similarly, North Lake, Horse Paddock Swamp and the Roe Swamp system (i.e. Lower Swamp, Melaleuca Swamp and Roe Swamp) are recognised as CCWs in DEC's Geomorphic Wetlands Swan Coastal Plain dataset, which is endorsed by the Environmental Protection Authority of Western Australia (EPA). This wetland mapping, classification and evaluation system was based on a geomorphic approach and provided greater scientific rigor than the Lakes EPP. Bibra Lake is classed as a Resource Enhancement Category Wetland (REW). The various categories of wetlands relevant to the project area are summarised in Table 3.3-3.

Presently, regulatory authorities are aggregating a common database that includes CCW and Lakes EPP wetlands. The sites identified by both classifications are considered critical environmental assets by the EPA. Generally, the EPA does not recommend approval to the Minister for Environment for proposals that are likely to have significant adverse impacts on critical assets, nor does it consider the use of environmental offsets to be appropriate in these circumstances. Notwithstanding this policy presumption for critical assets, the EPA also takes into account the extent to which the environmental values of the asset have a reasonable chance of survival in the medium to long-term (EPA 2006a).

In the context of the proposed project, this means that where the identified environmental values of Roe Swamp, North Lake and Horse Paddock Swamp have a reasonable chance of survival in the medium to long-term, short-term localised impacts on these assets need not prevent the EPA from recommending approval to the Minister for Environment.

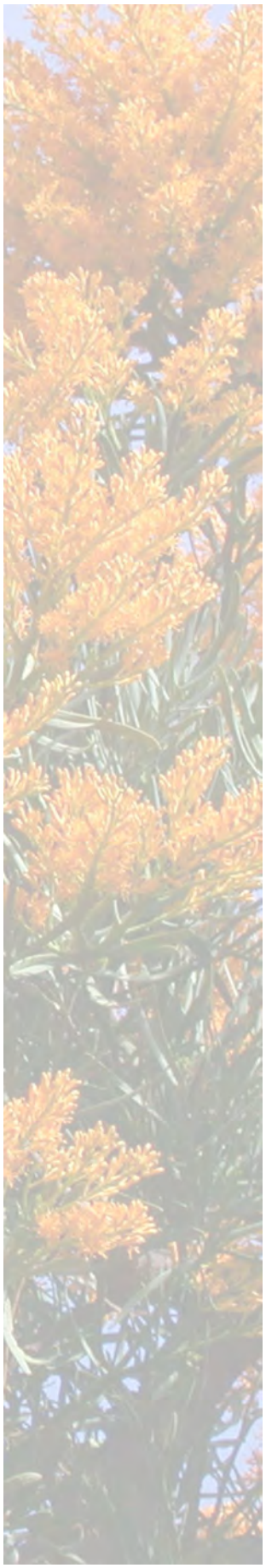
The EPA recognises that in certain circumstances, significant adverse impacts on critical assets may be approved by State Government Ministers to provide an essential community service, including transport infrastructure (EPA 2006a). Under these circumstances, the EPA's advice is that approval of a project of this nature should be made conditional on:

- Consideration or demonstration (to the maximum extent possible) of on-site impact mitigation; and
- Development and implementation of an acceptable, comprehensive offsets package for significant, residual adverse impacts.

Determination of the significance of impacts is a judgment of the EPA on a case-by-case basis, taking into consideration the advice of relevant government agencies.

Offsets for the proposed project will be considered after mitigation for potential environmental impacts are exhaustively addressed following EPA's mitigation sequence, as outlined in EPA Position Statement 9 - Environmental Offsets (EPA 2006a) and EPA Guidance Statement 19 – Environmental Offsets – Biodiversity (EPA 2008a):

- Avoid;
- Minimise;
- Rectify;
- Reduce; and
- Apply best practice.



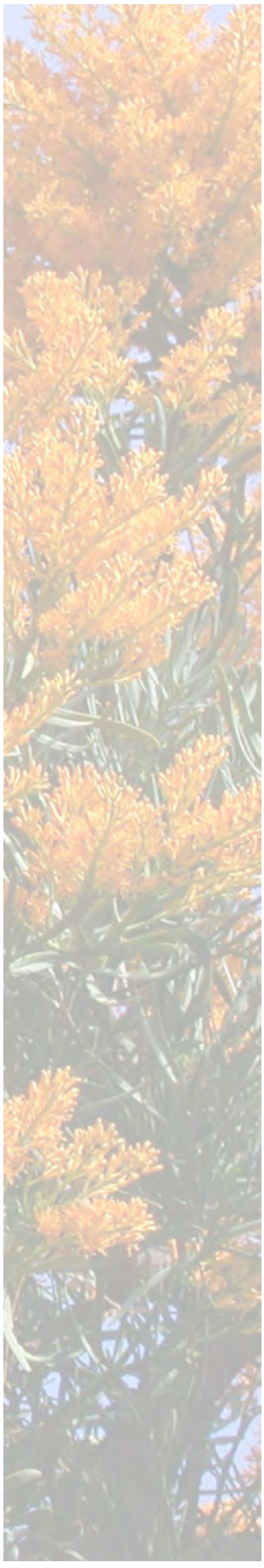


Table 3.3-3: Wetland Categories

Management Category	Description	Management Objectives
Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (EPP Lakes)	Lakes over 1,000m^2 as at 1 December 1991 and shown on DOLA Miscellaneous Plan No. 1815	Policy to protect the environmental values of lakes on the Swan Coastal Plain
Conservation Category Wetland (CCW)	Wetlands support a high level of ecological attributes and functions	Highest priority wetlands. Objective is preservation of wetland attributes and functions These are the most valuable wetlands Activities that may lead to further loss or degradation will be opposed
Resource Enhancement Wetland (REW)	Wetlands which may have been partially modified, but still support substantial ecological attributes and functions	Priority wetlands. Ultimate objective is for management, restoration and protection towards improving their conservation value Potential to be restored to conservation category by restoring wetland structure, function and biodiversity Protection is recommended through numerous mechanisms

Adapted from WRC 2001

DOLA – Department of Land Administration

3.4. Community and Stakeholder Engagement

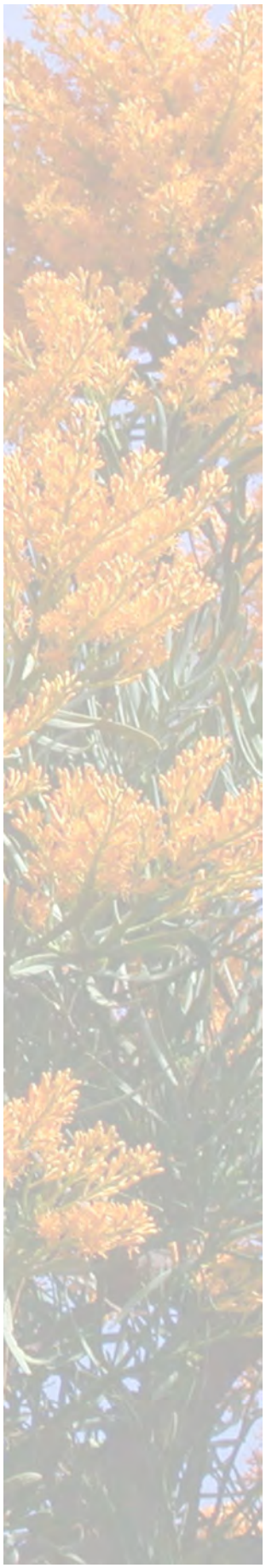
The Western Australian Government is committed to obtaining sustainable outcomes in achieving the objectives of the proposed project. The Minister of Transport has stated that:

> *"The highest levels of community engagement will be adopted on this sensitive and very important project to ensure sustainable outcomes are achieved" (19 August 2009).*

South Metro Connect (SMC) commenced an ongoing collaborative engagement programme as part of the project development process in August 2009. The programme consists of engagement with interested community members and stakeholders in order to achieve a sustainable outcome and minimise environmental and social impacts. Community and stakeholder engagement has been undertaken within the scope of pre-determined project boundaries (defined in Section 1) in accordance with the State Government commitment to extend Roe Highway. Consequently, alternative alignments or a 'no-build' option have not been included in the engagement process. However, all comments received regarding alternative options were recorded.

Information about the project and associated engagement activities has been widely disseminated via various communication methods including meetings, newspaper advertorials, electronic media, the project website and direct mail. Stakeholders that have participated in the engagement process include local members of parliament, local government authorities, regulatory agencies, education facilities and private industry. The purpose of the programme is to provide an opportunity for community members and stakeholders to influence the project design, explain interests and raise concerns. The following engagement activities have been undertaken as part of the proposed project:

- Three focus group sessions (two on 24 September 2009 and one on 23 November 2009);
- Two information/open days for the general public (24 October 2009 and 20 March 2010);
- Two multi-criteria analysis (MCA) information/open sessions (19 and 20 February 2010);
- A multi-criteria analysis (MCA) workshop (two sessions on 19 February 2010);
- Three design workshops, each with two sessions (held in March, May and June 2010);
- Two option selection workshops (29 June and 11 August 2010);
- 11 workshops on various topics, as outlined in Appendix C;
- Three design workshop feedback brochures;
- An interactive website, including three online discussion forums, FAQs, 17 information sheets and project resources, such as open day materials, meeting minutes, copies of studies and media releases;
- Direct mailings;
- Project updates published in four community newspapers;
- Monthly briefings to the Minister for Transport to ensure he can make an informed response to Ministerial-level enquiries regarding the project;
- Ongoing stakeholder meetings, including several meetings with various branches of DEC;
- Regular meetings with the Office of the EPA;
- One briefing to the EPA Board; and
- General project communication, including;
    - Enquiry email;
    - Toll free telephone number;
    - Project shop front; and
    - Subscriber bulk email.



3.4.1. Objectives and Approach

Engagement activities have been developed and implemented with regard to the following objectives:

- To engage with communities and stakeholders openly, to develop an understanding of issues and concerns and to gain local knowledge;
- To involve communities and stakeholders in the identification and development of the project concept design;
- To establish engagement processes to reach the broader community to ensure inclusion of stakeholders who support the proposed project, as well as those who oppose it;
- To be flexible in our approach, in order to meet varied engagement expectations;
- To establish a process to provide factual and honest information to potentially affected and interested communities and stakeholders;
- To provide input into the Public Environmental Review (PER) document;
- To build relationships with government agencies and local government; and
- To ensure a feedback loop for internal and external stakeholders.

The approach of the community and stakeholder engagement programme has been to encourage broad involvement in the process by interested community members, stakeholders and interest group representatives. The aim is to generate an understanding about the need of the proposed project for the public benefit, to meet the highest expectations and to obtain a high level of acceptance, while respecting the natural and social environments. The project team continues to engage collaboratively with the community in order to:

- Learn from the community and stakeholders to ensure important issues are included;
- Ensure that community and stakeholder requirements are incorporated into the concept design, as far as practicable;
- Increase community and stakeholder acceptance of the preferred design and alignment option;
- Allow understanding, respect and incorporation of social and environmental values;
- Leave a positive legacy for future generations; and
- Establish an effective project delivery process.

3.4.2. Influence on Design

An important outcome of the engagement process to date was to create an environment where community members and stakeholders could influence the preferred concept design. Various activities and methods of communication have been undertaken, including information days and workshops.

3.4.2.1. Community Information Days

A community information day was held on Saturday 24 October 2009 to create awareness about the project and input opportunities, commence the process of obtaining comment and to provide contact details of the project team. The event attracted 600–700 visitors between 10.00am and 4.00pm (Figure 3.4-1). Attendees included local residents, business owners, community group representatives and key stakeholders from local and state government agencies. The majority of attendees were from the City of Cockburn local government area.

Varying levels of support and opposition to the proposed project were expressed in person and on feedback forms received from attendees. Common concerns about the proposed project related to the effects on wetlands, flora, fauna and the environment, as well as the impacts of traffic congestion and potential pressure on local streets, if the highway extension is not constructed.

A second information day, held on Saturday 20 March 2010, received lower attendance, with approximately 80 visitors attending the event. The aim of this information day was to provide feedback from the design workshops that had been held to date and to continue the process of building awareness about the project. Details on both information days are provided in Appendix B.

A third information day is scheduled following the release of the PER for public comment, in 2011. This will provide an opportunity for the project team to explain the assessment process, answer questions and provide copies of the PER to interested community members.

Figure 3.4-1: Community Information Day

3.4.2.2. Design Workshops

A series of three design workshops were held to create awareness, provide information on concept designs and, importantly, to generate discussion and ideas for the design. Each design workshop had its own focus area:

1) Eastern Section: Kwinana Freeway to Bibra Drive.
2) Central Section: Bibra Drive to North Lake Road.
3) Western Section: North Lake Road to Stock Road.

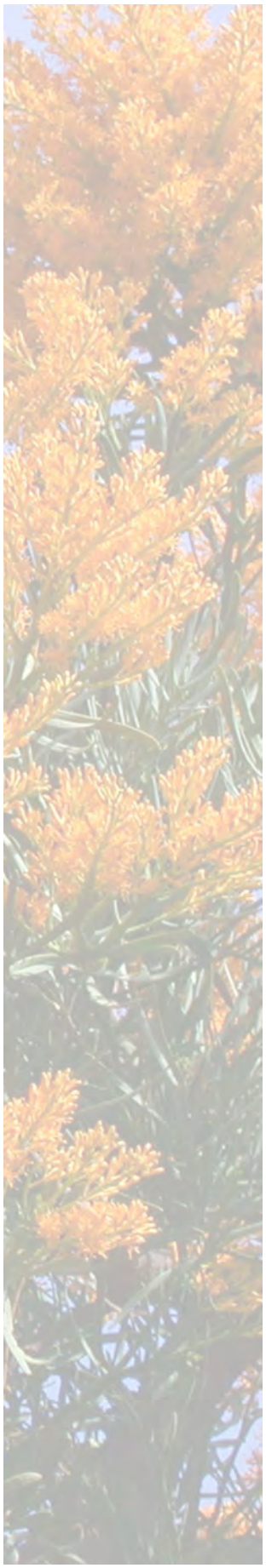
The three participatory design workshops were held in March, May and June 2010. These workshops were the most productive events in the engagement programme, with more than 1,300 individual comments generated (refer Table 3.4-1). Workshops were attended by supporters and opponents of the project, and each workshop received conflicting comments on whether the highway extension should proceed.

Dividing the proposed project into three sections - Kwinana Freeway to Bibra Drive (1); Bibra Drive to North Lake Road (2); and North Lake Road to Stock Road (3) - allowed the design team to provide separate concept designs for each section to be considered at the respective workshops. Information resulting from the workshops was used to evaluate concept designs, providing they met project requirements, government regulations and specialists' recommendations. Key issues expressed at the three workshops are summarised in Table 3.4-1. Further discussion regarding the design workshops is provided in Appendix B.

Table 3.4-1: Design Workshops and Key Issues

Design Workshops	Number of Participants	Number Comments Received	Key Issues/Concerns/Suggestions
Design Workshop 1 – Kwinana Freeway to Bibra Drive	morning: 44 afternoon: 35 79 total	650	Majority of participants preferred to have no connection from Roe Highway to Bibra Drive Concerns that Bibra Drive would be used as a short-cut, therefore increasing traffic The alignment would have significant negative impact on land used for recreational activities Relocating the freeway south-bound off-ramp onto Roe Highway east-bound closer to residences on the north-east quadrant (Leeming) and associated noise impacts Loss of vegetation
Design Workshop 2 – North Lake Road to Stock Road	morning: 47 afternoon: 25 72 total	280	Provision of a free-flowing interchange at the connection with Stock Road Retention of remnant vegetation Provision of local area access, east and west, inclusive of Hamilton Senior High School Provision of pedestrian and cyclist access and connectivity Reduced road access by the removal of the western connection to Stock Road from

Design Workshops	Number of Participants	Number Comments Received	Key Issues/Concerns/Suggestions
			Forrest Road
Design Workshop 3 – Bibra Drive to North Lake Road	morning: 54 afternoon: 54 108 total	376	Bridge the wetlands (Roe Swamp area) to reduce impact Bridge Horse Paddock Swamp to reduce impact Provide an enclosure for the highway through the wetlands area to protect fauna and reduce noise



3.4.2.3. Multi-Criteria Analysis (MCA)

An MCA workshop was held on Friday 19 February 2010 to generate a list of community values that could be weighted and interpreted into criteria for use in option selection workshops at a later stage of project development. Option selection workshops were then used where more than one viable concept design was produced for a particular section of the proposed highway. These criteria were also considered by the project team, as concepts were produced. Further details regarding the MCA process are provided in Appendix C.

Various elements of the concept designs were evaluated against project requirements and community and stakeholder comments, as appropriate. Only one section of the alignment presented more than one viable option. As a consequence, one option selection workshop was held on 29 June 2010 with a community and stakeholder group to select the preferred alignment for the central section of the proposed project.

The MCA Group was initially presented with one northern and one southern alignment option at the workshop:

- Option 1 - Southern alignment (Figure 3.4-2); and
- Option 2 - Northern alignment (Figure 3.4-3).

Figure 3.4-2: Southern Alignment for Central Section – Option 1

Figure 3.4-3: Northern Alignment (outside power line) for Central Section – Option 2

During the workshop proceedings the group identified a further two options, which were then included in the MCA assessment, presenting a total of four options as follows:

- Option 1 - Southern alignment;
- Option 2 - Northern alignment;
- Option 3 - Northern power line alignment (Figure 3.4-4); and
- Option 4 - Bridge spanning the entire length of the wetlands (not illustrated).

Figure 3.4-4: Preferred Option for Central Section (Northern Power Line Alignment) – Option 3

The group discussed all four alignment options and considered each option's performance against each of the 18 criteria (community values). While option 4 rated the highest in terms of environmental impacts (i.e. it represented the least environmental impacts) the capital and operational cost of it pushed its overall rating down. Of options 1 to 3, the group acknowledged that option 3 would create a smaller footprint and has the least potential impacts on the wider environment (regional surface and ground water movements, the Jandakot groundwater mound and groundwater source and species survival) and was the most sustainable option in terms of all of the environmental, social and economic criteria.

As a result of the analysis, the MCA work group discussed and reviewed the scores and agreed that the northern power line alignment is the preferred option for the central section of the proposed project (Figure 3.4-4).

3.4.2.4. Feedback

Once sections of the concept design were completed, a series of brochures was developed to provide feedback to the community on the changes that had occurred as a result of their participation. Topics of these brochures included:

- Bibra Lake/Murdoch Chase Residents Update;
- Bibra Drive to North Lake Road Section; and
- North Lake Road Section to Stock Road.

Project updates, in the form of newspaper advertorials, have been published in four community newspapers on a regular basis to keep the broader community informed of progress. Publications are also progressively added to the SMC website and distributed to subscribers of the project update email group. Community newspapers used to publish project updates include:

- Fremantle/Cockburn Gazette;
- Melville Times;
- Canning Times; and
- Weekend Courier (Kwinana).

Identification of stakeholders that may potentially be affected by the proposed project was undertaken early in the programme to ensure they would be offered the opportunity to participate in the community engagement process. Ongoing stakeholder meetings have been established on an as-needed basis. Stakeholders that could potentially be most affected by the proposed project and were invited to participate in workshops include:

- The City of Cockburn;
- The City of Melville;
- Local members for Jandakot, Riverton and Bateman;
- Murdoch University;
- The Spanish Club;
- Murdoch Pines Golf and Recreation Park;
- Lakeside Recreation Centre;
- Blue Gum Montessori School;
- Hamilton Senior High School; and
- Local community groups and government agencies.

3.4.2.5. Process

Feedback received from completed evaluation forms has indicated that most participants in the design workshops were satisfied with the engagement process. There were some individuals who believed that the engagement process should have allowed consideration of an alternate route option or a no-build option. Their view was that without these options, the engagement process was invalid.

3.4.2.6. Additional Methods of Communication

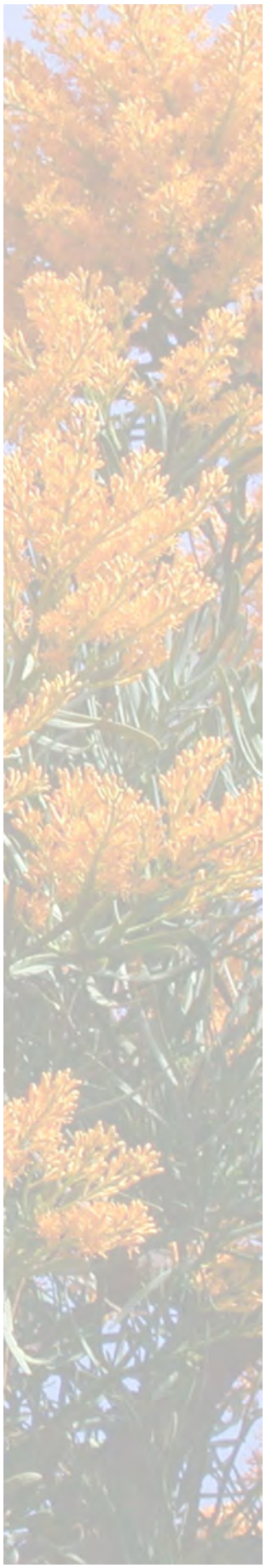
Additional methods of communication were established, including:

- A project-specific website, to enable easy access to project information;
- Online discussion forums to run concurrently with workshops, enabling contribution by those who could not attend the workshops;
- An email address for receipt of enquiries;
- A toll free telephone number;
- A shop front located at the project office (18 Blackly Row, Cockburn Central); and
- Various publications, including information sheets (listed in Appendix B) and advertisements.

3.4.3. Value of Community Engagement Programme

The community and stakeholder engagement process has enabled a large proportion of the community to express their views to the project team, raise concerns and influence changes to the concept designs initially presented at workshops. This process has created greater awareness of the proposed project, its location, proposed connections, local access, the existing environment and proposed changes to the general area. It has also created greater awareness within the project team of issues important to the local and broader communities and, to some extent, the general public. As a result of the programme, significant changes to the project design were implemented as follows:

- Redesign of the Kwinana Freeway/Roe Highway interchange;
- Modification of the southern connection to the Murdoch Activity Centre, to exclude connection from Roe Highway to Bibra Drive;
- Redesign of the southern connection to the Murdoch Activity Centre, to exclude connection to Allendale Entrance;
- Inclusion of bridges in the design to accommodate water and fauna connectivity in the section between Bibra Drive and Progress Drive; and
- Inclusion of retaining walls instead of batter slopes, to maintain the integrity of existing ecological corridors in the section between North Lake Road and Stock Road.



The Preferred Option was selected on the basis of extensive community engagement and options analysis

3.5. Preferred Option

Design options for the proposed project were selected on the basis of the avoidance and minimisation of impacts. The environmental, social, economic and governance constraints were identified through extensive and detailed engagement outlined previously and studies detailed in Section 5. Design options were developed to:

- Maximise use of existing cleared areas and degraded vegetation to avoid impacts on high and medium quality vegetation;
- Optimise the alignment to avoid potential Carnaby's Black-Cockatoo nesting sites, wherever practicable;
- Relocate the Murdoch Drive Extension Interchange from the area set aside in the MRS to cleared WAPC land to minimise impact on Conservation Category Wetlands and high quality vegetation and fauna habitat;
- Replace embankments and batters with retaining walls to minimise footprint in high environmental and heritage value locations;
- Reduce median strip width from the standard 15m to approximately 4m to minimise clearing footprint;
- Retain maximum possible widths of existing vegetation to maintain ecological linkages in key areas and act as buffers alongside the road;
- Align the proposed project along the western section of Hope Road, between North and Bibra lakes, and along the existing high tension power line corridor to minimise clearing footprint;
- Include bridges over a portion of Roe Swamp and south-east of Horse Paddock Swamp to minimise the risk of interruption to surface and potential subsurface flows, as well as maintain an ecological linkage for fauna species;
- Use top down construction methods to build the bridge at Roe Swamp and surrounding wetlands. This construction method will reduce the clearing footprint of the proposed project by removing the need for ground level access by machinery or vehicles, which is especially important in this high-value ecosystem;
- Minimise impacts of providing a southern access to and from the MAC, Murdoch University, Spanish Club of Western Australia, Murdoch Pines Golf and Recreation Centre and Lakeside Recreation Centre; and
- Reconfigure Kwinana Freeway interchange to retain areas previously set aside as offsets for Roe Highway Stage 7 as much as practicable.

The extensive community and stakeholder engagement process resulted in numerous design criteria being established, which formed the basis of a rigorous options analysis and selection process. As a result, during design development, numerous changes were incorporated into the design to avoid or minimise impacts on vegetation, fauna and fauna habitat, conservation wetlands and other factors.

A series of strip maps illustrating the proposed alignment and design elements of the preferred option for the proposed project is provided below (Figure 3.5-1 to Figure 3.5-6), along with illustrations of typical cross sections of embankments, full height retaining walls, partial-height retaining walls and wetland bridges (Figure 3.5-7). Also provided is a schematic that illustrates the typical plan area for the high tension power line poles, as they will be constructed alongside the section of the alignment between Bibra Drive and Progress Drive (Figure 3.5-8). The strip maps highlight where full or partial height retaining walls and bridges are proposed.

Indicative noise wall locations are provided. The noise wall design principles are outlined in detail in Section 6.10. The height and location of these walls are subject to change as detailed design is developed.

The design descriptions provided in Table 3.5-1 relate to the avoidance and minimisation measures that were incorporated into the design to mitigate impacts. Figure references correspond with the annotations on Figure 3.5-1 to Figure 3.5-6. For most factors, the incorporation of the avoidance and mitigation measures described has already substantially reduced the primary impact.

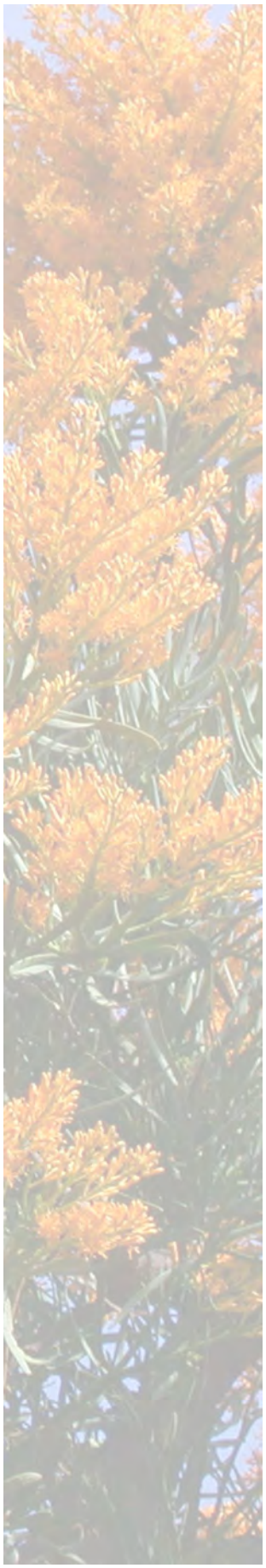


Table 3.5-1: Design Features

Figure No.	Figure Reference	Design Feature Description	Intent	Outcome
Figure 3.5-1	A-A	Construction of a retaining wall up to 11m in height along the north side of the project near the Coolbellup Avenue overpass	Maintain a 20m buffer of vegetation between the highway and houses along Sebastian Crescent, where possible	Reduced clearing of black cockatoo and potential Graceful Sun-moth habitat by ~1.2ha
				Reduced visual impacts
	B-B	Steepening of the cut batter slope on the south side of the highway	Maintain a 20m buffer of vegetation between the proposed project and adjacent houses where possible	Reduced clearing of black cockatoo and potential Graceful Sun-moth habitat
				Reduced visual impacts
				Separation of project from adjacent properties
	C-C	Alignment of proposed project through the centre of the road reserve, as much as practicable	Provide maximum width of vegetation on either side of alignment as an ecological corridor for fauna	Retention of at least 20m wide habitat corridor wherever possible
				Reduced visual impacts
	D	Provision of an underpass beneath Sudlow Road on both sides of the alignment	Maintain the connectivity of the ecological corridor utilising the PSP along the south side of the highway	Maintained connectivity between habitat corridors on south side of alignment
Figure 3.5-2	E-E	The Principal Shared Path (PSP) is diverted away from the highway at the Coolbellup Avenue overpass, along Malvolio Road and rejoins the proposed alignment where the east-bound off-ramp to North Lake Road commences	Minimise the extent of vegetation clearing alongside the proposed project	Reduced clearing of black cockatoo and potential Graceful Sun-moth habitat by ~0.5ha
	F-F	Alignment of proposed project through the centre of the road reserve, as much as practicable	Provide maximum width of vegetation on either side of the alignment as an ecological corridor for fauna	Retention of at least 20m wide habitat corridor wherever possible

Figure No.	Figure Reference	Design Feature Description	Intent	Outcome
	G-G	Construction of a retaining wall (6.7–8.1m in height) along the south side of the formation	Minimise encroachment of the formation into Bibra Lake EPP boundary	No filling of Bibra Lake required
				Reduced encroachment into Bibra Lake EPP area from approximately 1ha to 0.5ha
	H-H	Construction of a bridge and underpass	Provide for movement of fauna, pedestrians and cyclists and reduce potential impact on groundwater conveyance	Connectivity between north and south sides of the alignment at Horse Paddock Swamp
				Reduced risk of interruption to local hydrology
Figure 3.5-3	J-J	Diversion of PSP from beside road alignment to Hope Road	Minimise clearing and filling of CCW	Reduced clearing of CCW by 0.5ha
			Minimise clearing of very good condition vegetation	Reduced clearing footprint by 1ha
			Minimise clearing of high quality black cockatoo foraging habitat	Reduced clearing of high quality habitat by 0.2ha
	K-K	Alignment of the proposed project north of the MRS reserve	Make use of existing clearing for maintenance access to the Western Power high tension transmission line	Reduced clearing extent
			Minimise the length of the alignment through high quality black cockatoo foraging habitat	Reduced length of alignment through high quality black cockatoo foraging habitat by approximately 250m
			Avoid very good quality vegetation as much as practicable	Encroachment into very good quality vegetation kept to 0.1ha
	L	Construction of a bio-retention basin on the north side of the proposed project east of Horse Paddock Swamp, adjacent to Hope Road	Treat road runoff and provide recharge to groundwater via infiltration	Hope Road Bio-retention basin has been designed to avoid clearing of native trees
				Create additional wetland areas by rehabilitation with wetland species

Figure No.	Figure Reference	Design Feature Description	Intent	Outcome
	M	Relocation of the interchange between Murdoch Drive and Roe Highway away from its location in Roe Swamp into cleared land to the east	Minimise the extent of clearing and filling required within the Roe Swamp CCW	Reduced clearing of CCW from potentially 11ha to ~2.4ha
	N-N	Construction of a partial height retaining wall on the south side of the proposed project	Minimise the extent of clearing required	Reduced clearing extent by approximately 0.2ha
	O	Provision of an underpass	Facilitate the movement of fauna and pedestrians	Maintained connectivity between the north and south sides of the alignment
	P-P	Construction of a full height retaining wall on either side of the alignment	Minimise extent of clearing and filling of Roe Swamp CCW	Reduced clearing and filling of Roe Swamp by 0.5ha
	Q-Q	Construction of a multi span bridge using top down construction methodology	Maintain water conveyance and biological connectivity between north and south sections of Roe Swamp	Maintained connectivity
			Prevent vehicular access between bridge abutments	No vegetation will be cleared beneath the proposed bridge
	R-R	Replace existing transmission line towers with poles to be constructed within the road embankment	Minimise extent of footprint required to replace towers with poles	Pole construction footprint will be less than 0.06ha
	S-S	Construction of a partial height retaining wall on south side of alignment	Minimise clearing of very good quality vegetation	Reduced clearing footprint to 0.1ha from 0.3ha
			Minimise clearing and filling of CCW	Reduced clearing of CCW by 0.2ha
			Minimise clearing of high quality black cockatoo habitat	Reduced clearing of high quality habitat by 0.1ha

Figure No.	Figure Reference	Design Feature Description	Intent	Outcome
	T-T	Closure of Hope Road via installation of cul-du-sac near entrance to Native ARC and downgrading of access from Bibra Drive. Replacement of Hope Road west of cul-du-sac with a PSP	Remove through traffic from Hope Road	Reduced likelihood of road kill
				Improved connectivity within local ecological linkage
				Increased vegetative cover due to rehabilitation of western section
				Significantly reduced traffic numbers
				Rehabilitation of redundant section of Hope Road
		City of Cockburn will consider installation of a gate at Bibra Drive and prohibiting night access	Remove night traffic from Hope Road and Cockburn Wetlands Precinct	Reduced impact on nocturnal fauna
Figure 3.5-4	U-U	Construction of a full height retaining wall on west side of Bibra Drive realignment	Minimised clearing and filling of CCW	Reduced clearing of CCW by 0.1ha
	K-K	Alignment of the proposed project north of the MRS reserve	Make use of existing clearing for maintenance access to the Western Power high tension transmission line	Reduced clearing extent
			Minimise the length of the alignment through high quality black cockatoo foraging habitat	Reduced length of alignment through high quality black cockatoo foraging habitat by approximately 250m
			Avoid very good quality vegetation as much as practicable	Encroachment into very good quality vegetation kept to 0.1ha
Figure 3.5-5	V	Arrangement of road elements for Murdoch Drive to reduce its cross-sectional area, as much as practicable	Minimise the encroachment of the proposed project into the Melaleuca Swamp CCW and buffer	Encroachment into CCW boundary reduced to 0.24ha

Figure No.	Figure Reference	Design Feature Description	Intent	Outcome
Figure 3.5-6	W-W	Retention of existing alignment of east-bound exit ramp from Kwinana Freeway south-bound	Avoid impact on Roe 7 Offset Area E	No impact on Roe Stage 7 Offset Area E
				Reduced clearing of up to 4.7ha of black cockatoo foraging habitat
			Maintain existing separation between the exit ramp and local residents	Noise levels maintained at lowest possible levels
	X-X	Minimise encroachment of south-bound Kwinana Freeway on-ramp into Roe 7 Offset Area D	Avoid impact on Roe 7 Offset Area D	Reduced clearing within proposed Roe Stage 7 Offset Area D by up to 1ha
				Reduced clearing of up to 1.7ha of black cockatoo foraging habitat
	Y-Y	Installation of a retaining wall between the edge of the south-bound Kwinana Freeway on-ramp and Roe 7 Offset Area D	Minimise impact on Roe 7 Offset Area D	Reduced clearing within proposed Offset Area D by up to 0.7ha
				Reduced clearing of up to 0.7ha of black cockatoo foraging habitat

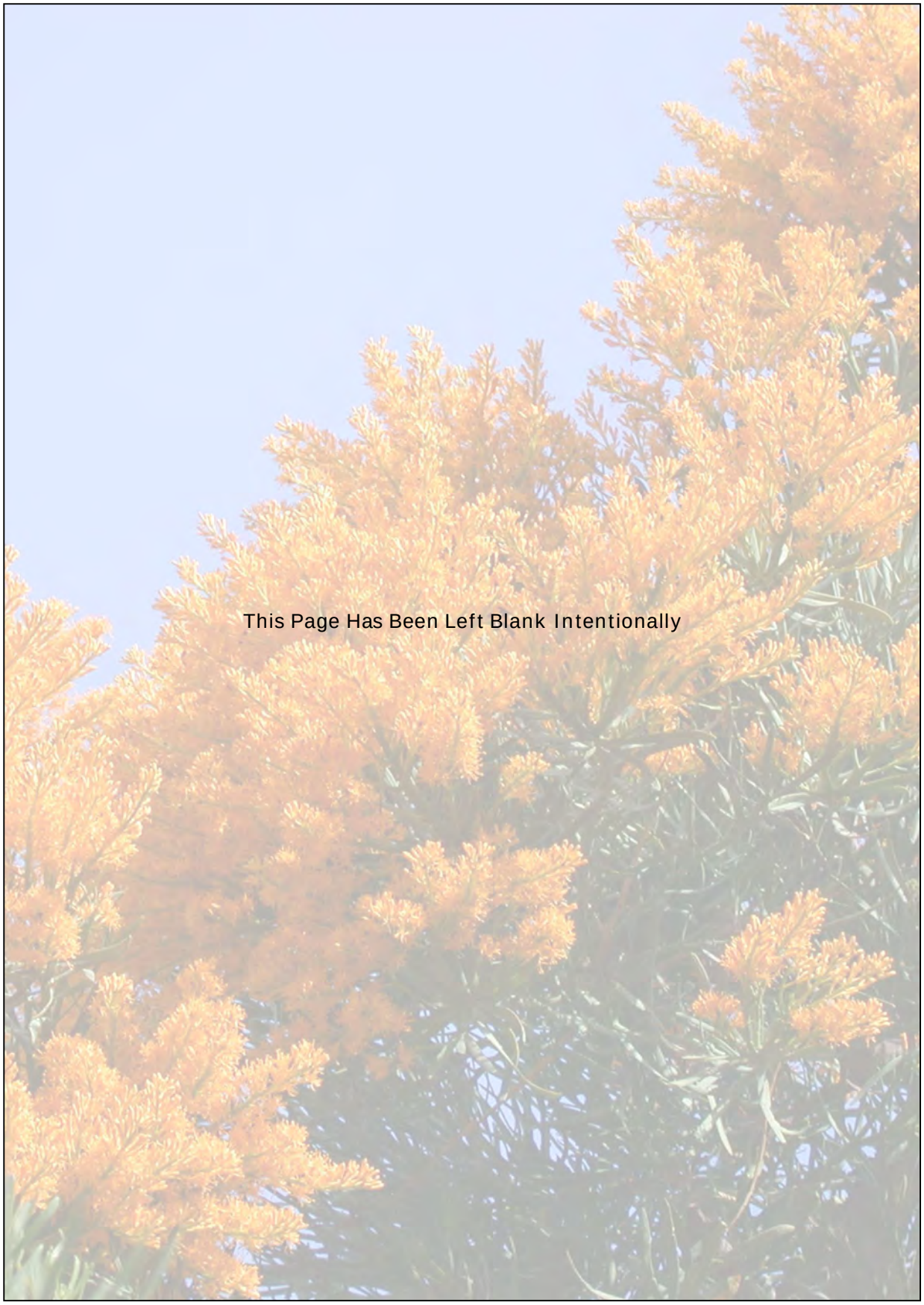
CCW – Conservation Category Wetland

EPP – Environmental Protection Policy

MRS – Metropolitan Region Scheme

Native ARC – Native Animal Rehabilitation Centre

PSP – Principal Shared Path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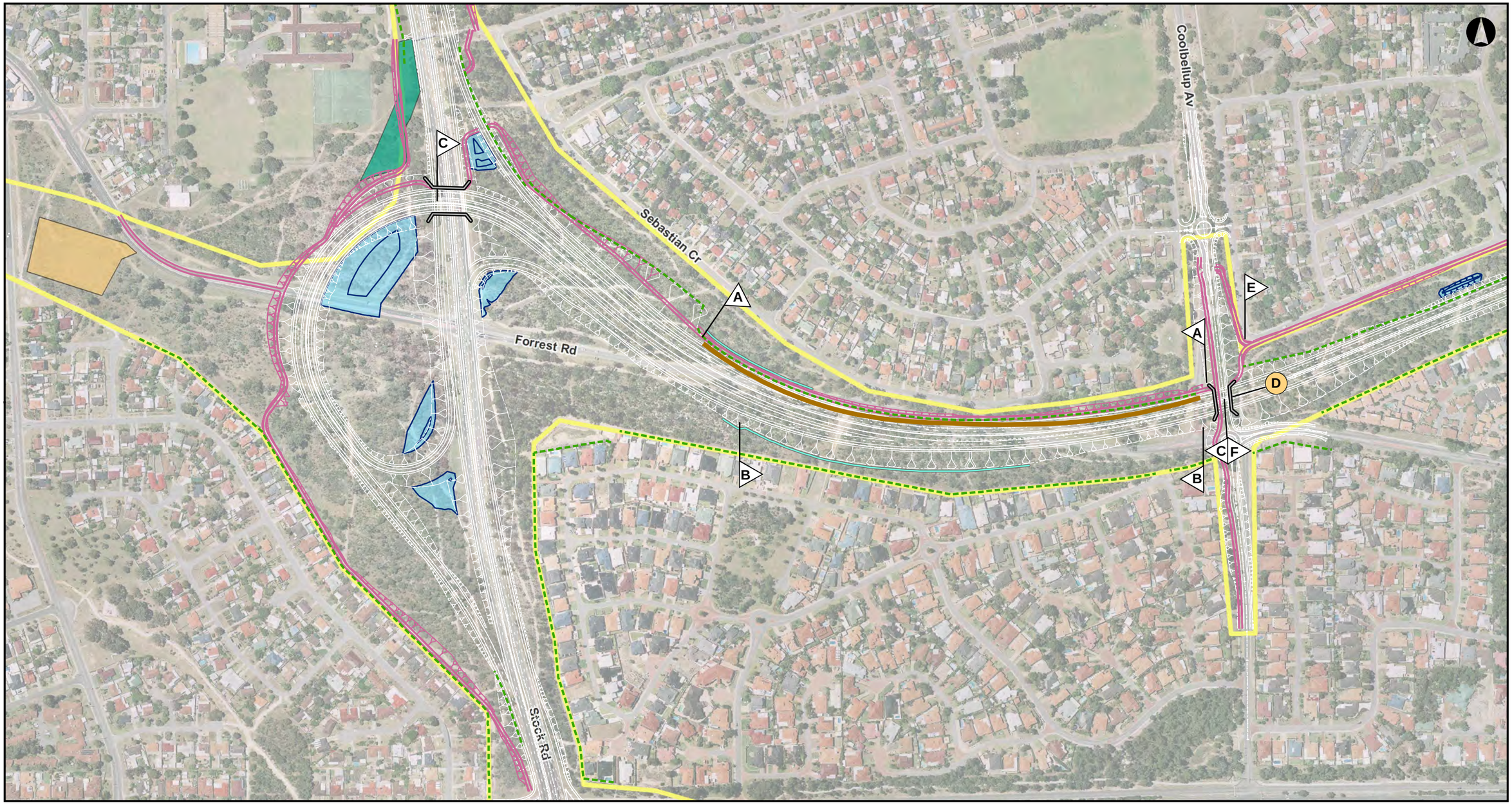

Design Features - Stock Road to Coolbellup Avenue

South Metro Connect

Figure 3.5-1

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Meters

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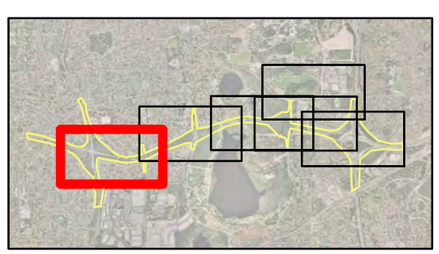

- Road Formation (white)
- PSP
- Noise Walls
- A / A — Table 3.5-1 Reference Markers *(To and From Points)*
- D — Table 3.5-1 Reference Markers *(Individual Location)*
- Bridge Abutment
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- Partial Height Retaining Wall
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- Drainage Areas
- Power Poles
- Proposed Laydown Area
- Temporary Construction Bypass
- MRS Boundary
- State Offset Areas
- State and Commonwealth Offset Areas

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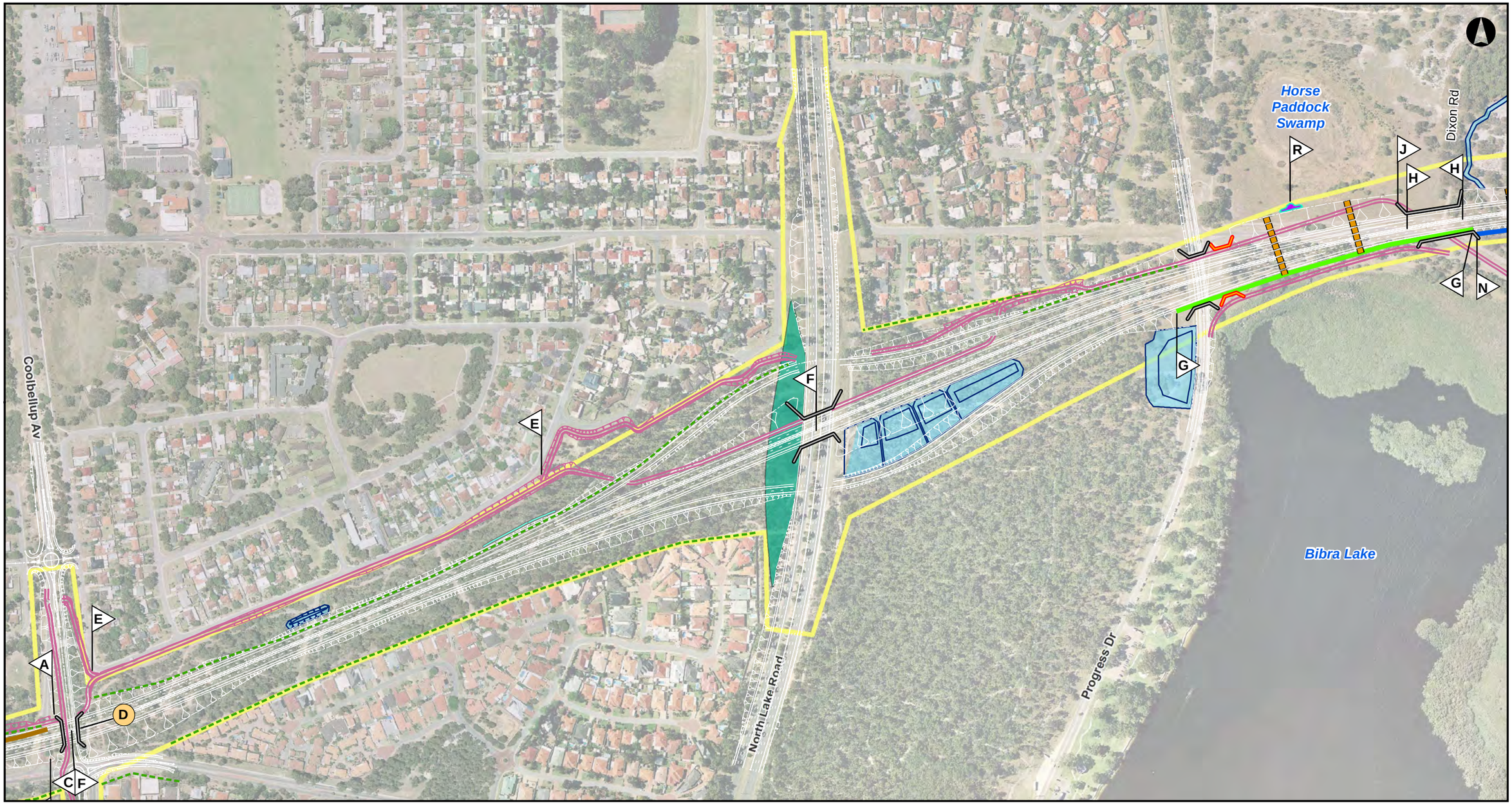

Design Features - Coolbellup Avenue to Progress Drive

South Metro Connect

Figure 3.5-2

0 50 100 150 200 250

Meters

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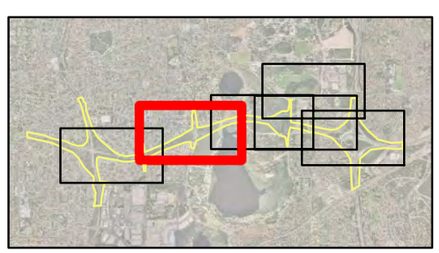

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North Lake

Lower Swamp
(Frog Swamp)

Farrington Rd

Horse
Paddock
Swamp

Dixon Rd

Roe Swamp

Hope Rd

Bibra Lake

Bibra Dr

Design Features - Progress Drive to Bibra Drive

South Metro Connect

Figure 3.5-3

0 50 100 150 200 250

Meters

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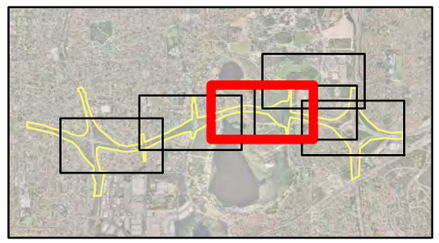

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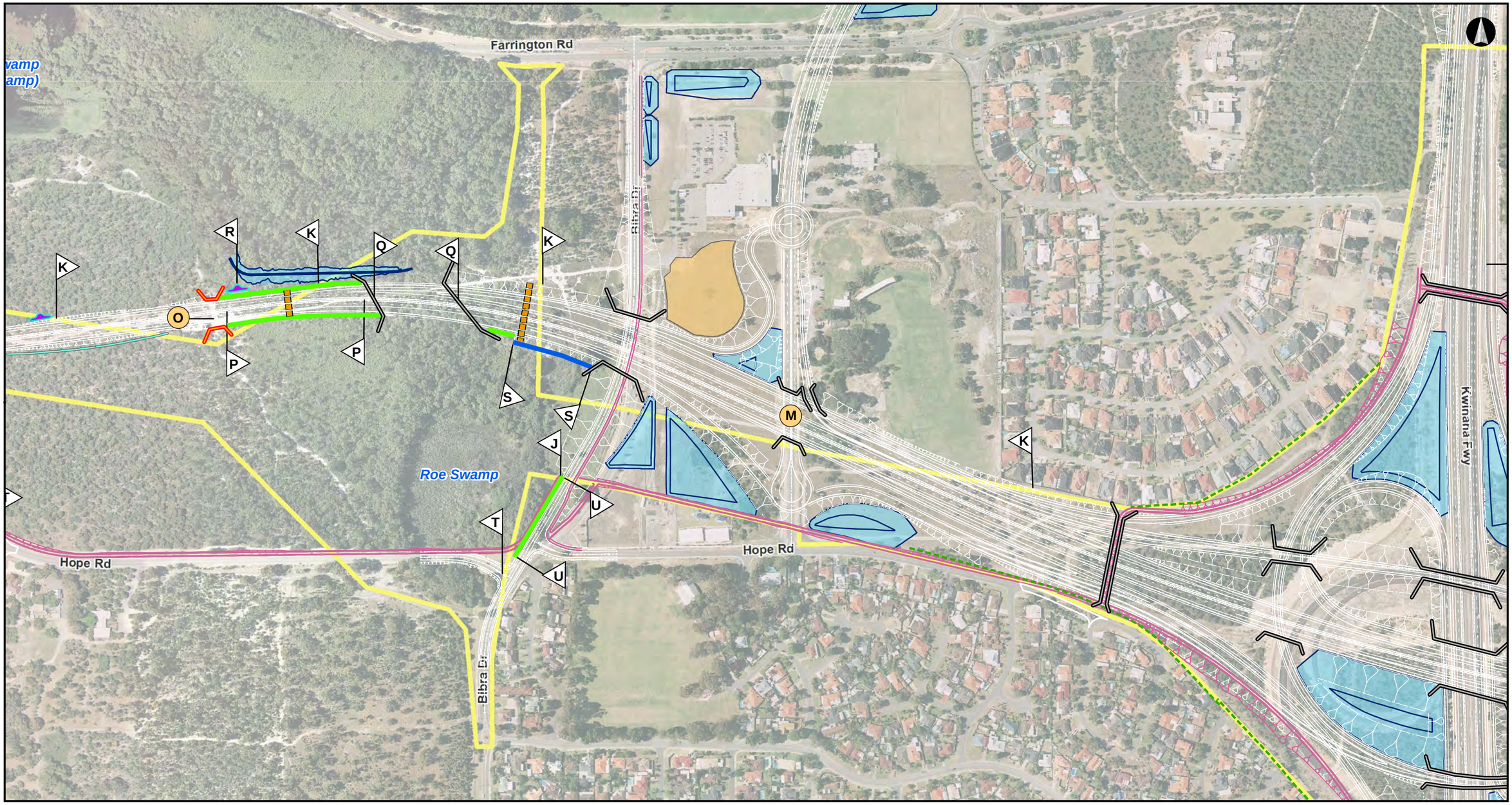

Design Features - Bibra Drive to Kwinana Freeway

South Metro Connect

Figure 3.5-4

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Meters

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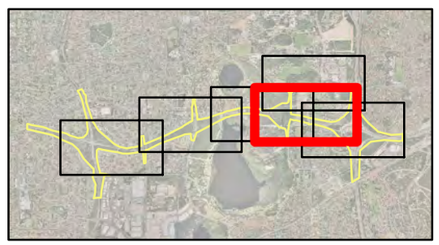

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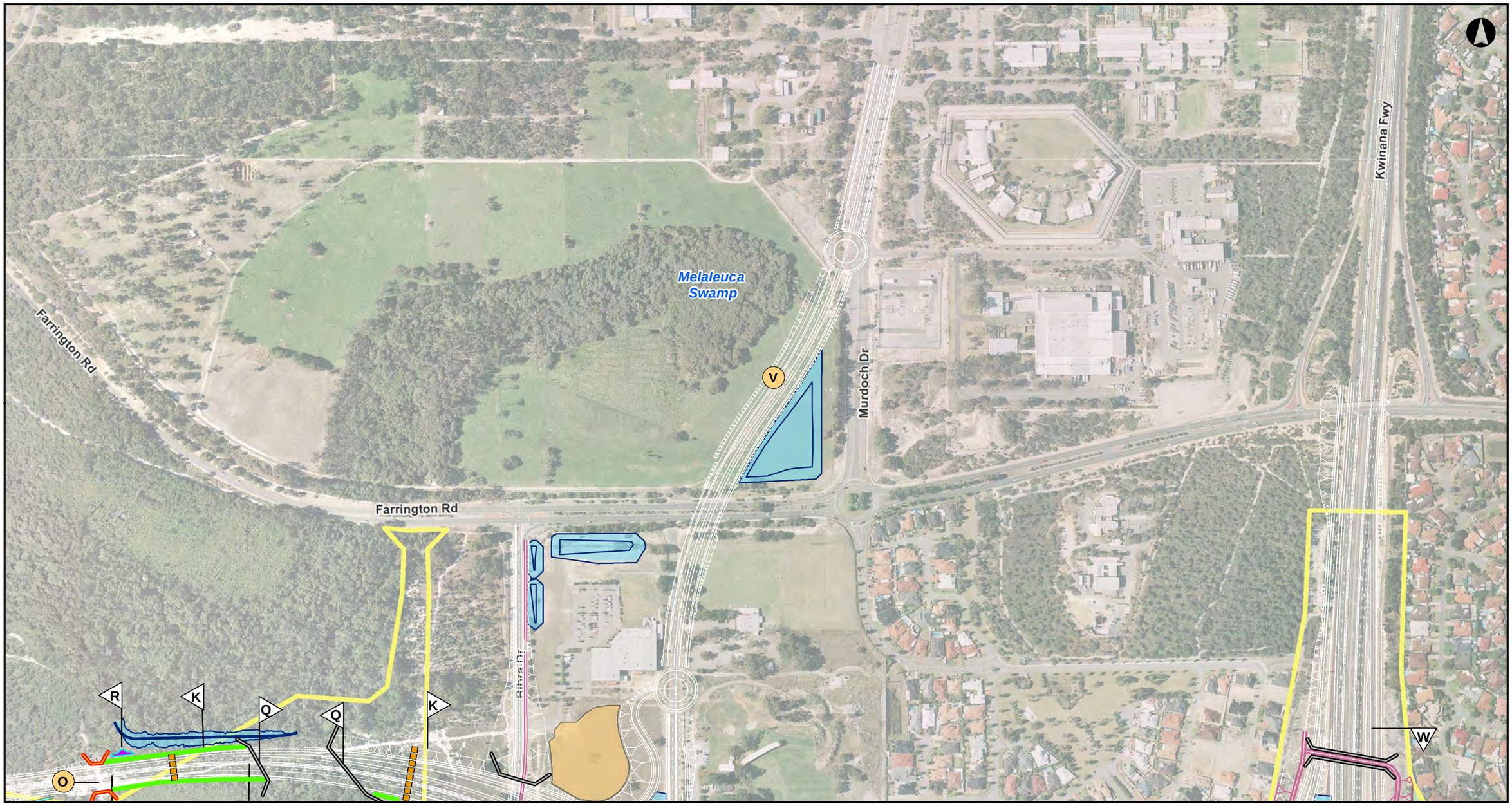

Design Features - Murdoch Drive Extension

South Metro Connect

Figure 3.5-5

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Meters

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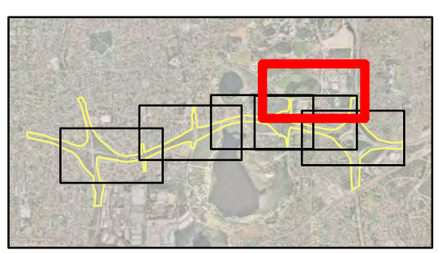

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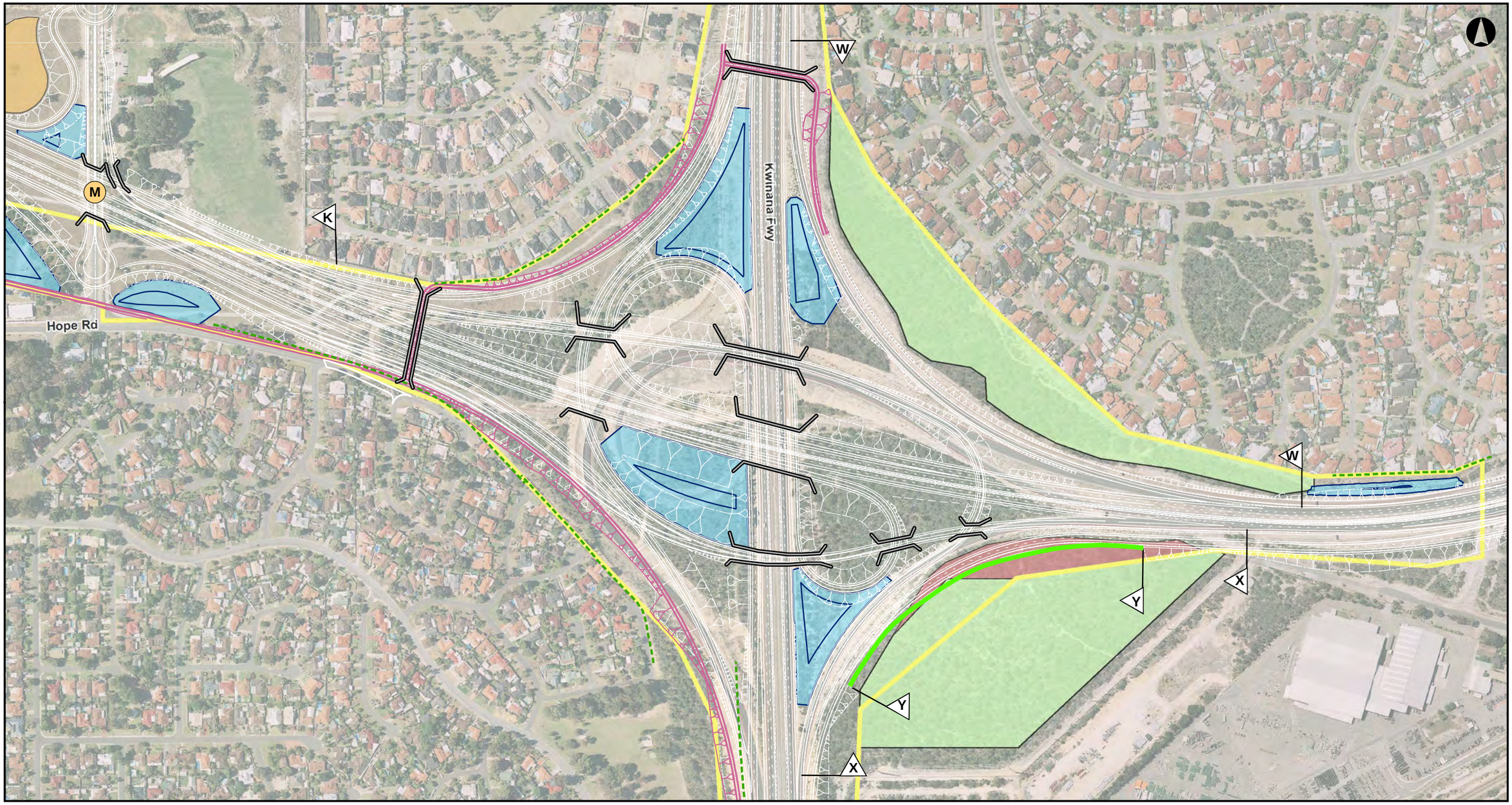


Design Features - Kwinana Freeway Interchange

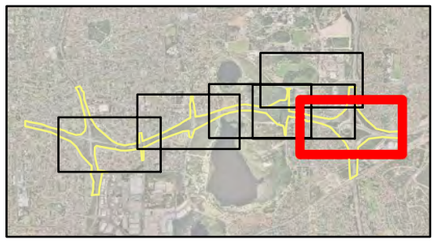
South Metro Connect

Figure 3.5-6

0 50 100 150 200 250

Meters

1:5,000 (A3)



- Road Formation (white)
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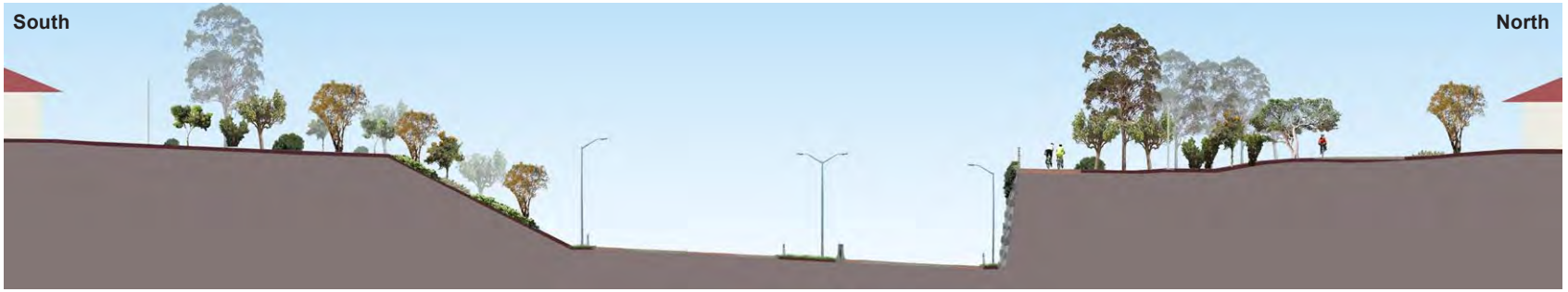
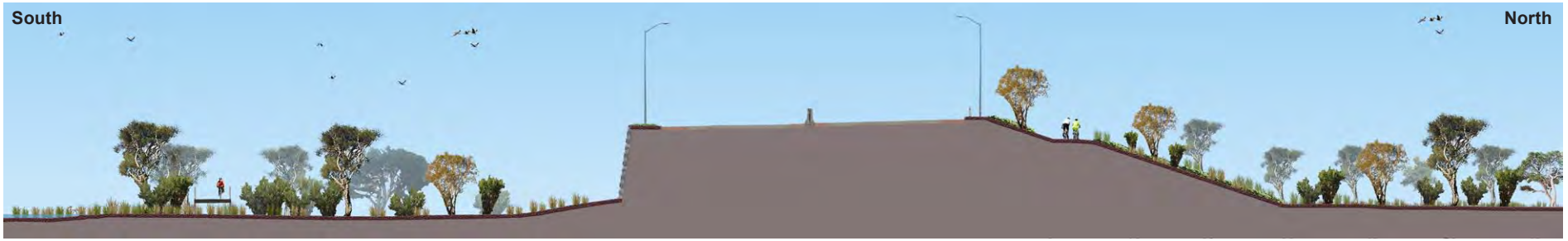


Indicative Cross-Section 1 - Deep Cut



Indicative Cross-Section 2 - Deep Fill

Indicative Cross-Section 3 - Bridge

Indicative Cross-Sections

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Figure 3.4-7

0 2 5 10 15 20 25 30

Metres

Key Plan

Legend

- Cross-Section Reference Line
- Proposed Road Design

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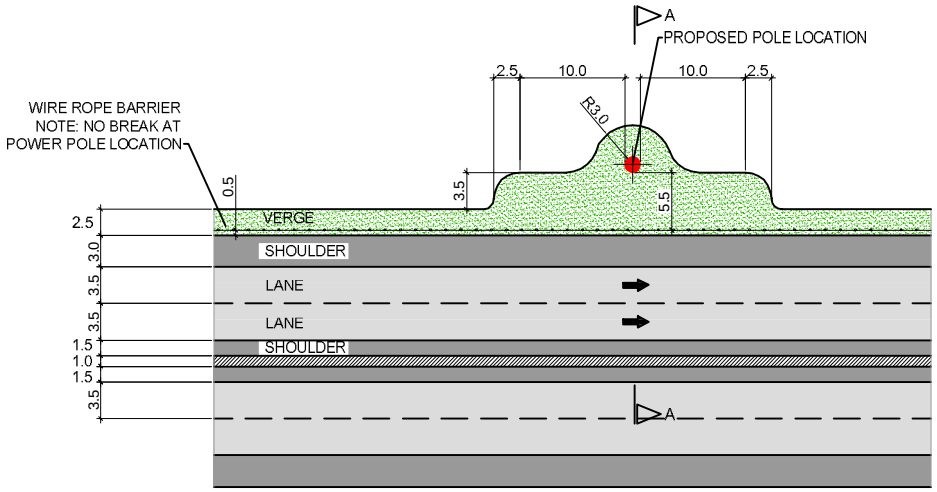

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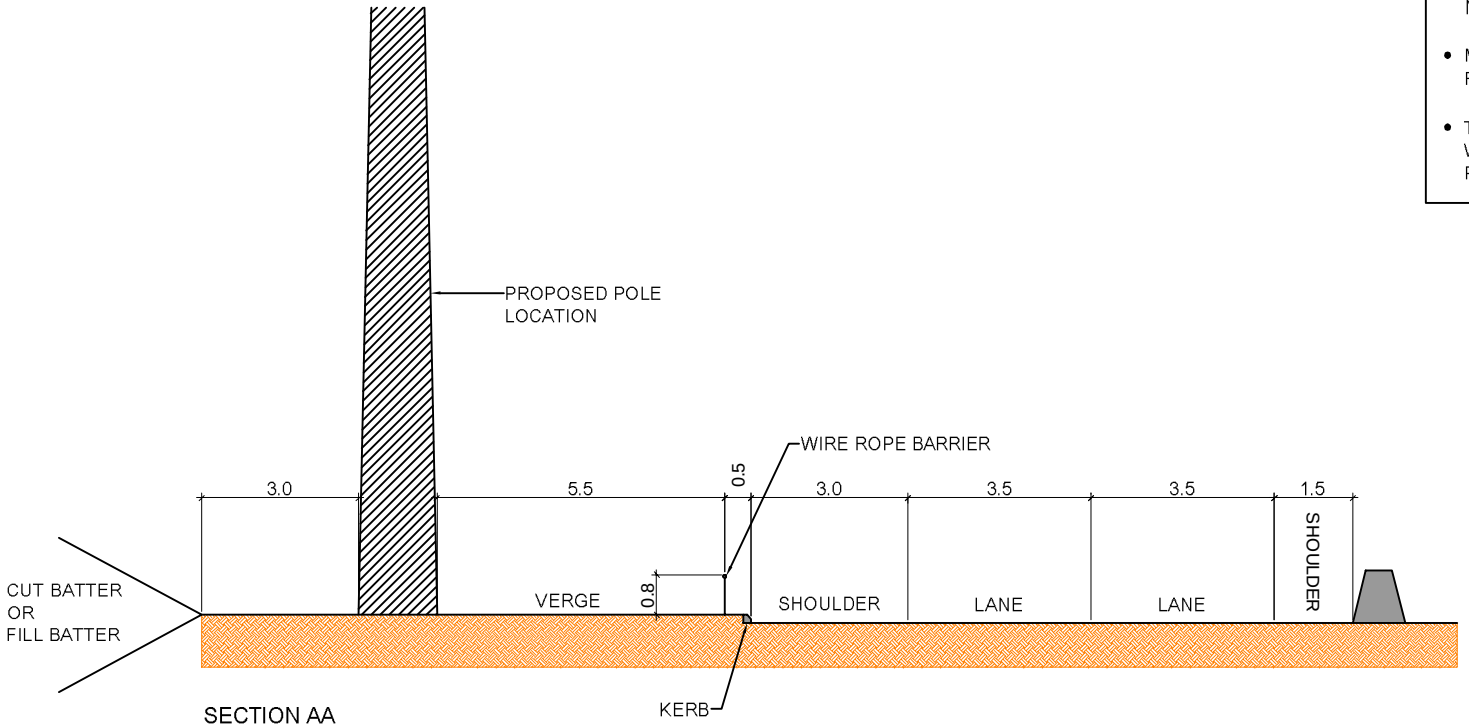


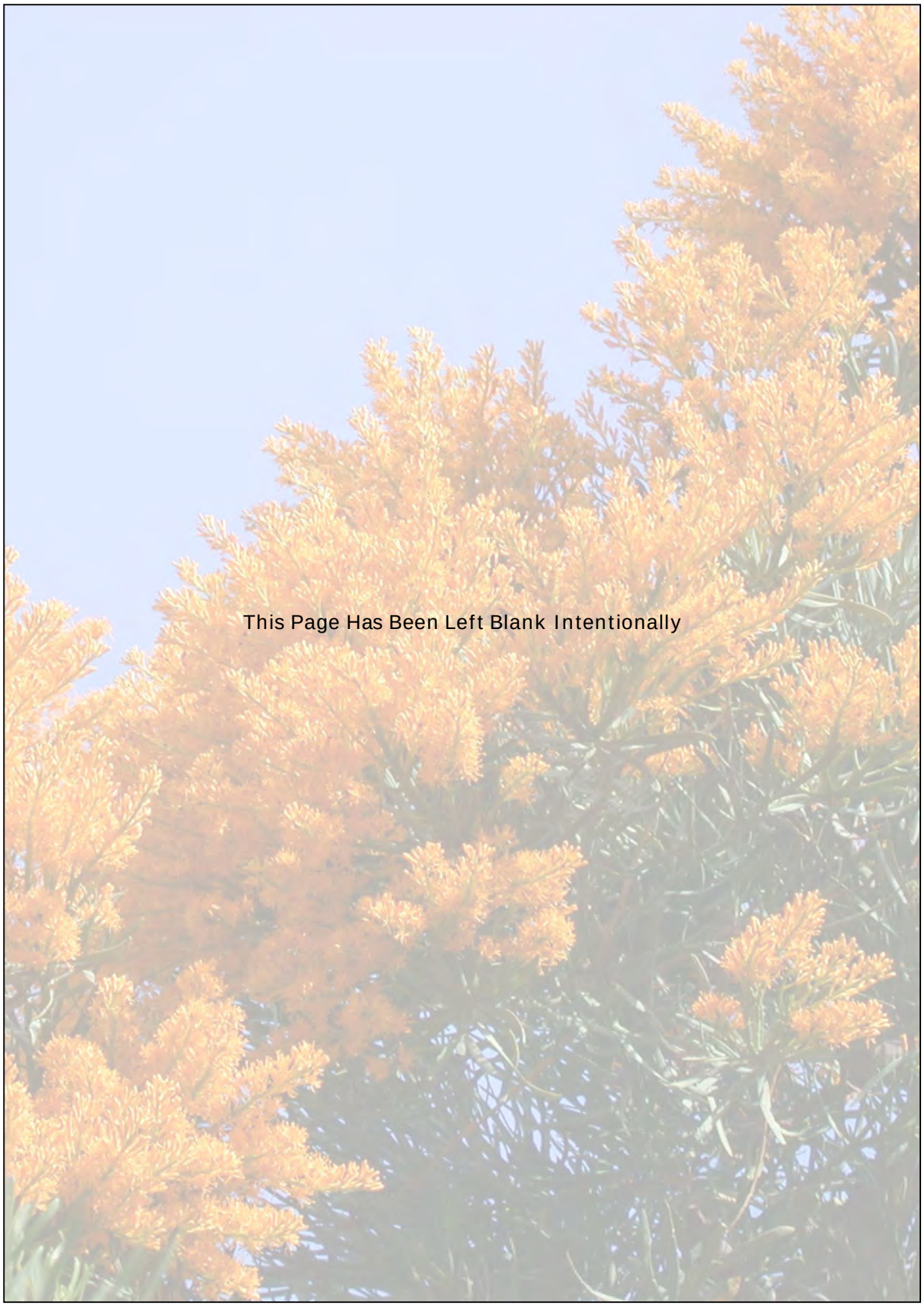
SECTION AA
1:50

NOTES:

- MAINTENANCE OF WESTERN POWER ASSETS WILL BE FROM THE EXTERNAL ROAD SHOULDER.
- TRAFFIC MANAGEMENT (INCLUDING LANE CLOSURES) WILL BE REQUIRED IN ACCORDANCE WITH MAIN ROADS PROCEDURES.

DRAFT

Figure 3.5-8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3.6. Land Tenure Amendments

Changes to land tenure arrangements will be required as a result of the proposed project. Whilst none of these changes require the resumption of private residential property, they will require an amendment of the MRS. Existing MRS and Local Planning Scheme zones and reserves within the project area are described in detail in Section 3.2, together with Beeliar Regional Park management zones and the various land tenure arrangements.

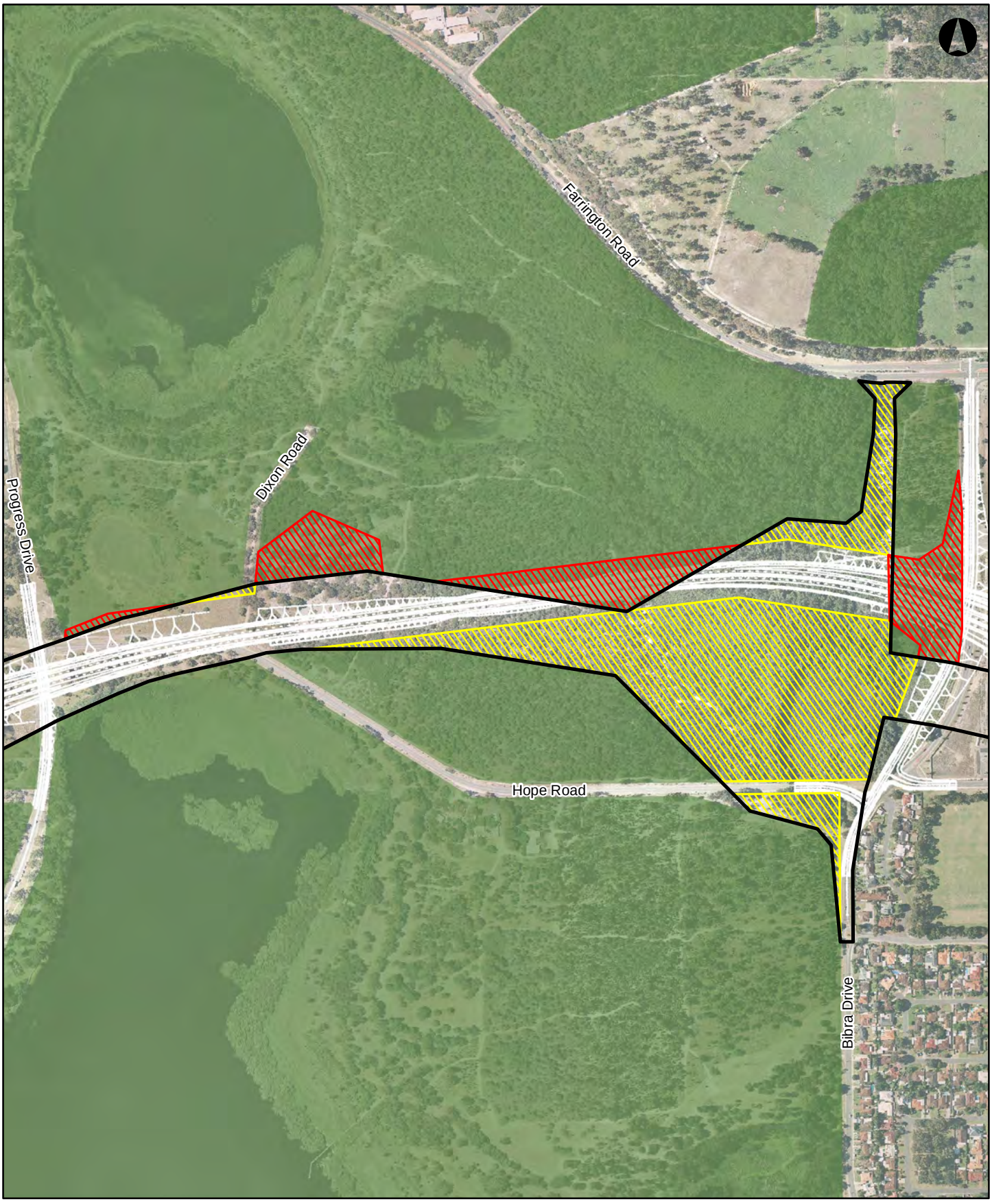
The alignment option selection process resulted in a preferred road alignment that partially extends outside the MRS primary regional road reserve boundary. The factors driving this decision are outlined in more detail in Section 3.3; however, the chosen alignment was considered the best outcome when weighed against environmental, social and economic factors. As a result of this decision, amendment of the MRS will be necessary to accommodate the preferred alignment and the corresponding need to acquire land outside the MRS road reserve, as indicated in Figure 3.6-1. It will also be necessary to resume approximately 5.4ha of the Beeliar Regional Park north of the MRS primary regional road reserve boundary.

When the MRS road reserve was first established in the 1960s, the proposed interchange for access to what is now known as the Murdoch Activity Centre was located over the top of Roe Swamp. This interchange has been moved east to minimise the impact on Roe Swamp and the high quality native vegetation existing within it. As a result, there is a large area of land currently part of the MRS primary regional road reserve that will no longer be required for this purpose, once the proposed project has been constructed.

Main Roads intends to transfer ownership of this land to an appropriate authority for its ultimate amalgamation as part of Beeliar Regional Park, with a corresponding change of tenure to ensure its continued protection and management for conservation and recreation purposes. Taking into account the need to retain a road reserve buffer on either side of the proposed road for maintenance access and minor variations incorporated during the detailed design phase, this strategy will result in the transfer of approximately 14.5ha of land currently reserved for primary regional roads to the conservation estate. (Figure 3.6-1). This represents an overall net increase in the conservation estate of 9.1ha, comprised of high quality native vegetation that is otherwise unlikely to be formally protected for conservation purposes. This commitment forms a key component of Main Roads' offset strategy, and is discussed in more detail in Section 10.

5.4ha of Beeliar Regional Park will be resumed

14.5ha of current road reserve will be transferred to conservation estate



Beeliar Regional Park Modifications

South Metro Connect

Figure 3.6-1

0 50 100 150 200 250

Metres

1:8,000 (A4)

- MRS Road Reserve
- Area Resumed from Beeliar Regional Park Conservation and Protection Zone
- Area Returned to Beeliar Regional Park Conservation and Protection Zone
- Beeliar Regional Park Conservation and Protection Zone
- Road Formation *(white)*

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3.7. Conclusion

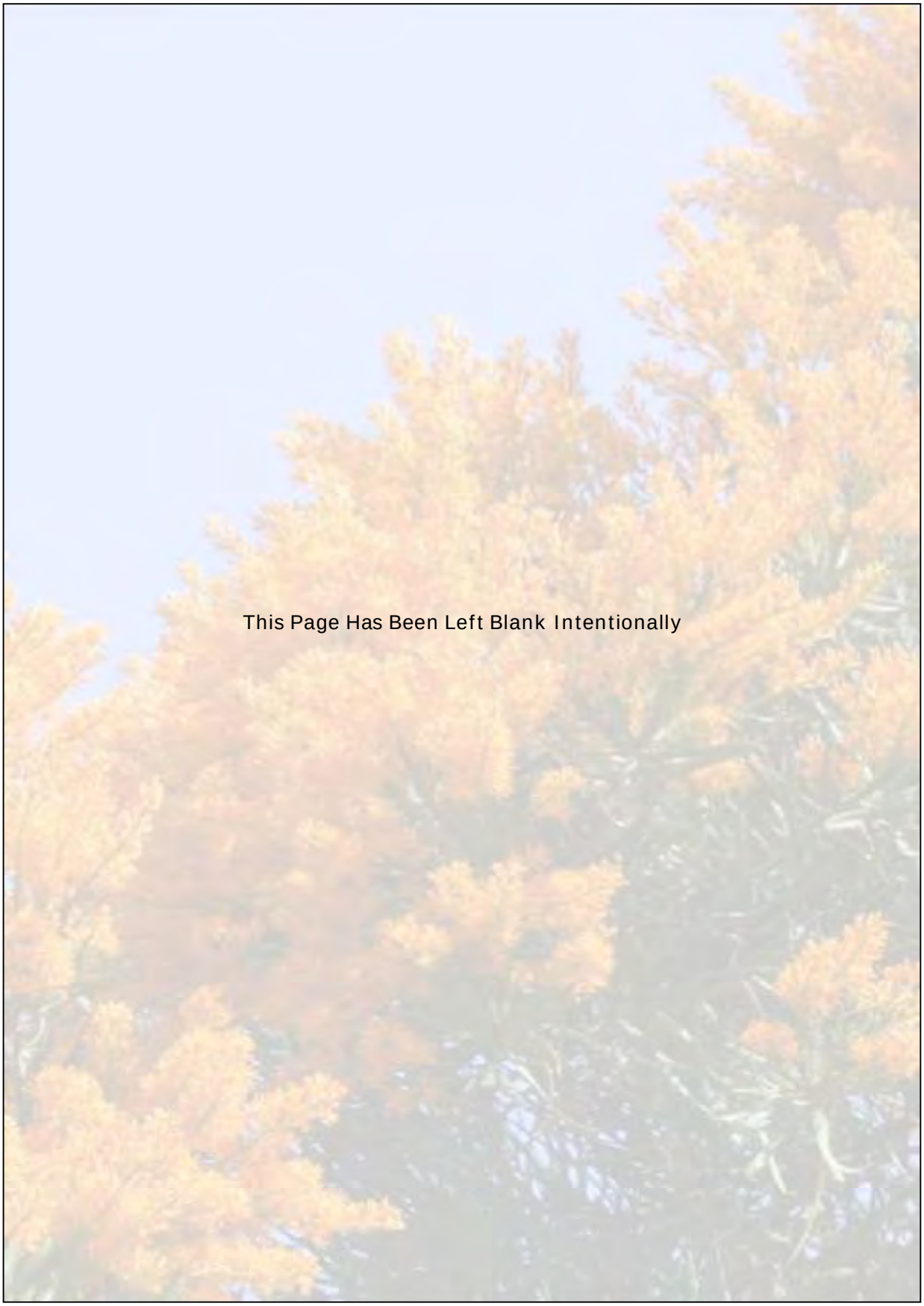
The South Metro Connect team has achieved its objectives of delivering an outstanding solution to road design in environmental sensitive areas and having a minimal impact on the environment. Substantial community and stakeholder engagement combined with the use of SMART and an MCA process to develop an innovative engineering solution has resulted in a highway design that minimises clearing of native vegetation, protects the values of wetland and adjacent lakes, whilst delivering a cost effective solution to relieve existing and future traffic congestion within the southern metropolitan area.

As a result of impact avoidance through design, SMC has achieved a net reduction in vegetation clearing between Stock Road and Bibra Drive of approximately 7ha. Of this, approximately 1.1ha is CCW. In addition, the design avoids several trees containing hollows suitable for black cockatoo nesting, minimises its impact on black cockatoo foraging habitat and reduces its impact on high quality vegetation communities.

In addition to 'impact avoidance through design', SMC will achieve a net environmental benefit as a result of a comprehensive set of management strategies to be applied during detailed design, construction and operation (presented in Section 6 and summarised in Section 7). These, combined with an offset package presented in Section 10, will achieve a net environmental gain through:

- Returning land within Roe Swamp CCW currently reserved as Primary Regional Roads to the conservation estate – a net gain of about 9ha to Beeliar Regional Park;
- Rehabilitation of presently degraded wetland areas;
- Rehabilitation of presently degraded vegetation;
- Installation of a bioretention basin to treat road runoff and increase availability of surface water to wetlands in the project area;
- Restoration of wetland functionality at Horse Paddock Swamp;
- Improved management of known, viable Graceful Sun-moth populations;
- Improvements in wetland migratory bird habitat with the Beeliar Regional Park; and
- Securing about 470ha of bushland for transfer to the conservation estate.

Design measures have reduced the construction footprint by 7ha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4. Regulatory Context

This Public Environmental Review (PER) has been developed in accordance with the *Guidelines for Preparing a Public Environmental Review/Environmental Review and Management Programme* (EPA 2009a) and the *EP Act Environmental Impact Assessment Administrative Procedures 2002* (EPA 2002a). The PER development also complies with Section 45 of *the Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and Section 38 of the *Environmental Protection Act 1986* (*EP Act*). In the context of project environmental approval, the overarching authorities for the Commonwealth and the State are the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) and the Environmental Protection Authority of Western Australia (EPA), respectively. The PER will be submitted to the EPA in accordance with the Bilateral Agreement between the Commonwealth and the State.

4.1. Environment Protection and Biodiversity Conservation Act 1999

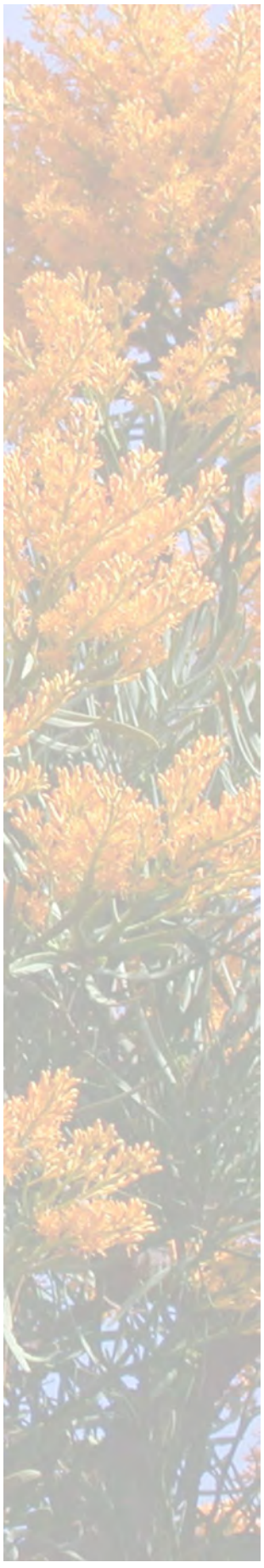
The *EPBC Act* is the Commonwealth Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places (Eight Matters of National Environmental Significance). The proposed project has the potential to affect several Matters of National Environmental Significance protected under the Commonwealth *EPBC Act* and was therefore referred to the Commonwealth Environment Minister in July 2009. These factors have been investigated as part of the environmental impact assessment process for the proposed project (summarised in Section 8).

4.2. Environmental Protection Act 1986

The *EP Act* is the primary legislative instrument for environmental assessment in Western Australia (WA). It specifies procedures for assessment and appeal processes, including responsibilities and functions of the Western Australian Minister for Environment and the EPA. Under Part IV of the *EP Act*, the EPA is responsible for coordinating environmental impact assessments for projects referred under Section 38 of the Act and considered by the EPA as likely to have a significant impact on the environment.

The *EP Act* also provides for the preparation of environmental protection policies, which are legally binding and may be directly relevant to the assessment of the proposed project. Through these and Environmental Protection Regulations, the Act regulates:

- Pollution and environmental harm offences;
- Clearing of native vegetation;
- Prescribed premises;
- Works approvals and licences; and
- Assessment of flora, fauna, wetlands and other environmental factors.



4.3. Other Regulatory Requirements

In addition to the key legislation outlined above, several other statutes are relevant to the proposal and are outlined in Table 4.3-1. Agencies responsible for administering the specified legislation are also identified.

Table 4.3-1: Statutes, Responsible Agencies and Requirements Summary

Statute	Responsible Agency	Requirements
International agreements		
Convention on Wetlands of International Importance (Ramsar)	DSEWPaC	Ramsar wetlands are protected as Matters of National Environmental Significance under the *EPBC Act*
China–Australia Migratory Bird Agreement (CAMBA)	DSEWPaC	Bilateral agreement between China and Australia relating to the protection of migratory birds. Migratory birds listed under this agreement are protected under the *EPBC Act*
Japan–Australia Migratory Bird Agreement (JAMBA)	DSEWPaC	Bilateral agreement between Japan and Australia relating to the protection of migratory birds. Migratory birds listed under this agreement are protected under the *EPBC Act*
Republic of Korea – Australia Migratory Bird Agreement (ROKAMBA)	DSEWPaC	Bilateral agreement between the Republic of Korea and Australia relating to the protection of migratory birds. Migratory birds listed under this agreement are protected under the *EPBC Act*
Commonwealth		
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	DSEWPaC	Protects significant Aboriginal areas and objects considered to hold particular significance in accordance with Aboriginal tradition
Energy Efficiency Opportunities Act 2006	DCC	Encourage more efficient use of energy by large energy-using businesses and for other related purposes
Environment Protection and Biodiversity Conservation Act 1999	DSEWPaC	Enables legislation for protection of migratory species under international agreements and other Matters of National Environmental Significance
National Greenhouse and Energy Reporting Act 2007	DCC	Mandatory reporting and dissemination of information about greenhouse gas emissions and energy use
Native Title Act 1993	National Native Title Tribunal	Recognises and protects Native Title and provides for land use agreements where Native Title exists

Statute	Responsible Agency	Requirements
State of Western Australia		
Aboriginal Heritage Act 1972 and *Regulations 1974*	Department of Indigenous Affairs	Provides a mechanism for recognising Aboriginal Heritage and considering the impacts of developments on Aboriginal Heritage values Requires submission of a request for Section 18 consent when disturbance of registered sites cannot be avoided
Agriculture and Related Resources Protection Act 1976	DAFWA	Provides for the management, control and prevention of certain plants and animals; the prohibition and regulation of the introduction and spread of certain plants; the introduction, spread and keeping of certain animals; the protection of agriculture and related resources generally; and for incidental and other purposes
Bush Fires Act 1954	State Fire and Emergency Services Authority	Provides for fire management and the control of fire in rural areas
Conservation and Land Management Act 1984	DEC	Provides for the use, protection and management of certain public lands, waters, flora and fauna Establishes authorities to be responsible for such protection Incidental or connected purposes
Contaminated Sites Act 2003 and *Regulations 2006*	DEC	Provides for the identification, recording, management and remediation of contaminated sites
Dangerous Goods Safety Act 2004	Department of Mines and Petroleum	Provides for the safe storage, handling and transport of dangerous goods
Electricity Industry Act 2004	Western Power	Transmission, distribution and maintenance of electricity to the South West Integrated System
Environmental Protection Act 1986 (Part IV)	Office of EPA	The principal statute pertinent to environmental protection in WA. It gives the EPA overall responsibility for the prevention, control and abatement of environmental pollution and for the conservation, preservation, protection, enhancement and management of the environment
Environmental Protection Act 1986 (Part V, Works Approval)	DEC	The principal statute pertinent to environmental protection in WA. A Part V Works Approval gives the DEC overall responsibility for works undertaken on a prescribed premise
Environmental Protection (Noise) Regulations 1997	DEC	Regulations that set noise limits for industry and methods for assessing and controlling noise

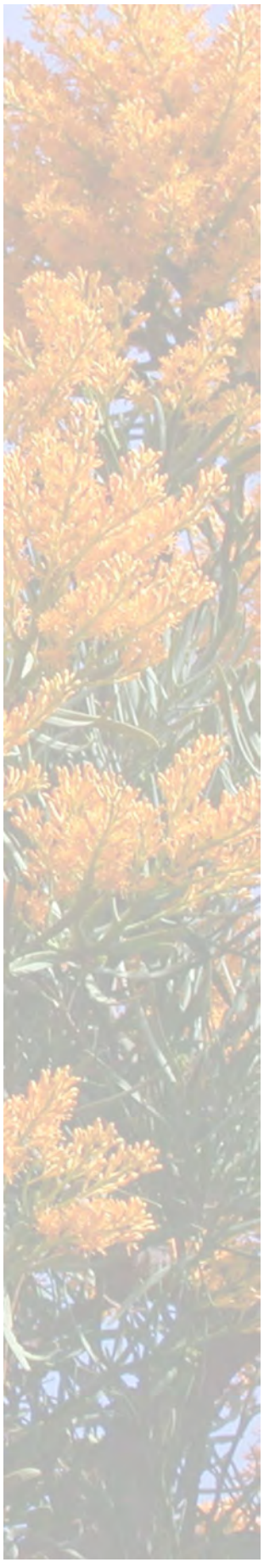
Statute	Responsible Agency	Requirements
Heritage of Western Australia Act 1990	Heritage Council of Western Australia	Provides for the conservation of places of significance to the cultural heritage of the State
Land Administration Act 1997	Department of Regional Development and Lands	Governs the administration of State land in Western Australia
Main Roads Act 1930	Main Roads Western Australia	Provides for the construction, maintenance, supervision and management of highways, main roads, secondary roads and other roads, the control of access to roads and for other relative purposes
Metropolitan Water Authority Act 1982	Water Corporation	Regulates drainage, water supply and sewerage
Occupational Safety and Health Act 1984	Work Safe	Provides regulations and guidance for the safety of workers
Planning and Development Act 2005	Western Australian Planning Commission	Provides for the preparation and amendment of local and regional planning schemes, interim development orders and State planning policies
Rights in Water and Irrigation Act 1914	DoW	Provides for planning and allocation of water in Western Australia
Water and Rivers Commission Act 1995	DoW	Provides for the conservation, protection and management of State water resources
Waterways Conservation Act 1976 and *Regulations 1981*	DoW	Provides for the conservation and management of certain waters and of the associated land and environment
Wildlife Conservation Act 1950	DEC	Provides for the conservation and legal protection of threatened flora and fauna, especially rare species
Planning and Development Act 2005	City of Cockburn, City of Melville	Provides for the preparation and amendment of local and regional planning schemes, interim development orders and State planning policies
Town Planning Scheme No. 3	City of Cockburn	The Scheme divides the local government district into zones to identify areas for particular uses and identifies land reserved for public purposes
Community Planning Scheme No. 5	City of Melville	The Scheme divides the local government district into zones to identify areas for particular uses

DAFWA – Department of Agriculture and Food (WA)
DEC – Department of Environment and Conservation
DCC – Department of Climate Change
DoW – Department of Water
DSEWPaC – Department of Sustainability, Environment, Water, Population and Communities

The EPA and other decision-making authorities (DMAs) issue guidance and policy statements that are also relevant to the environmental factors associated with this project and will be considered within the context of the proposed project. These are provided in Table 4.3-2.

Table 4.3-2: Relevant Policy and Guidance

Policies
Statement of Planning Policy: Environment and Natural Resources Policy
State Planning Policy 2.9 Water Resources
State Planning Policy 5.4 Road and rail transport noise and freight considerations in land use planning
Environmental Protection (Swan Coastal Plain Lakes) Policy 1992
Bush Forever and Statement of Planning Policy 2.8 Bushland Policy for the Perth Metropolitan Region (draft)
Draft Ambient Air State Environmental Policy, 2009
Guidance Statements
Guidance Statement 6: *Rehabilitation of terrestrial ecosystems*
Guidance Statement 8: *Environmental Noise* (Draft)
Guidance Statement 10: *Level of assessment for proposals affecting natural areas within the System 6 region and Swan Coastal Plain portion of the System 1 Region*
Guidance Statement 12: *Minimising Greenhouse Gas Emissions*
Guidance Statement 19: *Environmental Offsets*
Guidance Statement 20: *Sampling of short range endemic invertebrate fauna for environmental impact assessment in Western Australia*
Guidance Statement 33: *Environmental Guidance for Planning and Development*
Guidance Statement 41: *Assessment of Aboriginal Heritage*
Guidance Statement 51: *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia*
Guidance Statement 54: *Sampling of Subterranean Fauna in Groundwater and Caves*
Guidance Statement 54a: *Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia*
Guidance Statement 55: *Implementing Best Practice in Proposals Submitted to the Environmental Impact Assessment Process*
Guidance Statement 56: *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia*



Guidance Statements
Position Statement 2: *Environmental Protection of Native Vegetation in Western Australia*
Position Statement 3: *Terrestrial Biological Surveys as an Element of Biodiversity Protection*
Position Statement 4: *Environmental Protection of Wetlands*
Position Statement 9: *Environmental Offsets*
Contaminated Sites Management Series Guideline, 2001
Identification and Investigation of Acid Sulphate Soils and Acidic Landscapes, May 2009
Draft Treatment and Management of Soils and Water in Acid Sulfate Soil Landscapes, Jan 2009
Others
Environmental Protection (Environmentally Sensitive Areas) Notice 2005
Perth Metropolitan Transport Strategy 1995-2029
National Environment Protection Measure standards for ambient air quality
Carbon Pollution Reduction Scheme, Commonwealth Department of Climate Change

4.4. Decision-Making Authorities and Required Approvals

A key function of the EPA is assessing impacts of a proposal and making recommendations to the Minister for the Environment regarding its environmental acceptability. The Minister will be required to consult and reach agreement with relevant DMAs as to whether the proposed project may be implemented, and if so, under what conditions. Table 4.4-1 presents Commonwealth and State approvals that will be required for the proposed project; as well as applicable DMAs and relevant legislation for each approval.

Table 4.4-1: Required Approvals

Approval Required	DMA	Legislation
Environmental approval as assessed by this PER	Minister for the Environment in consultation with relevant DMAs	*EP Act 1986*
Section 18 Consent	Department of Indigenous Affairs	*Aboriginal Heritage Act 1972* (WA)
Consent to Construct and Operate Road	Main Roads Western Australia	*Main Roads Act 1930*
Consent to Remove/Construct Power line	Western Power	*Electricity Industry Act 2004*

Approval Required	DMA	Legislation
Dangerous Goods Licences	Department of Environment and Conservation	*Dangerous Goods Safety Act 2004*
Groundwater Licences	Department of Water	*Rights in Water and Irrigation Act 1914*
Land Tenure	Western Australia Planning Commission	*Land Administration Act 1997* and *Land Administration Regulations 1998*
Scheme Amendments – Metropolitan Region Scheme and Local Planning Scheme(s)	Western Australia Planning Commission	*Planning and Development Act 2005* and *Town Planning Regulations 1967*
Government Heritage Property Disposal Process	Heritage Council of Western Australia	*Heritage of Western Australia Act 1990*

4.5. Principles of Environmental Protection

In 2003, the *EP Act* was amended to include five core principles that are applied by the EPA to formal assessments to ensure environmental protection is achieved:

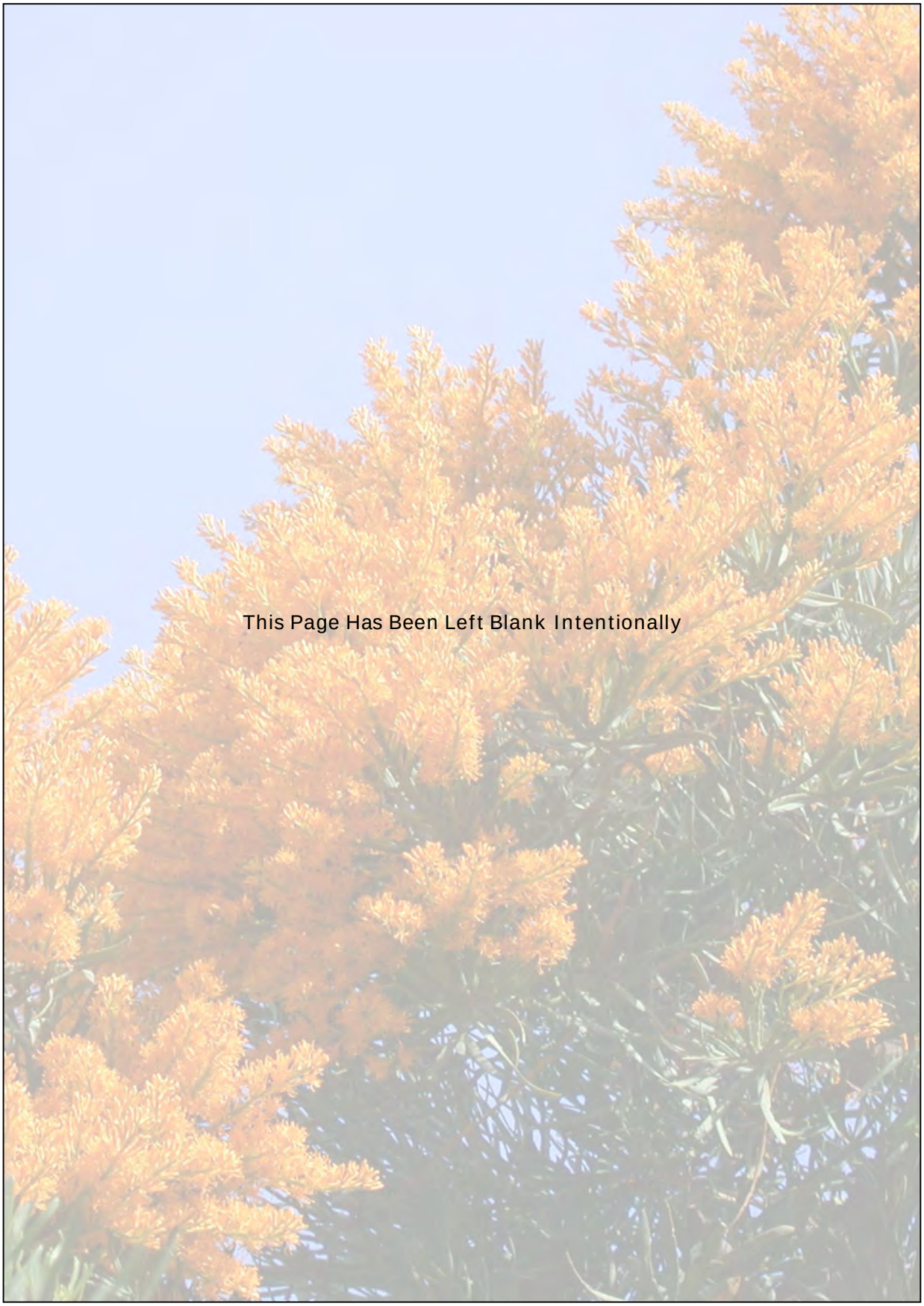
- Precautionary principle;
- Principle of intergenerational equity;
- Principle of conservation of biological diversity and ecological integrity;
- Principles relating to improved valuation, pricing and incentive mechanisms; and
- Principle of waste minimisation.

These principles have been applied throughout the project development process, including during options analysis, studies, surveys and impact assessment; as well as the stakeholder and community engagement programme. Consideration of environmental protection principles are summarised in Table 4.5-1. Environmental objectives for each factor are presented in Section 7.

Table 4.5-1: Consideration Given to Environmental Principles

Principle	Considerations Given to Principle	Relevant Sections in PER
The precautionary principle Where there are threats of serious or irreversible damage, lack of full scientific certainty must not be used as a reason for postponing measures to prevent environmental degradation In the application of the precautionary principle, decisions should be guided by: a) Careful evaluation to avoid, where practicable, serious or irreversible damage to the environment b) An assessment of the risk-weighted consequences of various options	To avoid the need for the precautionary principle: • Comprehensive desktop studies and field investigations of the biological and physical environment have been conducted; and • Significant conservation issues have been identified through the Environmental Impact Assessment process	*Section 5* *Section 6*
	The precautionary principle has been applied through incorporating bridges over Roe Swamp and in the section between Horse Paddock Swamp and Bibra Lake to ensure maintenance of hydrological flows in the absence of detailed groundwater investigations	*Section 1/3/6*
The principle of intergenerational equity The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations	Implementation of sustainability and innovation initiatives including use of multi-criteria analysis workshops to arrive at a preferred alignment	*Section 3*
	The project aims to achieve net environmental gain through: • Return of land within Roe Swamp currently reserved as Primary Regional Roads to Conservation Estate • Rehabilitation of presently degraded wetland/vegetated areas; the introduction of water treatment prior to bioretention basins to improve water quality and quantity, consequently reinstating wetland function to degraded areas adjacent to North Lake • Restoration of wetland values and functionality at Horse Paddock Swamp	*Section 10* *Section 6.2/6.3/6.6* *Section 10*
The principle of conservation of biological diversity and ecological integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration	Impacts on and conservation of biodiversity and ecological linkages have been specifically considered in depth	*Section 6*

Principle	Considerations Given to Principle	Relevant Sections in PER
	The design incorporates large openings such as bridges and faunal underpasses to facilitate movement of flora (in the long term), fauna and water in order to maintain ecological linkages	*Section 3/6*
Principles relating to improved valuation, pricing and incentive mechanisms 1) Environmental factors should be included in the valuation of assets and services 2) The polluter pays principle: those who generate pollution and waste should bear the cost of containment, avoidance or abatement 3) The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of waste 4) Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems	Valuation of environmental factors is achieved by ensuring they form a key consideration in decision-making A multi-criteria analysis process is used to ensure key factors are incorporated into the final design including: • Concept design • Environmental constraints • Heritage considerations • Community engagement • Stakeholder liaison Implementation of an Alliance delivery model to achieve improved valuation and pricing of project	*Section 5/6* *Section 3* *Section* 3.4 *Section 6* *Section 6.9* *Section 3*
The principle of waste minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment	Configuration of Roe Highway/Kwinana Freeway Interchange to make use of existing bridge Calculation and balance of cut and fill material to minimise external fill requirements Maintenance of project design above the water table, where possible, to minimise dewatering and wastewater discharge requirements Proposing the use of traditional waste materials such as crushed glass and red sands in road construction Implementation of energy efficient measures (e.g. low energy lighting and sensor lights), where possible	*Section 3*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5. Existing Environment

5.1. Introduction

This section outlines the existing physical, biophysical and social environments, as well as Aboriginal heritage values represented within the project area. There are three distinct zones of the project area, each characterised by their environmental and social values. The two outer portions of the project area (east of Bibra Drive and west of Progress Drive) are situated in areas of urban development, including residences and sensitive land uses (i.e. schools, churches, etc.). The central portion (between Progress Drive and Bibra Drive) consists of parklands, wetlands and vegetated areas.

The following section presents a series of discussions describing the existing environment, highlighting the key values as they are viewed by the Environmental Protection Authority (EPA) and other regulatory authorities. Where relevant, a review of previous reports is presented to provide an understanding of the degree to which the project area has changed over time. The order of chapters within this section generally follows the order of key factors as they are discussed in Bulletin 1088 (EPA 2003), with additional chapters inserted where relevant. The chapters do not seek to describe potential impacts arising from the proposed project on each factor; this is provided in Section 6. Rather, they seek to provide a factual account of what was measured during detailed investigations at the time of the study.

5.1.1. Critical Environmental Assets

The EPA identifies certain 'critical assets' that represent Western Australia's most important environmental assets. The EPA holds a presumption against recommending approval for proposals that are likely to have significant adverse impacts on 'critical assets', while acknowledging that in certain circumstances, such impacts may be approved by State Government Ministers where they relate to essential community services, including transport infrastructure (EPA 2006a).

The EPA identifies nine types of 'critical assets', of which four can be considered to occur within the project area. These include:

- Public conservation reserve system – the project area bisects (but is excluded from) the Beeliar Regional Park.
- Native vegetation – The project area includes a portion of Bush Forever Site 244 and clearing for the proposed project may be seriously at variance with Native Vegetation Clearing Principles.
- Wetlands – the project area includes Environmental Protection Policy (EPP) wetlands and Conservation Category Wetlands (CCW).
- Heritage – The project area includes sites registered on the Department of Indigenous Affairs (DIA) site register and is recognised as holding significant cultural heritage values.

The wetlands of the project area are recognised as complex, of high conservation value and in significant decline on the Swan Coastal Plain

Much of the wetland areas have been subject to historical and ongoing waste disposal

5.1.2. Studies and Investigations

In accordance with the Environmental Scoping Document (ESD) (South Metro Connect (SMC) 2010), an array of studies have been undertaken to develop a detailed understanding of the existing environment and inform this impact assessment. A brief description of the studies undertaken to inform consideration of relevant environmental factors is provided below.

5.1.2.1. Wetlands

The wetlands of the project area are considered to be complex, of high conservation value and in significant decline on the Swan Coastal Plain (EPA 2003). SMC invested a significant amount of effort into describing the wetland values and functions of the project area. Wetlands of the project area are described in detail in Section 5.2. In addition, Section 5.4 discusses the current status of potential contamination within the project area; Section 5.5 describes the risk of acid sulfate soils (ASS) being encountered; Section 5.6 details the surface and ground water movement through the project area and particularly within the wetlands; and Section 5.7 outlines the water and sediment quality. While all of these factors integrate to describe the form, function and values of the wetlands within the project area, they are sufficiently distinct to warrant separate descriptions.

Syrinx Environmental & V&C Semeniuk Research Group, 2011. Roe Highway Extension Project. Wetland Ecology Investigations (Appendix D)

This study included the installation and monitoring of an extensive network of piezometers, which extend well beyond the immediate project area. These have enabled a detailed understanding of the hydrology and stratigraphy across the project area wetlands. Groundwater levels and some hydrochemical properties were monitored at each piezometer on a monthly basis over a 12 month period.

The study also mapped the extent of Groundwater Dependent Ecosystems (GDEs) within the project area, describing GDE units at a finer scale than standard flora and vegetation mapping. This provided an indication as to what vegetation units may be at risk from changes in groundwater levels or surface water availability.

The results of this report are referred to in Sections 5.2, 5.3, 5.6, 5.7 and 5.8.

AECOM 2011. Preliminary Contaminated Site Investigation (Appendix E)

The purpose of this study was to determine the potential for historically contaminated sites to be disturbed as a result of construction of the proposed project. Such disturbance has the potential to result in significant environmental and public health impacts. Records indicate that much of the wetland areas have been subject to formal and informal waste disposal. As far as practicable from the records available, this study determined the locations of historically contaminated sites. It recommends additional investigations in locations within the project area where the exact location of recorded landfill could not be determined.

The information provided in this report is discussed in Section 5.4.

AECOM 2011. Preliminary Acid Sulfate Soil Investigation (Appendix F)

This desktop review and preliminary site investigation provides an indication of the likelihood that ASS will be encountered within the project area during construction. It highlights the need for additional investigations prior to construction activities occurring within the wetland areas, in order to prevent wetlands being contaminated by ASS.

This report forms the basis of the discussions presented in Section 5.5.

AECOM 2011. Roe Highway Extension – Modelling Existing Groundwater and Surface Water Movement (Appendix G)

The objective of the modelling study was to develop a tool to aid the understanding of the interaction of groundwater and surface water movements within the project area. The purpose of this tool is to inform the decision making process in the development of the proposed project.

The results of this report are discussed in Sections 5.2 and 5.6.

South Metro Connect 2011. Drainage Report – MUSIC Modelling (Appendix H)

The objective of the Drainage Design Report is to provide the background information used for the development of the concept drainage design covering the proposed project. The scope of the concept drainage design was to establish an infrastructure arrangement that would adequately serve the proposed concept design of the road, for a level of service represented by standard MRWA guidelines and DoW principles, including the *Stormwater Management Manual of Western Australia* (DoW 2004) and the Decision Process for Stormwater Management in Western Australia (DoW 2009).

The report also includes an assessment of the design requirements for ensuring nutrient water balance is achieved by bioretention and infiltration basins.

The information presented within this report is discussed in Section 5.7.

AECOM 2011. Baseline Water and Sediment Quality (Appendix I)

This study involved a sampling programme aimed at providing background information on the water and sediment quality of the wetlands within the project area. Water and sediment samples were collected and analysed for general constituents, nutrients, elements, hydrocarbons, organics and biological components. Samples were collected from:

- Stormwater outlets within the wetland catchments;
- North and Bibra lakes, Roe Swamp and Horse Paddock Swamp for water (when present) and sediment; and
- Groundwater Bores.

The EPA notes that vegetation and flora of the project area is in reasonable ecological condition and represents a diverse array of complex vegetation units

Fauna habitats in the project area support a diverse range of fauna, including several conservation significant species

The study's main purpose was to establish a baseline for water and sediment quality within the wetlands, against which stormwater treatment performance criteria could be set for the proposed project. The study also provided additional indicators regarding wetland health and value.

The results of this report are referred to in Section 5.7.

AECOM 2011. Transport Infrastructure Effects: Case Study (Appendix J)

This case study analyses the historical effects of a high volume road located in a similar wetland setting to the proposed project, by reviewing trends in wetland and vegetation change indicated by historical aerial photography.

The study is referred to in Section 6.2.

5.1.2.2. Vegetation and Flora

AECOM 2011. Flora and Vegetation of the Roe Highway Extension (Appendix K)

The vegetation and flora of the project area is identified by the EPA as being in reasonable ecological condition and representing a diverse array of complex vegetation units (EPA 2003). SMC has undertaken extensive surveys throughout the project area, which, in addition to the requirements of EPA Guidance Statement No. 51 (EPA 2004b) included two targeted spring Declared Rare Flora (DRF) surveys and vegetation surveys in each of the four seasons. In addition to this, detailed surveys have been undertaken to accurately quantify the extent of Graceful Sun-moth habitat throughout the project area and beyond.

The report provides the detail for a comprehensive description of the existing conditions within the project area. This description is presented in Section 5.8.

Glevan 2010. Dieback Survey (Appendix L)

SMC commissioned a *Phytophthora cinnamomi (*dieback) mapping exercise to be undertaken. The purpose of the study was to provide an indication of dieback risk areas, details regarding the occurrence of dieback within the project area, and advice on likely quarantine requirements during construction.

In addition to the above studies, GDE mapping is provided in Appendix D (Syrinx 2011), which is discussed in Section 5.8.

5.1.2.3. Fauna

The project area and its surrounds support a vast array of fauna habitats, ranging from aquatic habitats, through riparian vegetation and wetlands to a range of woodlands. As a result, the project area is recognised as supporting a diverse range of fauna, including several conservation significant species. SMC has undertaken a range of surveys and investigations in order to determine the assemblage of fauna species that utilise the project area.

The majority of these studies have informed the preparation of Section 5.9, unless otherwise specified below.

Phoenix 2011. Roe Highway Extension Vertebrate Survey (Appendix M)

The purpose of this investigation was to sample the vertebrate populations within the project area and areas immediately adjacent to it. The survey methodology was developed in close consultation with the Department of Environment and Conservation (DEC) and included spring and autumn Level 2 surveys, targeted searching and spotlighting, and black cockatoo nesting surveys.

Phoenix 2011. Roe Highway Extension Southern Brown Bandicoot Monitoring Programme (Appendix N)

The Southern Brown Bandicoot is recognised as a significant mammal species known to exist within the project area (EPA 2003) and is presently classified as Priority 3. As a result, DEC specifically requested a study into the Southern Brown Bandicoot population within the project area. SMC extended this study to neighbouring areas, as well as areas surrounding the previously constructed Roe Highway Stage 7 that are connected by fauna underpasses. The original intention was to fit all captured individuals with radio tracking devices in order to gain an understanding of their range and movements. Given that these devices were easily shed by individuals, an analysis of movements was instead made on the basis of recapture of micro chipped individuals.

Western Wildlife 2010. Wetland and Migratory Bird Survey (Appendix O)

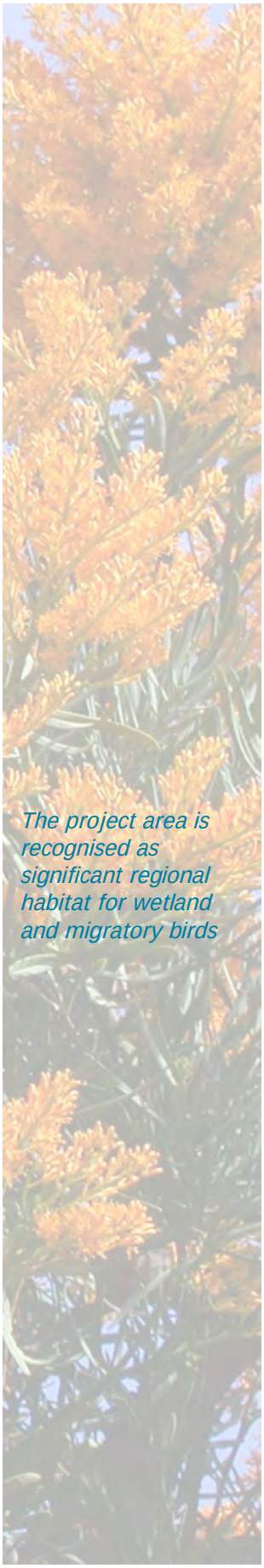
The project area is recognised as a significant regional habitat for wetland and migratory birds, providing summer refuge for species when more arid areas east and north of the project area are dry (EPA 2003). SMC commissioned a 12 month study that undertook a monthly census of 13 wetlands forming part of the Eastern Chain of the Beeliar Wetlands. The study also included a detailed literature review investigating the recorded effects of major roads on wetland and migratory birds, as well as providing examples of impact management applied in various situations.

Phoenix 2011. Short Range Endemic and Invertebrate Fauna Survey (Appendix P)

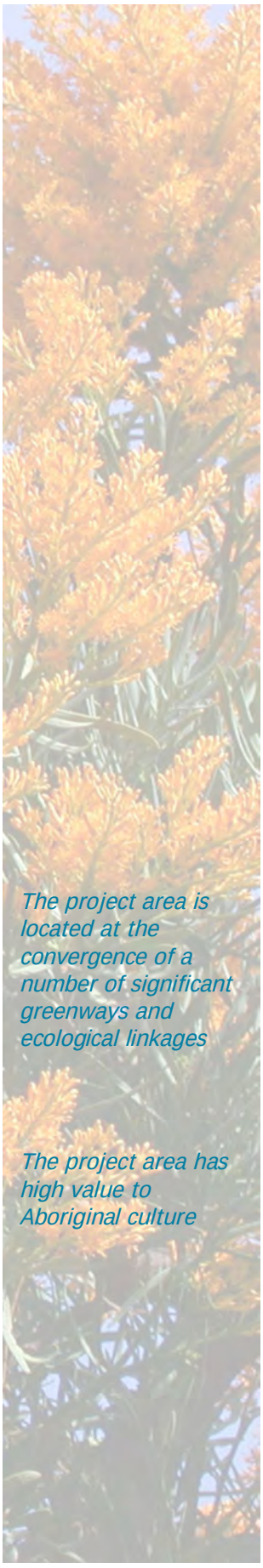
South Metro Connect commissioned a survey of invertebrate species within the project area, with the main objectives of determining the presence of Graceful Sun-moths or Short Range Endemic (SRE) species. The Graceful Sun-moth investigation was targeted on the basis of the results of a detailed *Lomandra hermaphrodita* survey, conducted in accordance with DEC guidelines, and adapted to the project area to provide additional detail.

Phoenix 2011. Aquatic Macroinvertebrate Survey (Appendix Q)

South Metro Connect undertook several rounds of sampling to describe the aquatic macroinvertebrates within the wetlands of the project area. The study was proposed in response to historical reports of fresh water sponges within North Lake (EPA 2003), as well as to provide an indication of wetland health at the time of the study.



The project area is recognised as significant regional habitat for wetland and migratory birds



The project area is located at the convergence of a number of significant greenways and ecological linkages

The project area has high value to Aboriginal culture

Phoenix 2011. Roe Highway Extension Oblong Turtle Survey (Appendix R)

Although not originally proposed in the Environmental Scoping Document (SMC 2010), SMC undertook a survey of the Oblong Turtle population within North and Bibra lakes in response to community requests. The study was undertaken during the breeding season to attempt to determine the location of preferred nesting sites.

Phoenix 2011. Graceful Sun-moth Survey (Appendix S)

South Metro Connect undertook two seasons of Graceful Sun-moth investigations. The first season's results are reported in Appendix P. Appendix S presents the findings of the 2011 survey, which resurveyed the project area, as well as sites deemed to contain suitable habitat within approximately 8km of the project area. The results of this report are used to provide the description of conservation significant species within the project area in Section 5.9.

Phoenix & AECOM 2011. Investigation into the Effect of Road Noise on Birds (Appendix T)

Phoenix Environmental (Phoenix) and AECOM collaborated to undertake a brief, initial study into the potential effects of noise on wetland birds. Phoenix undertook spot bird censuses at wetlands adjacent to high volume roads, and compared the results with spot noise measurements. The results were combined with the findings of a desktop investigation undertaken by AECOM into the measured effect of noise in locations around the world. The findings suggest that noise levels above 55dB may result in some impacts on breeding behaviour. While these results are inconclusive, they highlight the fact that there has been little long-term research into this effect. The outcomes of this study are discussed in Section 6.7.

5.1.2.4. Ecological Linkages

The project area is located at the convergence of a number of significant greenways and ecological linkages. The EPA recognised the importance of these linkages in its advice through Bulletin 1088 (EPA 2003). SMC undertook a desktop assessment of the regional and local greenways and ecological linkages to provide a detailed description of their relationship with the project area. This assessment is provided in Section 5.10.

5.1.2.5. Aboriginal Heritage

The project area is considered to be of high archaeological and ethnographical value to Aboriginal culture. This is recognised by the existence of several registered Aboriginal heritage sites within and adjacent to the project area. A detailed desktop assessment, followed by an extensive Aboriginal Consultation programme was undertaken in accordance with requirements of the *Aboriginal Heritage Act 1972*. The report was reviewed, and information relevant to the Environmental Impact Assessment process is presented in Section 5.16.

5.1.2.6. Residential Amenity

The EPA identifies residential amenity within the section west of Progress Drive and east of Bibra Drive as being of concern (EPA 2003). In this regard, residential amenity refers to noise and vibration impacts on residences and sensitive land uses.

AECOM 2011. Acoustic Assessment Report (Appendix U)

South Metro Connect undertook a comprehensive investigation into the likely noise levels resulting from the proposed project. This study included the collection of site data and development of a detailed noise model to predict the likely noise levels adjacent to the proposed project in the years 2016 and 2031. The outcomes of this study are discussed in Sections 5.11 and 6.10. It is important to note that the noise modelling is based on a concept design that is subject to change during detailed design, at which time noise modelling will need to be revised.

5.1.2.7. Recreation and Education

South Metro Connect 2011. Community and Stakeholder Engagement Programme (Appendix B)

The EPA considers that the project area contains high recreational and educational values, which warrant consideration (EPA 2003). SMC undertook a comprehensive Community engagement programme, which is detailed in Section 3.3. The outcomes of this process are provided in Sections 5.15 and 6.11.

5.1.2.8. Additional Studies

In addition to investigations relating to the key factors identified by the EPA in Bulletin 1088 (EPA 2003), SMC undertook the following studies:

- AECOM 2010. Roe Highway Extension Air Quality Report (Appendix V)

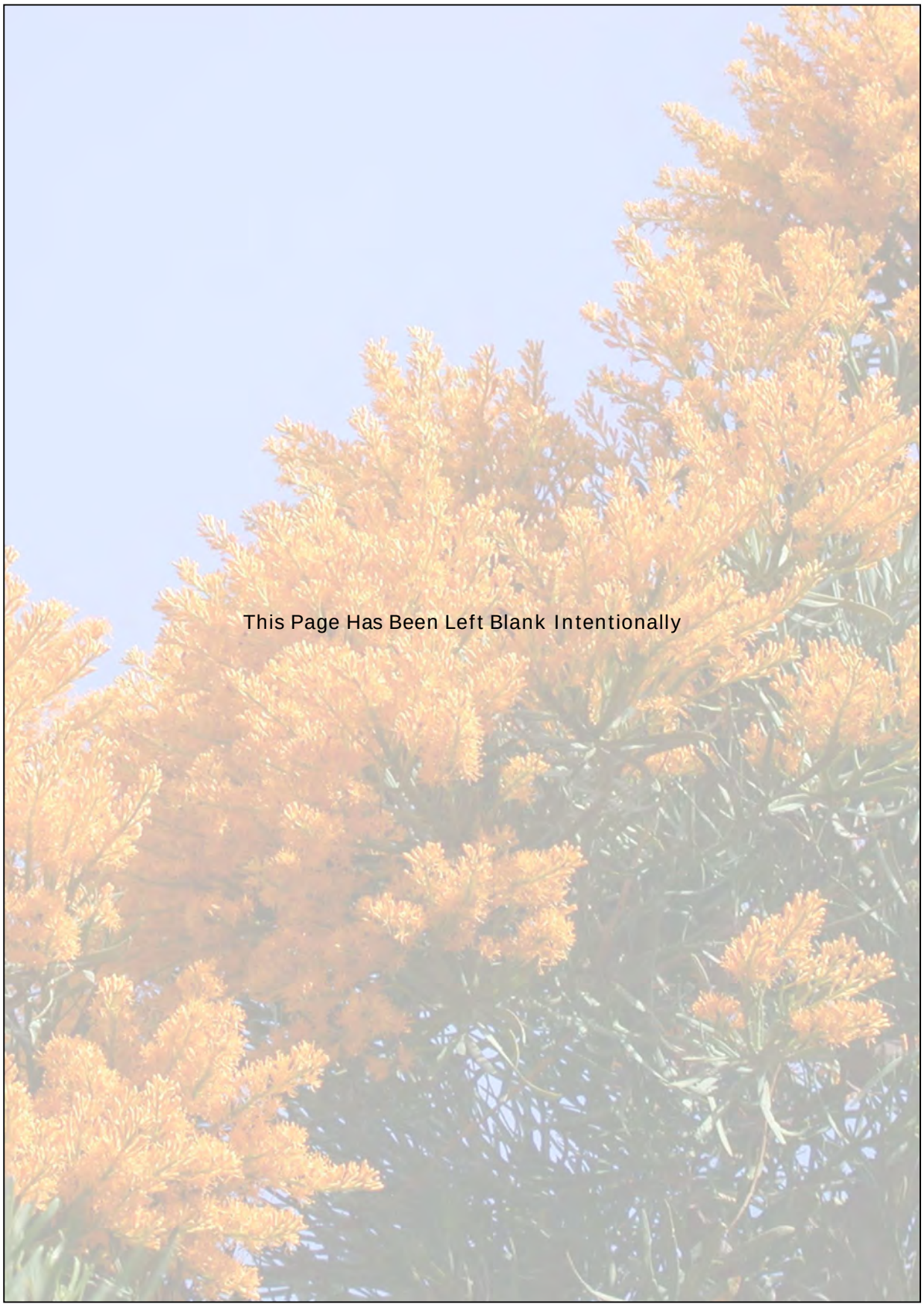
  A report describing the results of a review of current background air quality data and modelling of future air quality parameters resulting from the project. The information provided in the report is presented in Sections 5.12 and 6.13.

- AECOM 2010. Greenhouse Gasses and Climate Change (Appendix W)

  SMC commissioned an investigation into the current factors influencing global climate change and the contribution that the proposed project may have on these. The report has been used to inform the description of the existing climate in Section 5.6 and the assessment of the impact of greenhouse gas emissions in Section 6.14.

- AECOM 2011. Visual Impact Assessment (Appendix X)

  A report investigating the likely visual impacts arising from the proposed project, including a draft Landscape and Urban Design Framework prepared with the intention that it form the basis of visual impact mitigation during detailed design. The study forms the basis of the description of the current visual landscape presented in Section 5.14 and the potential impacts of the proposed project as described in Section 6.12.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5.2. Conservation Status of Wetlands

The *Environmental Protection Act* (*EP Act)* defines wetlands as areas of seasonally, intermittently or permanently waterlogged or inundated land (whether natural or otherwise) and includes lakes, swamps, marshes, springs, damplands, tidal flats or estuaries. The Beeliar Wetlands are part of the hydrology of the Swan Coastal Plain and widely recognised as being significant for their ecological, hydrological, social and economic values (EPA 2008b).

Wetlands have characteristic vegetation, faunal assemblages, stratigraphy and geomorphology (EPA 2008b). The latter two of these attributes are summarised for the project area in this section. Vegetation and fauna assemblages are detailed in Sections 5.8 and 5.9, respectively. Visual, recreational and heritage values associated with project area wetlands are detailed in Sections 5.14, 5.15 and 5.16, respectively.

Wetlands act as biological filters by retaining sediment and absorbing nutrients and pollutants, and can provide flood control by storing and detaining stormwater. These naturally occurring wetland functions are detailed in this section, with Sections 6.2 and 6.3 describing the predicted impacts on these natural functions.

5.2.1. State Wetland Legislation and Policy

This section describes the legal and policy framework provided by the State which defines the conservation significance of wetlands. There are no Commonwealth listed wetlands within the proposed project area.

The overarching State Government policy for the protection of wetlands is the Wetlands Conservation Policy. This policy was enacted as part of a commitment to identify, maintain and manage the State wetlands, including the full range of wetland values, for the long-term benefit of the people of Western Australia (Government of Western Australia 1997).

The *EP Act* provides the legislative context for protection of wetlands, making it an offence to cause environmental harm without seeking the permission of the EPA. A major amendment to the *EP Act* in 2003 made it an offence to cause environmental harm.

Under Part III of the *EP Act*, the EPA has prepared an Environmental Protection Policy (EPP) for lakes on the Swan Coastal Plain: *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* (*Lakes EPP*). An EPP establishes:

- The boundaries of the area and the portion of the environment to which the policy applies; and
- The basis on which the environment in this area is to be protected or pollution is to be prevented, controlled or abated.

Bibra Lake and Horse Paddock Swamp are protected under Lakes EPP

The *Lakes EPP* includes 27 maps (referred to as Department of Land Administration Miscellaneous Plan 1815) and seeks to 'prohibit filling, mining, pollution or changing the drainage of wetlands on the Swan Coastal Plain, except where absolutely necessary'.

The *Environmental Protection (Environmentally Sensitive Areas) Notice 2005* describes Environmentally Sensitive Areas (ESAs). This includes defined wetlands and the area within 50m of the wetlands. In this regulation, a defined wetland includes a wetland designated as a Conservation Category Wetland (CCW), as described in the Geomorphic Wetlands Swan Coastal Plain dataset (Hill *et al.* 1996).

5.2.1.1. Geomorphic Wetland Dataset

The DEC administers the Geomorphic Wetlands of the Swan Coastal Plain dataset (Hill *et al.* 1996). Wetlands of the Swan Coastal Plain, from Wedge Island to Dunsborough, have been mapped, classified and evaluated. This work developed management categories for wetlands that evaluate wetland attributes, functions and environmental values.

The Geomorphic wetland dataset provides aspirational guidance on management objectives for three wetland management categories. The management categories applied to the Swan Coastal Plain (including those in the Beeliar Chain of relevance to this proposal) are:

- Conservation Category Wetland (CCW) – the EPA urges that all CCWs and appropriate buffers are fully protected;
- Resource Enhancement Wetland (REW) – the EPA urges that all reasonable measures are taken to minimise the potential impacts on REWs and appropriate buffers. Rehabilitation of these wetlands is encouraged; and
- Multiple Use Wetland (MUW) – the EPA urges that reasonable measures are taken to retain the wetland hydrological functions (including on-site water infiltration and flood detention) and, where possible, other wetland functions.

The EPA developed *Position Statement 4: Environmental Protection of Wetlands* for further guidance on the protection and management of wetlands (EPA 2004b). The policy is designed to be consistent with the Wetlands Conservation Policy. EPA (2004b) provides a summary of the aspects regarding environmental protection of wetlands in Western Australia that the EPA considers important in guiding its decisions and advice to government on matters of environmental protection.

5.2.1.2. Wetland Buffers

The wetland buffer is the designated area adjoining the margins of a wetland that is identified and managed, as it may assist to protect a wetland's ecosystem health. To maintain wetland values, it may be important to determine, protect and manage an adequate buffer. The DEC measures the buffer from the geomorphic wetland boundary. Wetlands that are to be afforded the highest protection require a minimum 50m buffer distance (EPA 2008b).

5.2.2. Physiography of Regional and Local Wetlands

The regional and local setting in which wetlands are situated determines their attributes - size, shape, depth, periodicity of water, recharge and discharge mechanisms, broad range of water chemistry, and style and composition of wetland fill.

5.2.2.1. Regional Wetlands

Wetlands in south-western WA generally occur within the Swan Coastal Plain, which is a 30km-wide strip from the coast to the Darling Scarp uplands, from Cape Naturaliste in the south to north of Perth. The plain consists of sandy soils that contain a number of wetlands.

From east to west on the Swan Coastal Plain, the wetlands change from dominant channel and flat forms to basin forms (Semeniuk 1988). This change in wetland shape and style reflects the various landform settings and underlying geology. The hollows in the Bassendean Dunes produce irregular to meandering, rounded, seasonally inundated and seasonally waterlogged basin wetlands, hydrologically connected and poorly drained, being at or near the regional water table.

The hollows in the Spearwood Dunes produce linear permanently and seasonally inundated basin wetlands, in chains along inter-ridge swales, which are also close to the water table. These types of wetlands form the Western Chain of the Beeliar Wetlands and are located west of the project area.

In the contact depression between the Spearwood and Bassendean dunes, a chain of rounded to ovoid, predominantly seasonally inundated basins occurs with geometric and scalar attributes deriving from both Spearwood and Bassendean dune topography. These types of wetlands form the Eastern Chain of the Beeliar Wetlands (the Eastern Chain) and it is in the northern part of this chain that the project area is located (Semeniuk 1988). The Eastern Chain extends as far north as Blue Gum Lake and south to Bollard Bulrush Swamp (Figure 5.2-1).

5.2.2.2. Wetland Systems of the Project Area

The Eastern Chain is a series of macroscale to microscale, rounded to ovoid wetlands. The wetlands within this chain are considered to be similar to most other basin wetlands on the Swan Coastal Plain, outside urban areas, in having generally very simple water balances.

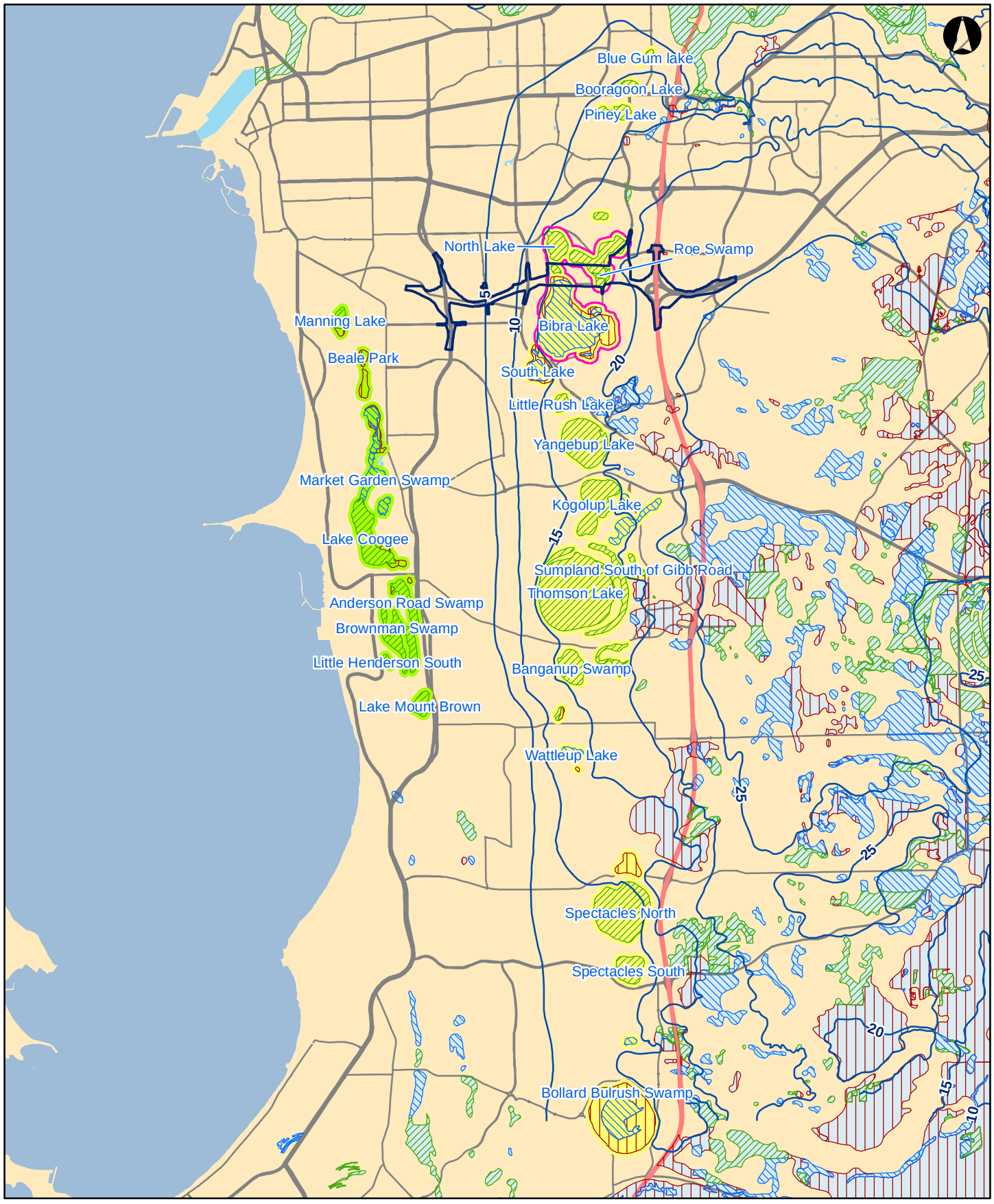
Most wetlands are perceived simply as hollows that lie below the level of the local water table. Rainfall recharges the surface water directly and is recharged through the sandy soils surrounding the lake. Water is lost by discharge into underlying aquifers, direct evaporation from the water surface and by evapotranspiration from emergent and phreatophytic fringing vegetation.

Lakes receive groundwater on the up gradient side and discharge water on the down gradient side. As such, they are termed 'through flow' lakes, which in the local context generally flow from east to west. Wetlands located within urban areas sometimes have a more complex set of water balance components, including additional sources of water such as stormwater drainage, runoff from adjacent car parks, drainage from adjacent wetlands, and additional losses through irrigation and bore extraction of groundwater up slope. The Eastern Chain of wetlands is in direct hydraulic continuity with the unconfined aquifer of the superficial formations and is thus an expression of the groundwater. This means that the surface water in the wetlands is, under natural conditions, largely comprising exposed groundwater.

As a result of the water balance, the project wetland system comprises a group of interrelated, seasonally flooded (or permanently inundated) basins (lakes), seasonally inundated basins (sumplands) and seasonally waterlogged basins (damplands) (Semeniuk 1987; Semeniuk and Semeniuk 1995). Lakes are made up of three zones that conform to a hydrological gradient of greatest wetness in the centre to least wetness at the margin. Only the central zone has the characteristics of a lake. The outer zone is a zone of seasonal waterlogging or ephemeral inundation.

There are similar but fewer divisions in a sumpland: an inner zone of seasonal inundation and an outer zone of seasonal waterlogging. Lakes and sumplands have surface water for all or part of each year, respectively; whereas damplands have water saturating the root zone of plants but no surface expression. Sources of the surface water contained within the lakes and sumplands consist of groundwater under the basin, lateral flows from the eastern margins and direct rainfall.

The project area wetlands are listed in Table 5.2-1 along with their geomorphic classification and evaluation. Their locations are illustrated in Figure 5.2-2.



Regional Wetlands

South Metro Connect

Figure 5.2-1

0 1 2 3 4

Kilometres

1:120,000(A4)

Wetland Classification

- Conservation
- Resource Enhancement
- Multiple Use
- Maximum Groundwater Contours (5m)

Beeliar Wetlands

- Eastern Chain
- Western Chain
- Project Wetland System
- Project Area

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Table 5.2-1: Classifications of Project Area Wetlands

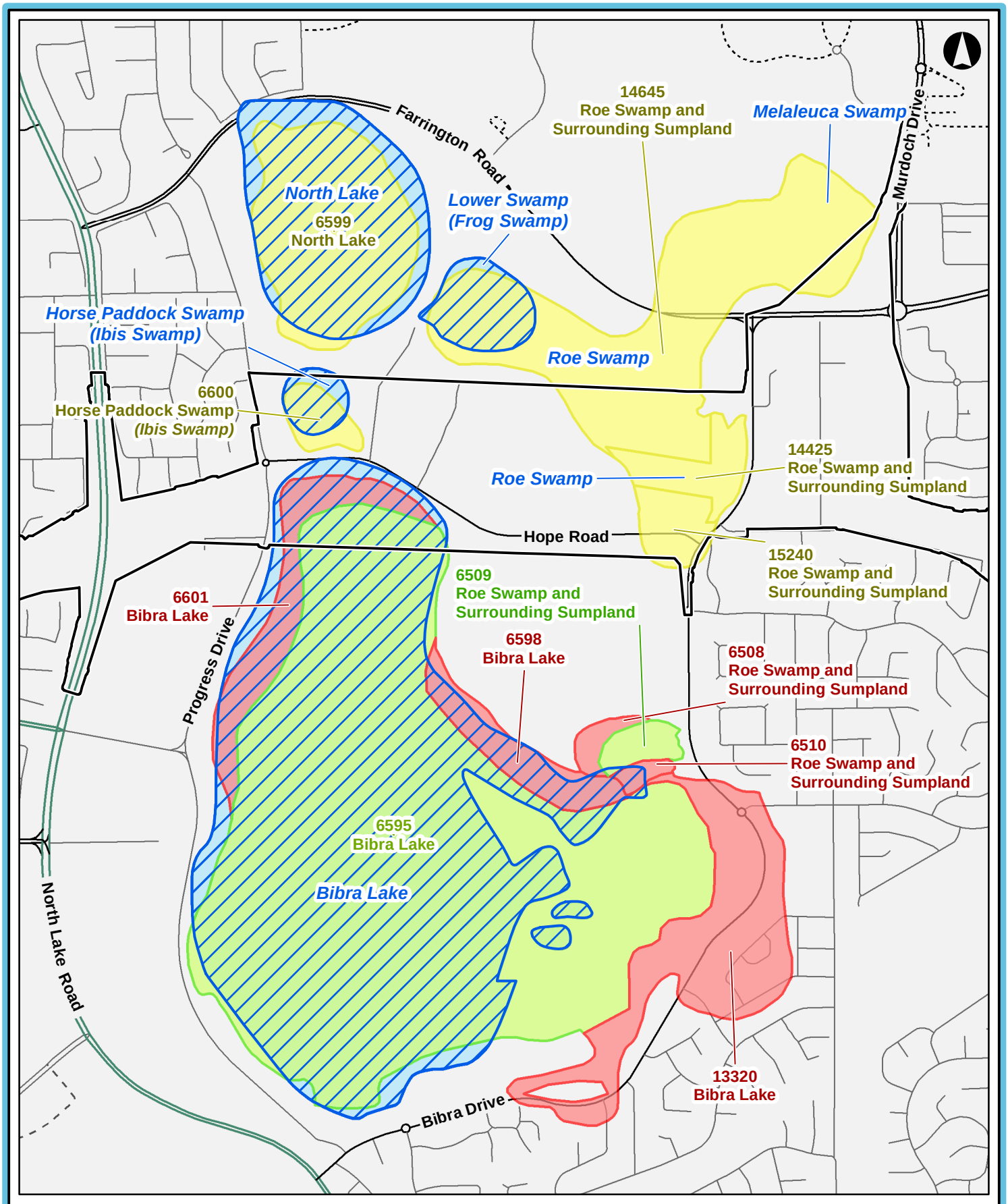
UFI	Wetland Name	Classification	Evaluation	Location
6595	Bibra Lake (Walliabup)	Lake	Resource Enhancement Lakes EPP	Northern most portion of this wetland is within project area
6522	Bibra Lake (Walliabup)	Lake	Resource Enhancement Lakes EPP	Approximately 1.5km south of project area
6601	Bibra Lake (Walliabup)	Lake	Multiple Use	Within project area
6598	Bibra Lake (Walliabup)	Lake	Multiple Use	Approximately 340m south of project area
13320	Bibra Lake (Walliabup)	Lake	Multiple Use	Approximately 760m south of project area
6508	unknown	Sumpland	Multiple Use	Approximately 450m south of project area
6510	unknown	Sumpland	Multiple Use	Approximately 600m south of project area
6509	unknown	Sumpland	Resource Enhancement Lakes EPP	Approximately 475m south of project area
6600	Horse Paddock Swamp (Ibis Swamp)	Lake	Conservation Lakes EPP	Within project area
15240*	Roe Swamp and surrounding sumplands	Sumpland	Conservation	Within project area
14425*	Roe Swamp and surrounding sumplands	Sumpland	Conservation	Within project area
14645*	Lower Swamp (Frog Swamp) and Melaleuca Swamp	Sumpland	Conservation Lower Swamp-Lakes EPP	Partially within project area
6599	North Lake (Coolbellup)	Lake	Conservation Lakes EPP	Approximately 80m north of project area

Source: DEC 2009a

UFI – Unique Feature Identifier

*UFIs 15240, 14425 & 14645 are referred to as Roe Swamp and surrounding sumplands

Note: multiple entries reflect 'Geomorphic Wetlands of the Swan Coastal Plain' dataset



CCW and Lakes EPP Boundaries

South Metro Connect

Figure 5.2-2

0 100 200 300 400

Metres

1:15,000 (A4)

- Project Area
- Conservation Category Wetland
- Resource Enhancement Wetland
- Multiple Use
- EPP Lake

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Roe Swamp, Horse Paddock Swamp and North Lake are classified as CCWs

The Bibra Lake system is the most complicated part of the Beeliar Wetland chain as it is composed of basins: former buried basins and stranded basins, a merging of extant and ancient basins, and low-relief channels inflowing from the Bassendean Dunes (Appendix D).

5.2.2.2.1. Bibra Lake (Walliabup)

Bibra Lake is one of the largest lakes in the project wetland system and consists of open water, which is a reflection of groundwater on the western side of the Jandakot Mound. The Geomorphic Wetlands Dataset classifies Bibra Lake (Unique Feature Identifier (UFI) 6595 and 6522) as a REW sumpland, whereas UFIs 6601, 6598 and 13320 are evaluated as MUW sumplands.

The REW (UFI 6595) and MUWs (UFIs 6601, 6598 and parts of UFI 6510) are protected under the *Lakes EPP* (DEC 2009a). There are an additional three sumpland wetlands (UFIs 6508, 6510 and 6509) adjoining Bibra Lake, which are unnamed but classified as REW and MUW (Table 5.2-1).

Bibra Lake has relatively impermeable lake deposits, with sandy shores restricted to a small area to the west. As a consequence, groundwater inflow and outflow is restricted when the water level drops (EPA and Water Authority of Western Australia 1990). Bibra Lake forms part of Bush Forever Site 244 (discussed in Section 5.8).

5.2.2.2.2. Horse Paddock Swamp (Ibis Swamp)

The DEC Geomorphic Wetlands Dataset classifies Horse Paddock Swamp (UFI 6600) as a CCW located between North and Bibra lakes. This wetland is also protected under the *Lakes EPP*. The swamp has been completely cleared, with only scattered trees on its gently sloping shores. The swamp itself is dominated by introduced grasses and other weeds. Horse Paddock Swamp is located within Bush Forever Site 244, which describes the wetland vegetation as being equivalent to the Herdsman Complex.

5.2.2.2.3. Roe Swamp (Frog Swamp)

Roe Swamp, Lower Swamp, Melaleuca Swamp, and surrounding sumplands (UFIs 15240, 14425 and 14645, herein referred to as Roe Swamp) are seasonally inundated wetlands, located to the east of North Lake. An artificial drain, known as Murdoch Drain (Frog Brook), links the three wetland areas. Despite this anthropogenic feature, Roe Swamp is considered unique, diverse and of high fauna habitat value relative to other wetlands in the Perth region and is accordingly classified as a CCW (VCSRG 1988).

Despite surrounding urban development, Roe Swamp has remained relatively unaltered in terms of its hydrological regime and vegetation cover (EPA 2003). During recent inspections (August 2010), it was observed that these sumplands are infested by various weed species, particularly the Arum Lily, but also *Ficus* sp. and *Cortaderia jubata* (pampas grass). Roe Swamp is composed of two channel-ways with deeper water pockets draining into North Lake (LeProvost, Semeniuk and Chalmer 1984).

The high value of the swamp results largely from its physical relationship via drainage lines and its morphological relationship to the Bibra suite of wetlands (Department of Planning and Urban Development 1990).

The majority of Roe Swamp (with the exception of the eastern section) is also located within Bush Forever Site 244, which describes the wetland vegetation as being equivalent to the Bassendean Complex. The swamp contains a number of large *Melaleuca* species. The DEC Geomorphic Wetlands Dataset identifies Roe Swamp as a CCW sumpland. Additionally, the northern portion of Roe Swamp (UFI 14645) (Lower Swamp) is protected under the *Lakes EPP*.

5.2.2.2.4. North Lake (Coolbellup)

The Geomorphic Wetlands Dataset classifies North Lake (UFI 6599) as a CCW (DEC 2009a). It is a groundwater expression of the western Jandakot groundwater mound. Groundwater flow enters the lake through the sandy eastern shore (EPA and Water Authority of Western Australia 1990). This CCW is also protected under the *Lakes EPP*. North Lake forms part of Bush Forever Site 244.

5.2.2.3. Changes in the Project Wetland System from 1987 to 1995

Wetlands in urban areas sometimes have a more complex water balance, including additional sources of water such as stormwater drainage, runoff from adjacent car parks and drainage from adjacent wetlands. Water losses can result from irrigation and bore extraction of groundwater.

Water regimes within the wetland system have changed over time. This is most likely as a result of changes to the surrounding land use and in weather patterns. These changes are listed in Table 5.2-2 and discussed in more detail in Section 5.6.

Wetlands have changed as a result of changes to surrounding land use and in weather patterns

Table 5.2-2: Changes in Wetland Identification and Classification*

Wetland Name	Classification of Wetland in Original State	Classification of Altered Wetland
North Lake (Coolbellup)	Lake	Lake
Horse Paddock Swamp (Ibis Swamp)	Sumpland	Sumpland
Bibra Lake (Walliabup)	Lake	Lake
Lower Swamp (Frog Swamp)	Sumpland	Lake/Sumpland
Melaleuca Swamp	Dampland	Sumpland
Roe Swamp	Sumpland	Sumpland
Roe Swamp surrounds	Dampland	Dampland

Source: Appendix D

*1987 to 1995

5.2.3. Wetland Geomorphic Structure

The wetland geomorphic structure influences how a wetland functions and alters in response to changes in surrounding land use. Beneath the wetlands in the project area, there is an interface between limestone and quartz sand. This interface is expressed as basins: former buried basins and stranded basins, a merging of extant and ancient basins and low-relief channels inflowing from the Bassendean Dunes. Consequently, the project area wetland system exhibits a diversity of hydrological and stratigraphical processes and ecological functions.

The project area wetland system is the only representative wetland system that has developed along the interface between Bassendean Dunes and Spearwood Dunes on the Swan Coastal Plain. The stratigraphy of the project area wetland system (with some buried wetlands), micro-hydrology, hydrochemistry and subsurface geochemistry results in a mosaic of vegetation related to the variability of these surface and subsurface natural features. The vegetation occurring within the project area, including Groundwater Dependent Ecosystem (GDE) vegetation, is detailed in Section 5.8.

The project area was subdivided into three hydrological zones, Eastern, Central and Western (Appendix D), as represented in Figure 5.2-3 and detailed below. This was due to the wetland system encompassing a dual framework; a hydrological system of east to west regional groundwater flow from the Darling Scarp to the ocean; and a stratigraphic system that is composed of transmissive Bassendean Sand in the eastern area adjoining a less transmissive limestone terrain in the western area. A description of the hydrological zones is provided in the following sections.

5.2.3.1. Eastern Zone (Bassendean Sand of the Bassendean Dunes)

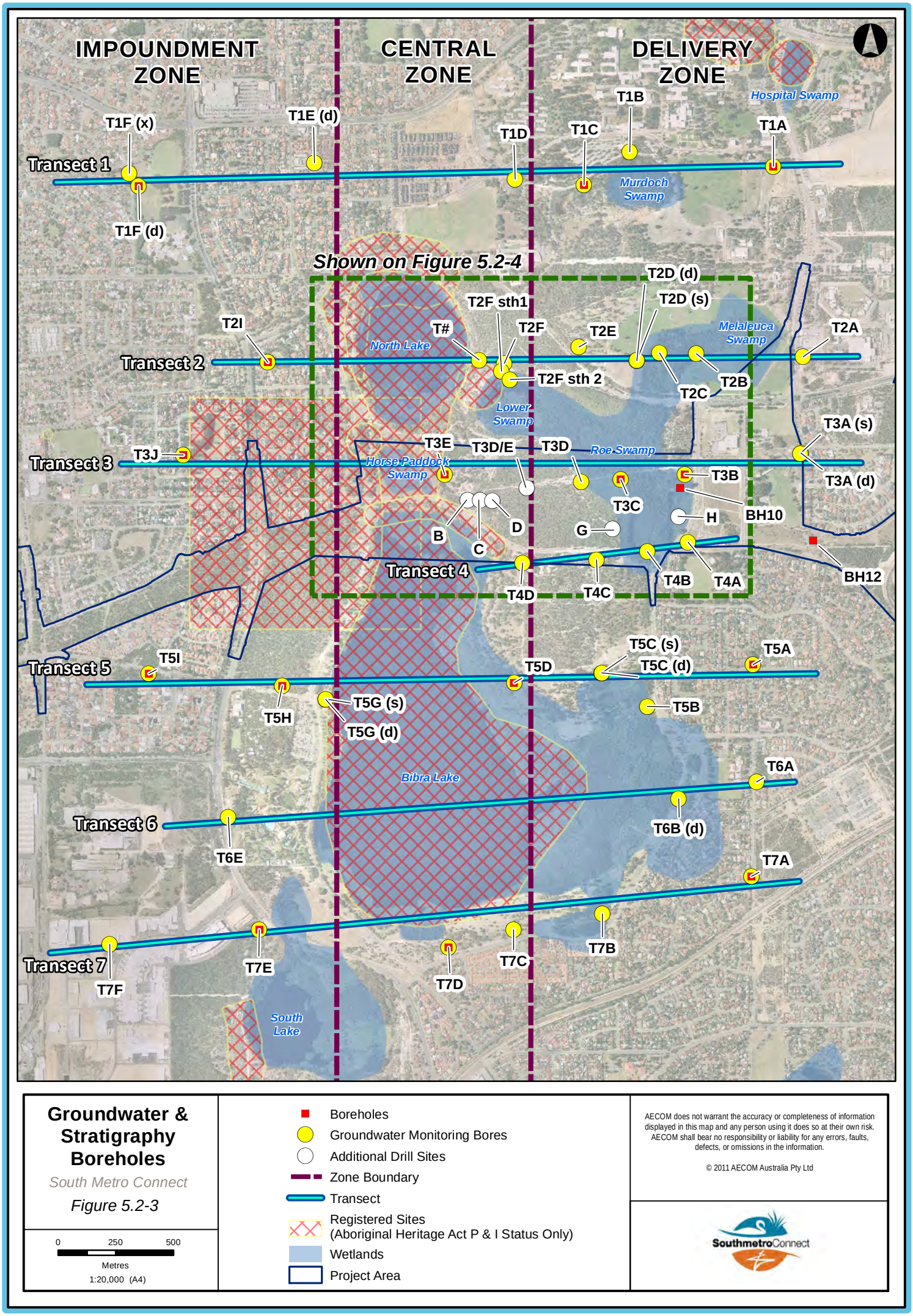
This zone is termed the 'Delivery Zone' as groundwater is delivered to the project area via the Bassendean Sand, under relatively transmissive conditions. Underlain by relatively simple stratigraphy of the quartzose Bassendean Sand, the groundwater is generally unconfined with the water contours showing discharge to the west.

5.2.3.2. Central Zone (Bassendean Sand of the Bassendean Dunes)

This is a north-south trending zone, where the impoundment of discharging groundwater has locally raised the regional water table, so that it may locally intersect the land surface to form wetlands in the lowland basins. These wetland basins have filled with a variety of sedimentary materials such that along the central zone there are lenses and saucers of peat, clay, diatomite and sand, and interlayered sequences of these sediments. These wetland deposits impede and, locally, partially confine the groundwater, which results in complex hydrological patterns. The groundwater in the central wetland has hydrochemistry reflective of its adjoining Bassendean Sand derivation, but also reflects the local effects of hydrochemical interaction with wetland sediments.

5.2.3.3. Western Zone (Spearwood Dunes or Zone of Limestone and Sand)

The western zone or 'Impoundment Zone' is underlain by Tamala Limestone with overlying and underlying sheets and lenses of quartz sand, all comprising the Spearwood Dunes. The groundwater delivered from the Bassendean Sand is relatively impounded by the less transmissive limestone. The groundwater is mostly unconfined with a general discharge to the west, but locally discharging to the east into the central wetland zone. This zone has hydrochemistry reflective of its limestone and quartz sand local provenance, but also reflects hydrochemical interaction with the central wetland zone and Bassendean Sand.



Groundwater & Stratigraphy Boreholes

South Metro Connect

Figure 5.2-3

0 250 500

Metres

1:20,000 (A4)

- Boreholes
- Groundwater Monitoring Bores
- Additional Drill Sites
- Zone Boundary
- Transect
- Registered Sites (Aboriginal Heritage Act P & I Status Only)
- Wetlands
- Project Area

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5.2.4. Wetland Stratigraphy

Stratigraphy is the organisation of sediments and geological attributes beneath the ground surface. This section includes details of stratigraphy as it relates to the hydrological zones. For a description of local geology and soils, refer to Section 5.3.

The project wetland system is bordered to the west by a ridge of Spearwood Dunes that has an average height of 22m. The ridge slopes at a steady gradient of approximately 1:10 and this relatively steep slope results in a straight western shoreline to the wetlands. On the eastern side of the wetlands, clusters of hills 8–10m high, interspersed with flats and hollows belonging to the Bassendean Dunes, determine the meandering shape of the wetland basins, in particular their eastern shorelines. Although no longer exhibiting dune forms or processes, these hills are oriented north, east and west, suggesting that the low depressions associated with them were originally aeolian excavations, during a more mobile phase. The contours and spot heights of the wetland basins suggest that they are asymmetric in profile; the western margins against the limestone are deeper than the eastern shores (Landgate 1:2,000 topography).

The sediments present in each of the three hydrological zones were investigated. The methodology used and a detailed discussion of the findings of this study is in Appendix D. The stratigraphy of the project area and surrounds was defined through the installation of over 40 piezometers. The locations of these are indicated in Figure 5.2-3. Additional piezometers were installed to provide further definition of the stratigraphy within the proposed footprint and the location of these is indicated in Figure 5.2-4.

The stratigraphic sequences, based on diagenetic effects and lithology, show several important features:

- Significant groundwater flows through North Lake and through Bibra Lake south;
- An established structural matrix of heterogeneous layers ranging from very coarse to fine aeolian sand layers, which act as specific aquatards and aquifers for groundwater transfer; and
- Diagenetic overprints in the quartz sands, particularly at the eastern margins of the wetlands, which alter and perturb the general westward flow of groundwater, causing short-term retardation of infiltration to the water table and impedance to westward flow.

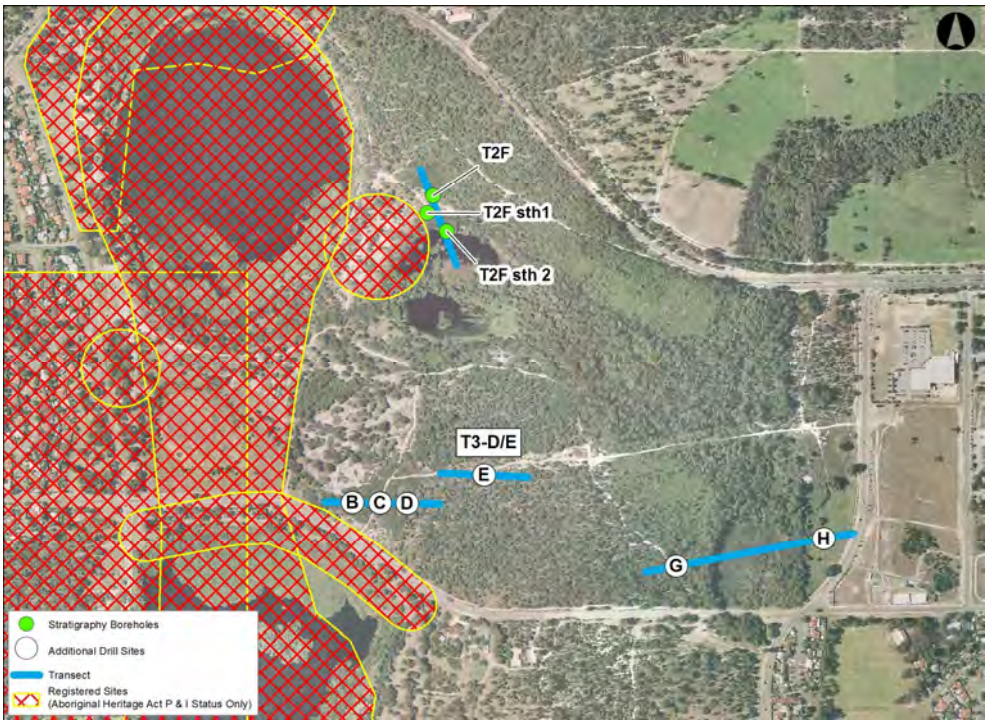


Figure 5.2-4: Groundwater and Stratigraphy Boreholes – Infill Drilling Sites

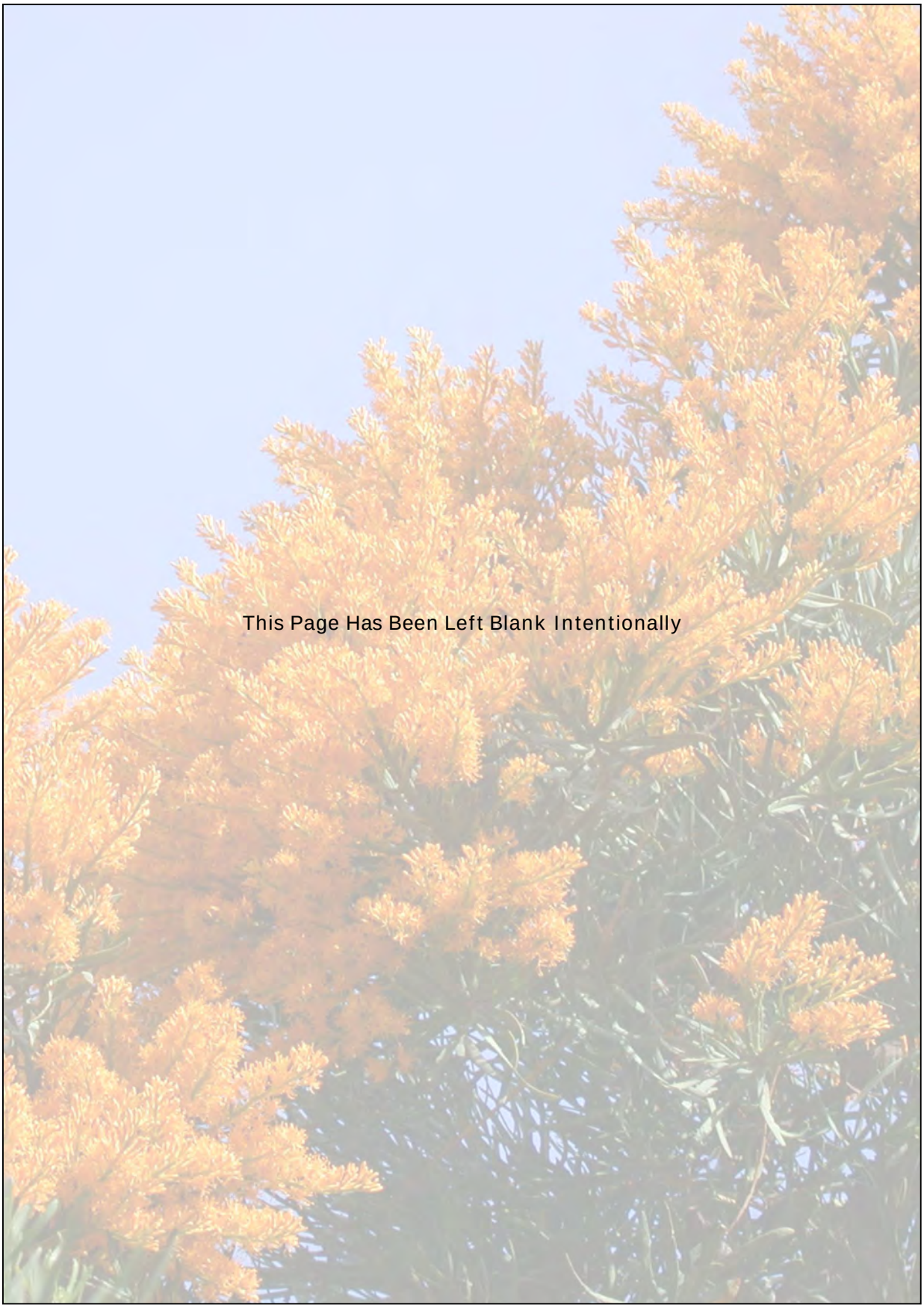
There may be small localised (currently undetected) strata that retard water transmission rates, leading to localised groundwater mounding. The intention of ongoing groundwater monitoring (or additional bores) is to identify the occurrence of differential infiltration or mounding effects. During 2010, no large differences in groundwater levels were detected along the bore transect beneath the proposed project. The presence of limited layers of iron cementation and formation of ferricrete (coffee rock) was noted on some bore logs along the proposed project between Bibra Drive and to a site east of Horse Paddock Swamp. However, there was no indication that impervious and/or retarding layers are laterally continuous. This means that the soils would not vertically retard water infiltration on the regional groundwater table, nor create seasonally perched watertable(s) above the regional watertable. Table 5.2-3 provides the composition of sedimentary fill underlying the wetlands within the project area. These results show that the wetland sediments are varied.

Table 5.2-3: General Description of Wetland Sediments

Wetlands	Wetland Fill
Murdoch Swamp	Kaolinitic and quartz silt muddy sand
North Lake	OME spongolitic, phytolithic, diatomaceous mud
Horse Paddock Swamp	Unknown
Lower Swamp	Spongolitic, phytolithic, diatomaceous kaolin mud
Melaleuca Swamp north of Farrington Road	OME phytolithic muddy sand
Melaleuca Swamp south of Farrington Road	Kaolinitic and quartz silt muddy sand
Roe Swamp	Kaolinitic and quartz silt muddy sand
Bibra Lake	Spongolitic and diatomaceous mud

OME – organic matter enriched

Stratigraphic profiles (Appendix D) illustrate that limestone lenses are present and that they impede water flow from the wetlands, when they occur beyond the western margins. In areas where they are absent and yellow sand is present, the westward flows of groundwater and the diagenetic plumes from the wetlands are unimpeded. In some locations where groundwater is obstructed by limestone lenses, flows may be re-routed along the tongues of more transmissive yellow sand, increasing both the volume and the flow rates in local areas.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5.3. Geology and Soils

The regional and local geology and soils in the project area are described in this section.

5.3.1. Regional Geology

The project area falls within the Swan Coastal Plain, which is the Quaternary surface of the Perth Basin. In a regional context, the Perth Basin is a Phanerozoic sedimentary basin bordering the Darling Fault, which is approximately marked by the Darling Scarp. The sediments filling this basin range from Permian to Quaternary, although Pliocene, Pleistocene and Holocene history has had the major role in determining the form of the coastal plain and its stratigraphy (Appendix D).

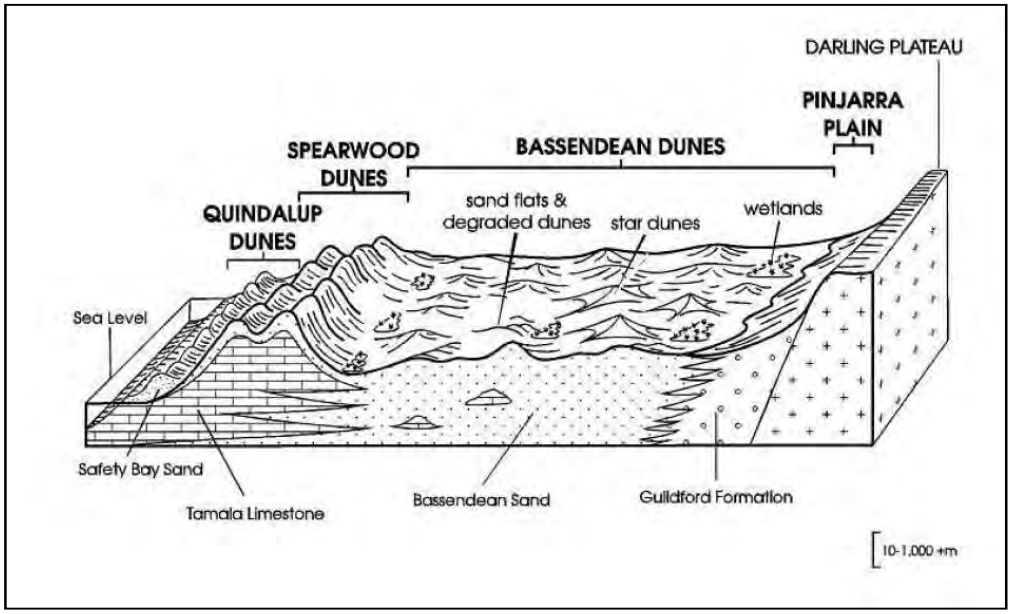
The Darling Fault separates the Phanerozoic sedimentary rock and sediment-filled Perth Basin from the Precambrian rocks of the Yilgarn Craton. The Perth Basin has been subsiding along the Darling Fault for at least 200 million years, accumulating over 5,000m of sedimentary material. In the past 1.5–2 million years, there has been accumulation of sedimentary materials in the upper parts of the Perth Basin as alluvial fans, alluvial flats, riverine channel deposits, desert sand deposits, near-shore marine deposits, coastal sands, estuarine deposits and wetland deposits, that form the upper sedimentary deposits of the Perth Basin up to 100m thick (VCSRG 2009).

The Swan Coastal Plain is the terrain of sand, limestone and fluvial deposits that form a coastal strip between the Darling Scarp and the Indian Ocean, forming a low-land of between approximately 5m and 90m in height above sea level. A thin veneer of Late Tertiary and Quaternary regolith comprise the surficial cover over much of the Perth Basin. These 'superficial' formations collectively referred to by Allen (1976), consist mainly of sand, silt, clay and limestone in varying proportions. The eastern margin of the Swan Coastal Plain is dominated by silts and clays (muds), while those in the central area are predominantly sandy. To the west, the sandy materials pass laterally into limestone, which borders the coastal strip (VCSRG 2009). These formations include the Ascot Formation and the Kwinana Group, which comprises the Yoganup Formation, Guildford Clay, Gnangara Sand, Bassendean Sand, Tamala Limestone, Becher Sand and Safety Bay Sand, of which only the Bassendean Sand and Tamala Limestone are relevant to the project area (Appendix D).

Several major dune systems, oriented in a north-south direction, transect the Swan Coastal Plain. The Quindalup and Spearwood dune systems lie closest to the coast, with the Bassendean dune system further to the east. The Bassendean Dunes (Bassendean Sand Formation) are the oldest and most leached of the series, and comprise fine to coarse sand and ferruginous sand. These occur in the eastern portion of the project area. A depression exists where the interface between the two dune systems occur.

The Bassendean Sand overlies the Cretaceous and Tertiary strata, and inter-fingers to the east with the Guildford Formation. To the west, it is overlain by the Tamala Limestone (Figure 5.3-1) and although unclear, it was likely deposited in a variety of fluvial, estuarine and shallow-marine environments.

The Tamala Limestone Formation, from which the Spearwood Dunes are derived, outcrops approximately two kilometres west of Bibra Lake and comprises calcarenite and calcareous cemented, fine to very coarse, poorly sorted, sand.



Source: VCSRG 2009

Figure 5.3-1: Typical Block Diagram of the Swan Coastal Plain

5.3.2. Local Geology

Local geological information is derived from geotechnical investigations undertaken across the project area, with the exception of those areas with restricted access due to Aboriginal heritage sensitivity.

The geology of the project area is illustrated in Figure 5.3-2. It is evident that North and Bibra lakes form part of a chain of lakes that occupies interdunal depressions in the Spearwood dune system at the contact with the Bassendean dune system. A low saddle in the Spearwood dune system separates Bibra Lake from North Lake. Beneath the lakes are lacustrine sediments comprising unlithified silt and clay-sized clastic and organic sediments (Davidson 1983). Each dune system is the result of accumulation and subsequent distribution of beach sands of successive shorelines. The major factors influencing their formation are thought to be a series of marine transgressions and prevailing westerly winds.

Geotechnical investigations undertaken within the project area indicate that the site is typically underlain by up to four different geological units which are described below.

5.3.2.1. Bassendean Sands

The eastern portion of the project area is defined by the Bassendean Sands geologic unit, which is present over much of the central Perth region and has a maximum thickness of about 80m. It is pale grey to white and includes fine to coarse sand that is predominantly medium grained. It comprises moderately sorted, sub-rounded to rounded quartz sand and commonly exhibits fining upward textures. A layer of friable, limonite-cemented sand, commonly known as 'coffee rock', occurs throughout most of the area near the water table (AECOM 2010a).

Bassendean Dunes are characterised as pale grey, white, medium grained, moderately sorted quartz sand with little or no calcium carbonate content. Bassendean Dunes (located in the eastern portion of the project area) tend to be acidic, highly leached and nutrient poor. They are thought to be about 800,000 years old (Bolland 1999).

5.3.2.2. Swamp Deposits and Organic Sediments

The areas surrounding Bibra Lake, North Lake and the swamp areas adjacent to and west of Bibra Drive are underlain by swamp deposits comprising peaty silt.

Organic sediments of Swan Coastal Plain wetlands range from fine silty oozes of deeper lakes, derived from phytoplankton production settling out on the lake bottom, to sediments formed by coarser organic matter, usually called peat. Peat is derived from decaying vascular plant material that accumulates in shallow swamps or in stands of sedges fringing open lakes (Pinder 2005). Peaty silt soils are located within and around the wetland areas where soils have been modified by the addition of organic matter and finer grain sedimentary material. Regionally, wetland areas comprise peaty clays, silts and sandy silt, possessing variable clay content. These soils have been formed over the western part of the Bassendean Sands and over quartz sand derived from the Tamala Limestone (Thompson and Palmer 2006).

5.3.2.3. Spearwood Dunes

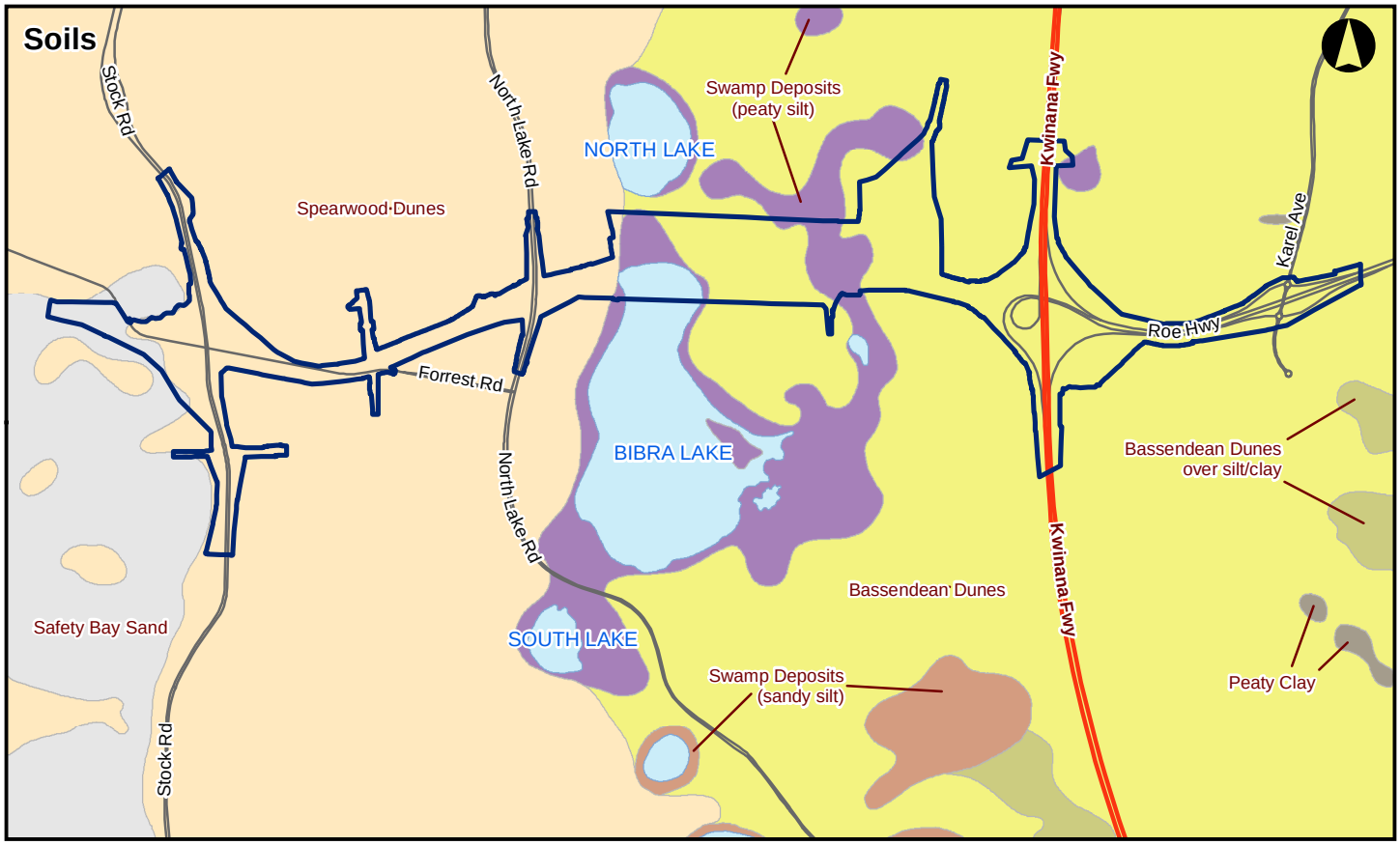
The western portion of the project area is predominantly underlain by sand derived from Tamala Limestone. The exception to this is at the western end of the proposed road corridor at Stock Road, which is underlain by Tamala Limestone. The sand derived from Tamala Limestone forms part of the Spearwood dune system and is described as a pale yellowish brown, medium to coarse grained, sub-angular quartz sand that is moderately sorted and of residual origin (AECOM 2010a).

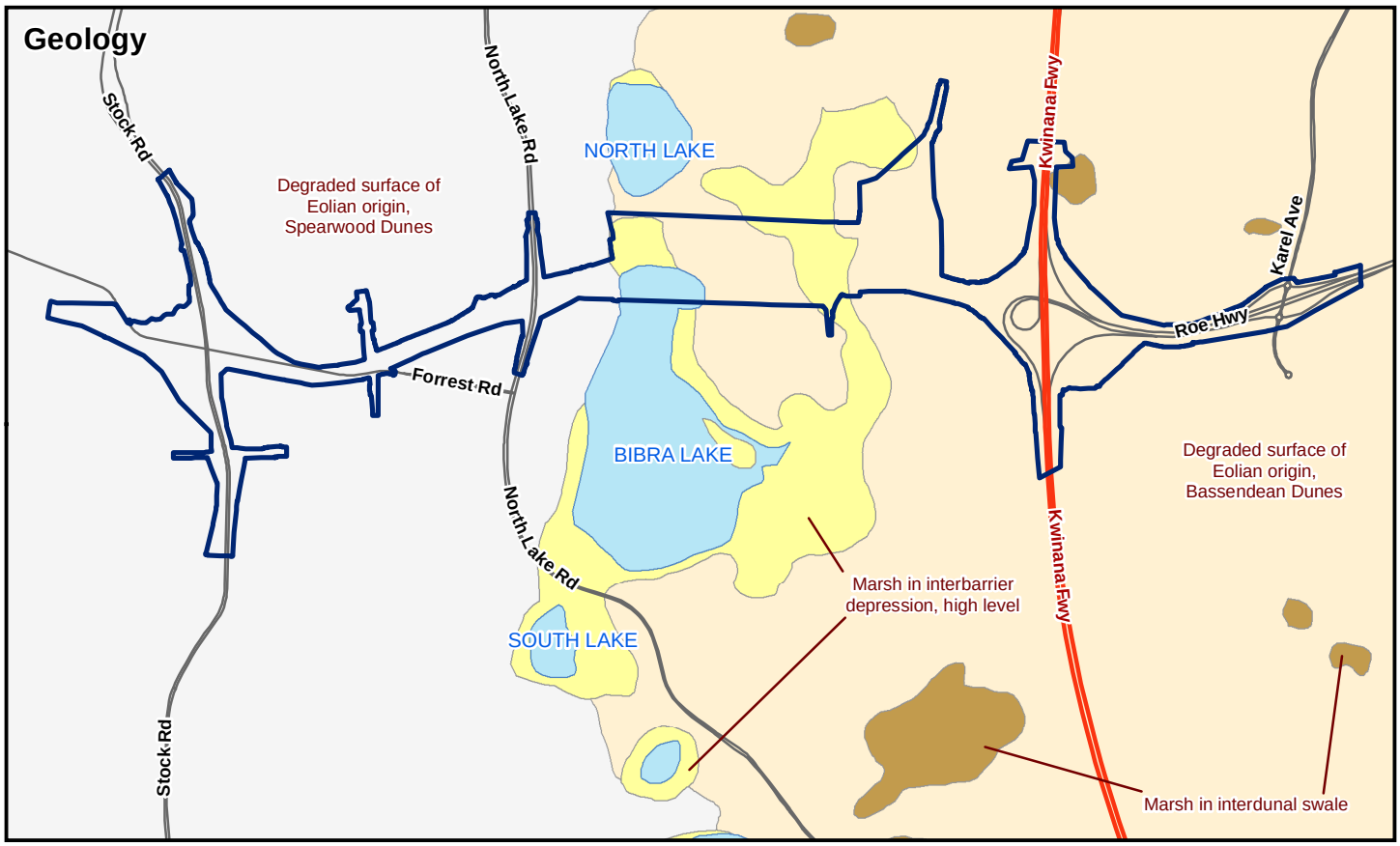
The Spearwood dune system is leached limestone and comprises fine to very coarse, very slightly calcareous, sand. In the Spearwood Dunes, limestone variously forms well-defined ridges, lenses and composite forms of ridges with lateral extensions or tongues. Limestone features occur within thick sections of yellow quartz sand. The limestone bodies occur at various scales: up to 10m thick and 20–150m wide. Cementation of the quartz sand by brown iron oxide and clays form local nodules and sandstone. There is a transition from limestone-dominated environments to quartz sand-dominated environments (Appendix D).

The younger soils of the Spearwood Dunes comprise yellow sands known as Karrakatta Sands, located on the upper slopes of the dunes, and red/brown sands called Cottesloe Sands, nearer to the coast that are believed to have been formed about 40,000 years ago (Bolland 1999). West of the Spearwood Dunes are yellow phase Karrakatta Sands. As previously discussed, these sands are derived from Tamala Limestone. The proposed project terminates in yellow phase Karrakatta Sands at Stock Road.

5.3.2.4. Tamala Limestone

The Tamala Limestone forms part of the Spearwood dune system and is an Aeolian, or wind derived, deposit. It is typically described as a pale yellowish brown, fine to coarse grained calcarenite, comprising sub-angular to well-rounded quartz with a trace of feldspar and shell debris. The Tamala Limestone is variably lithified and ranges from a limestone to calcarenite to uncemented sand. The limestone is characterised by solution cavities, which are commonly developed at the water table. Its surface is covered by yellow sand which also extends along its unconformities, and underlies it. The Tamala Limestone outcrops sporadically (as evidenced at the coast and in road cuttings) and its surface ranges from convex, horizontal and sloping to pinnacled, depending on the degree of weathering (Appendix D).





Geology & Soils

South Metro Connect

Figure 5.3-2

0 0.5 1 1.5

Kilometres

1:42,500 (A4)

Datum: GDA94 Projection: MGA z50

Soils

- Peaty Clay
- Safety Bay Sand
- Swamp Deposits (peaty silt)
- Swamp Deposits (sandy silt)
- Spearwood Dunes
- Bassendean Dunes
- Bassendean Dunes over silt/clay
- Water

Geology

- Degraded surface of Eolian origin, Spearwood Dunes
- Degraded surface of Eolian origin, Bassendean Dunes
- Marsh in interbarrier depression, high level
- Marsh in interdunal swale
- Water
- Project Area

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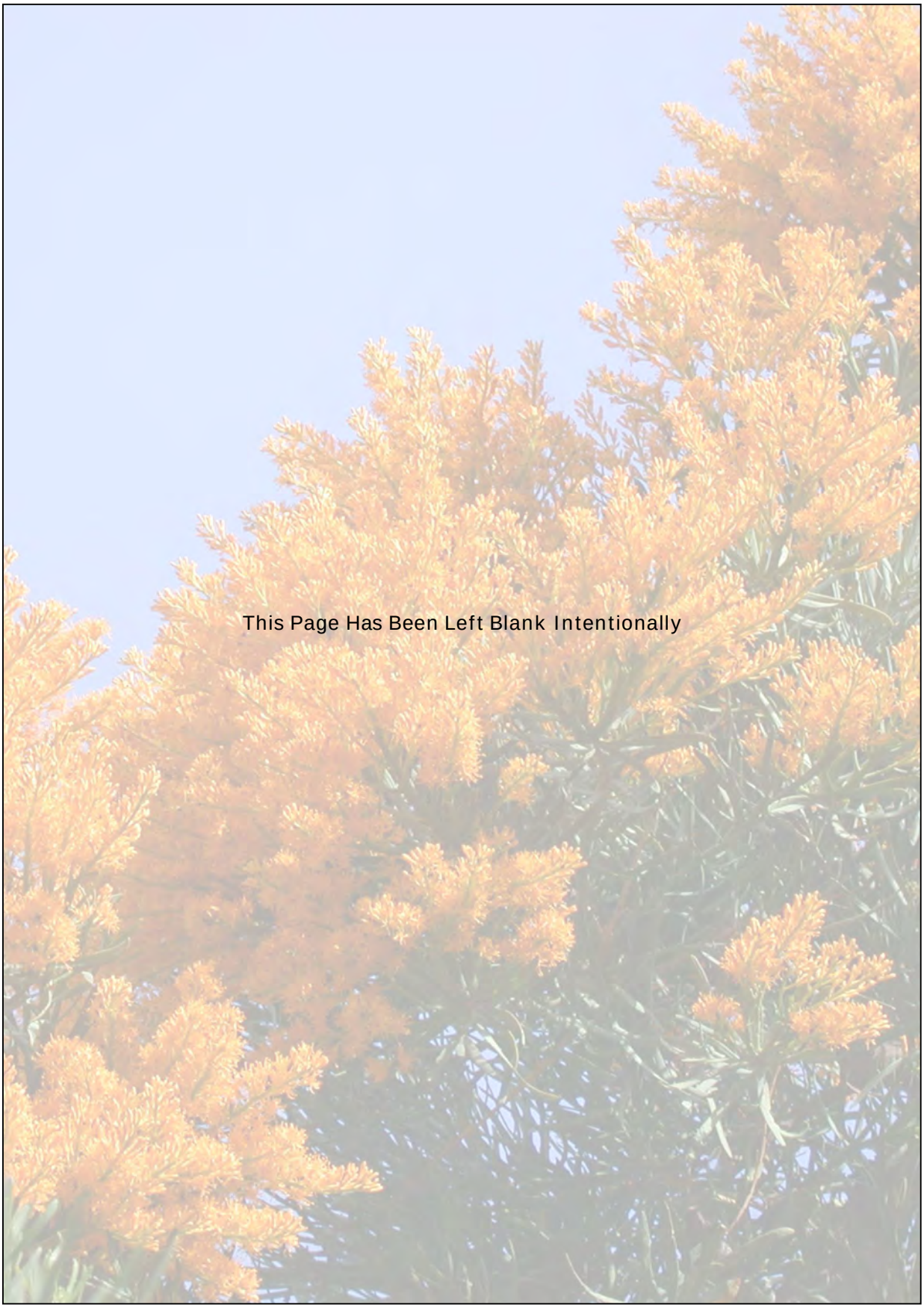
Source: Geology of the 1:50 000 mapsheet FREMANTLE (2033-IV) , Geological Survey of Western Australia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5.4. Contamination

The area between North Lake Road and Kwinana Freeway has a very high vulnerability to contamination. This is due to the sand, peat and clay deposits in wetland areas having a shallow water table of less than three metres below the ground surface (Appleyard 1993).

The surficial unconfined aquifer in the project area is located in sand formations (Bassendean Sand and Sands derived from Tamala Limestone) and the water table is shallow in some locations, making it susceptible to contamination. Moreover, sediments such as those found in urbanised wetlands can act both as a carrier and a possible source of contaminants in aquatic systems, and these materials may also affect groundwater (and soil) quality when disturbed (Ahlf and Förstner 2001).

A preliminary site investigation (PSI) was undertaken to assess the potential occurrence of soil and/or groundwater contamination that may impact or be impacted by the proposed project (Appendix E). The PSI report was prepared referencing the DEC (formerly Department of Environmental Protection (DEP)) guideline, *Reporting on Site Assessments* (DEP 2001).

A summary of historic land use in the general area of the proposed project is presented in Table 5.4-1.

Table 5.4-1: Summary of Historical Land Uses

Date	Land Use(s)	Source
Prior to 1820s (pre-European)	Locality of site used by Aboriginal people for camping and hunting	Strategen 2009
1800s	Early pastoral leases (George Robb and Benedict Von Bibra)	Strategen 2009
1890s	Market gardens and dairy enterprise on land near Bibra Lake, oats/pastures on higher ground	Strategen 2009
1920s	Establishment of schools, extension of North Lake Road and a decline of dairy and market gardens	Strategen 2009
1970s and 1980s	Encroachment of suburban development	Strategen 2009
1975	Establishment of Murdoch Veterinary School and animal handling facilities	Clark and Grandage 2005
1940s to 1960s	Sanitary landfill at the southern end of Bibra Lake	Riggert 1983

5.4.1. Groundwater Use

There are numerous bores in the vicinity of the project area (Figure 5.4-1), including 42 monitoring wells used by the Department of Water (DoW) for groundwater quality and level monitoring. Typically, the groundwater is used in residential areas for irrigation of yards and, in some instances, irrigation of vegetable gardens. The bores and their locations are discussed further in Sections 5.2 and 5.6.

Due to its shallow depth, groundwater in the project area is susceptible to contamination

There are no classified contaminated sites within the project area

5.4.2. Potentially Contaminating Land Uses, Industry and Activities

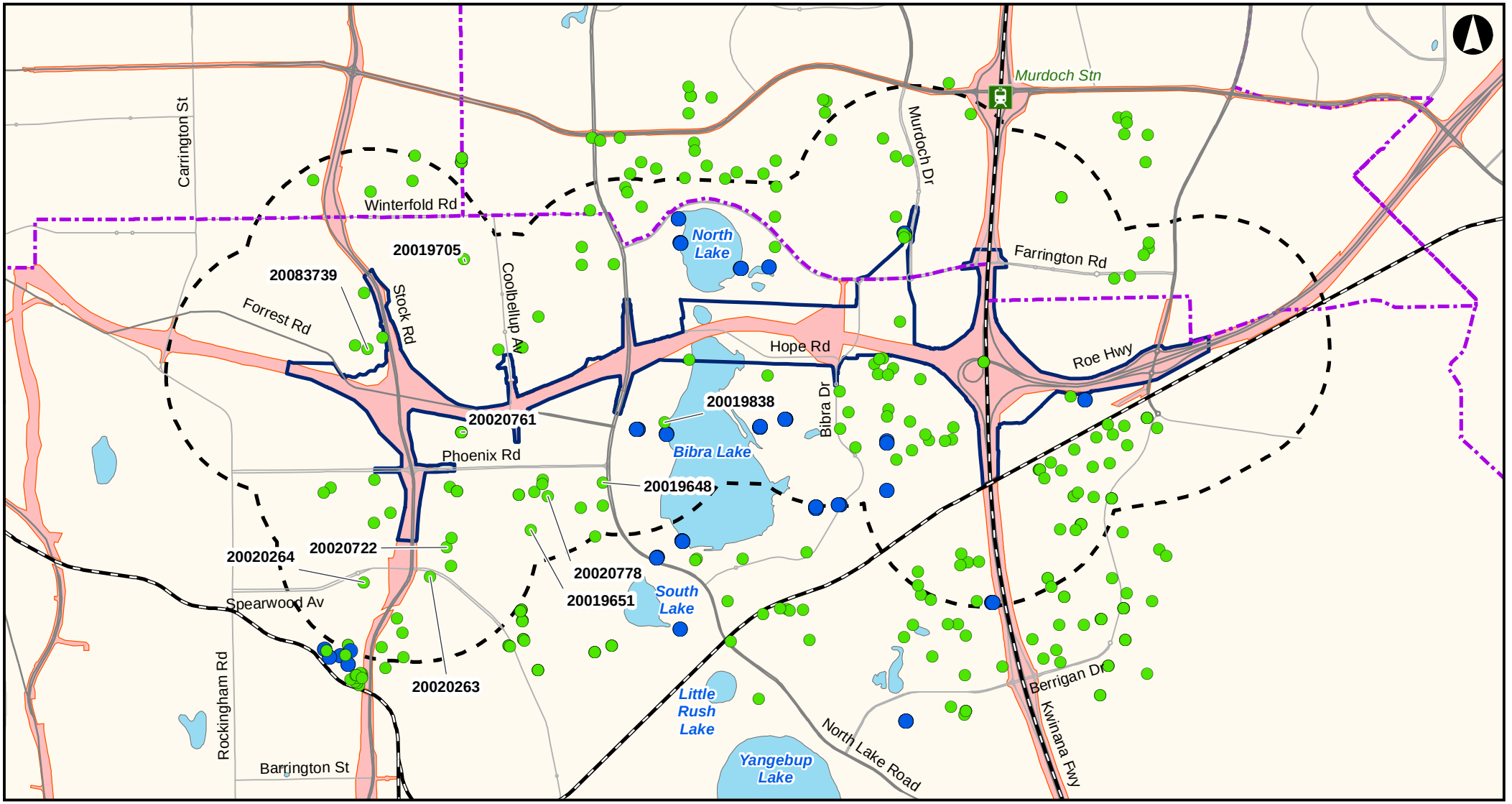
The historical and current activities, industries and land uses identified for the project area and surrounds during desktop investigation are listed in Table 5.4-2 and their approximate locations are shown on Figure 5.4-2. It is possible that other current or historical land uses having the potential to release contaminants were not identified in the PSI and may be located within the project area and surrounds.

Table 5.4-2: Identified Potentially Contaminating Activities

Potentially Contaminating Activity/Industry/Land Use (based on DoE 2004)	Relevance to Project Area
Project Area	
Intensive agriculture	A site located near the south-west edge of North Lake is identified (in Hirschberg 1991) as a point source of potential contamination (animal-based waste from a former piggery)
Landfill sites	Parts of Bibra Lake have historically been used as a sanitary landfill (EPA 1990)
Mining and extractive industry	Possible sand mining/extraction west of Bibra Lake, as evidenced from a review of historical aerial photographs from 1970
Surrounding Area	
Airports	Jandakot Airport is located approximately 800m to the south-east of the project area
Chemical manufacturing, blending or mixing	Associated with historical paper mill to the south of the project area
Intensive agriculture	Historical farming prior to urban development
Service stations, petrol stations and fuel storage facilities	Potentially associated with historical farming activities
Electrical transformers	Western Power facility south-east of the project area plus laydown area for various power companies and electrical component companies (e.g. ABB, Utilux, Areva) near the terminus of Roe Highway

Parts of the edges of Bibra Lake have been used previously as a sanitary landfill (EPA and Water Authority of Western Australia 1990). There are several historical land uses that may have released contamination, including a commercial laundry, buried animal bodies, a former paper mill, former piggeries and abandoned sanitary landfills (Hirschberg 1991) (Figure 5.4-2). Located south of the proposed alignment and west of Bibra Lake is an area with identified soil and groundwater contaminant impact that is now under management (Golder Associates 2004).

An online search of the contaminated sites database (CSD) maintained by the DEC (DEC 2010a) identified several sites within two kilometres of the project area that have been classified by the DEC. There are no classified contaminated sites within the project area, with the closest site located 0.8km to the south of the project area. Details of the CSD search are contained in Appendix E.



Project Area Groundwater Use

South Metro Connect

Figure 5.4-1

0 500 1,000 1,500

Metres

1:45,000 (A3)

Project Boundary

LGA Boundaries

MRS - Primary Regional Roads

1km from project area

Groundwater Boreholes

Other

Department of Water

Source: WIN Database 5/11/2010

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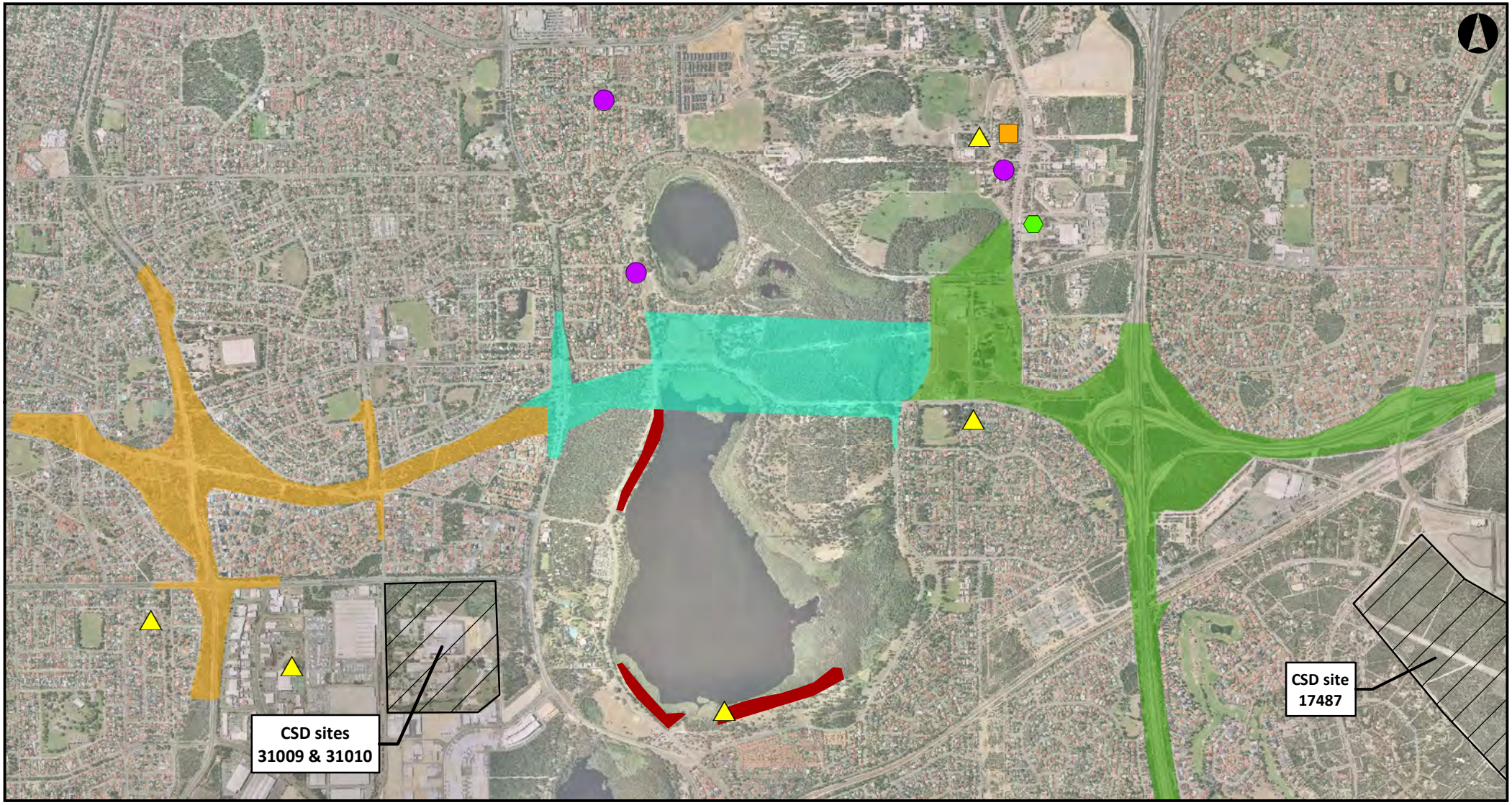

Known Potential Regional Sources of Contamination

South Metro Connect

Figure 5.4-2

0 500 1,000

Metres

1:28,000 (A4)

- Commercial Laundry
- Buried Animal Bodies
- Former Piggery
- Abandoned Landfill
- Contaminated Sites Database (CSD) Registered Sites
- Historic Landfilling at Bibra Lake (after Riggert 1983)
- Reference Area 1
- Reference Area 2
- Reference Area 3

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5.5. Acid Sulfate Soils

Acid sulfate soils (ASS) are naturally-occurring soils and sediments containing sulphide minerals, commonly pyrite and iron sulphide. These soils typically form in wet and oxygen-limited horizons, such as those found around wetlands. When ASS are exposed to air (for example, disturbance during earthworks or drainage works), iron sulphides may react with oxygen and water to produce a variety of iron compounds and sulphuric acid. Initially a chemical reaction, the process is accelerated by soil bacteria. The resulting acid can lower pH conditions, but can also leach potentially toxic levels of elements (e.g. heavy metals) from the soil, which may in turn be released into the surrounding environment.

ASS that have already oxidised and display existing acidity are termed Actual ASS (AASS). ASS which have not oxidised are referred to as Potential ASS (PASS). Undisturbed PASS remaining in anaerobic conditions (e.g. below the water table), do not generally pose a risk to the environment. While PASS remain undisturbed, their potential to generate acid is minimised. Non-ASS (NASS) are those in which actual (previously oxidised) or potential acidity is at levels not considered environmentally hazardous and do not require management. In Western Australia, shallow ASS is commonly present in the following general locations:

- Riverine, estuarine and coastal lowland areas, such as mangroves, brackish lakes, tidal flats, salt marshes and pans, swamps and seasonally inundated plains;
- Wetland areas; and
- Saline inland areas.

Occurrence of water logged soils in the lakes and, at times, in the adjacent swamps, together with the existence of swamp-tolerant reeds, rushes and paperbarks indicate the presence of PASS in the lakes and adjacent wetlands.

5.5.1. Baseline Acid Sulfate Soil Risk Mapping

The Western Australian Planning Commission (WAPC), in consultation with the DEC, has compiled ASS risk maps that are based on surface geology mapping and provide a broad scale indication of the risk of occurrence of ASS (Figure 5.5-1).

The WAPC (2009b) *Acid Sulfate Soils – Planning Bulletin No.64* identifies portions of the project area falling within one of the following three risk classifications (for PASS occurring within three metres of the natural soil surface):

- Class 1 — high to moderate risk;
- Class 2 — moderate to low risk; or
- Class 3 — no known risk.

Part of the eastern portion of the project area traverses sections that have been mapped by Davidson (1995) as 'marsh in interbarrier depression, high level'. These areas are classified as high to moderate risk areas, owing to the presence of wetlands and organic material.

The remainder of the eastern portion of the project area is classified as moderate to low risk, owing to the presence of Bassendean Dunes. Parts of the Bassendean Dune profile (extending below the present water table) may contain pyrite and sulphur and hence have an acid generating capacity separate to that identified in swale (peaty) soils (Prakongkep *et al*. 2009).

The western portion of the project area (west of Progress Drive), which comprises approximately half of the project area, is classified as having 'no known risk occurring within three metres of the natural soil surface (or deeper)'. This area is situated on the sands derived from Tamala Limestone and is underlain by the limestone at a depth of approximately 40m adjacent to Progress Drive (Department of Environment (DoE) 2004).

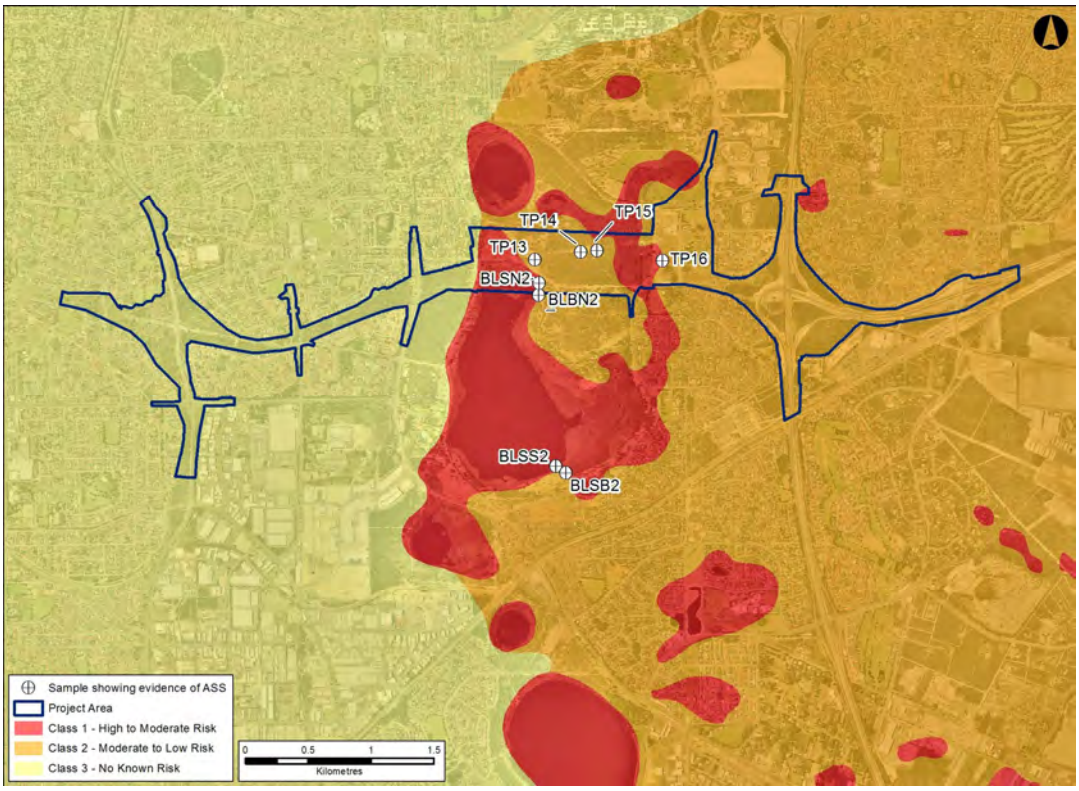

Figure 5.5-1: Acid Sulfate Risk Map

5.5.2. Field Sampling and Analysis

A preliminary ASS investigation was conducted to determine the actual extent of PASS and ASS in the project area. Details of the ASS investigation report, including sampling methodology and results, are contained in Appendix F.

5.5.2.1. Sampling

A soil sampling programme was conducted as part of the preliminary ASS assessment. This consisted of excavation and sampling of five test pits (TP13 to TP17) to an average depth of approximately 3 metres below ground level (mbgl). These pits were excavated in the Bassendean Sands in the 'moderate to low' ASS risk area (Figure 5.5-1) and were located outside of registered Aboriginal heritage sites. This work was undertaken in conjunction with the geotechnical investigation. Test pit locations are shown on Figure 5.5-2 and test pit logs presented in Appendix F.

Shallow sediment samples were collected from six locations (BLSN1, BLSN2, BLSM2, BLSM1, BLSS1 and BLSS2) around Bibra Lake on 8 April 2010. Samples were collected at surface and a depth of 0.3mbgl. The sampling locations are shown in Figure 5.5-2.

Owing to the surrounding wetland area, the Hope Road embankment that runs between Bibra Lake and Horse Paddock Swamp may have been built on ASS. From visual inspection of surface conditions, it appears that the underlying natural soils may comprise Bassendean Sands with the road embankment built up with sand. Due to Aboriginal heritage status of this area, it was not feasible to undertake ground disturbing activities in this area.

5.5.2.2. Field and Laboratory Analysis

Soil samples were tested in the field for the following parameters:

- Field pH (pH_F);
- Field peroxide pH (pH_{FOX}) using 30% hydrogen peroxide; and
- Reaction vigour or effervescence ('Fizz' rating).

The field tests were undertaken at depth intervals of 0.5m to provide an indication of the likely presence and severity of AASS and PASS. The results were used to identify soil samples to be selected for laboratory analysis. Selection of soil samples for suspended peroxide oxidation combined acidity and sulfate (SPOCAS) analysis was conducted in accordance with DEC guidelines (DEC 2009b).

Acid Sulphate Soil Test Locations

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Figure 5.5-2

0 100 200 300 400 500

Meters

1:15,000 (A4)

Test Locations

Project Area

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5.5.3. Site Acid Sulfate Soil Status

Eight of nine samples analysed by laboratory testing indicated that either AASS or PASS was present. The sample analysed from TP17 (TP17/2.0) was the only exception. Net Acidity (SPOCAS) values in the samples ranged from 26mol H^+/t (TP14A/2.0) to 763mol H^+/t (BLSN2). The highest concentrations were in relation to lake sediments.

ASS is present in soils within the study area that are located close to the wetlands. This was indicated by SPOCAS laboratory test exceedances of the DEC Texture-Based Acid Sulfate Soils 'Action Criteria' by selected samples obtained from depth horizons between 2-3mbgl (samples TP13/2.6, TP14/2.0, TP15/2.7,TP16/3.0). Samples were dark brown, fine to coarse-grained sands with associated coffee rock.

ASS is present in soils within the study area

The results indicate that ASS material is also present in sediments located within the study area, with SPOCAS laboratory test exceedances of the DEC Texture-Based Acid Sulfate Soils 'Action Criteria' reported by samples obtained from depth horizons between 0.0-0.3mbgl.

This ASS investigation generally confirmed that the spatial distribution of ASS occurrences conform to DEC's regional ASS 'moderate to high risk' category mapping for the area. No soils were tested for ASS below 3 mbgl; therefore, ASS may be present at depths greater than 3 mbgl. However, this is below the depth of disturbance in this area. Additionally, this ASS investigation did not include groundwater testing. However, based on the depth of ASS and the likelihood of shallow groundwater in the proximity of the wetlands, groundwater within localised parts of the study area may potentially be affected by ASS.

A summary of the ASS laboratory test results is presented in Table 5.5-1. The following general indicators of ASS were evidenced by the field test results:

- Soils:
  - The presence of sulphides in soil was indicated at test pit TP13 by a pH_{FOX} <4.0. However, with pH_F equal to or greater than 4.1 and pH_{FOX} values of 3.1 or greater, and with mostly only slight reactions, the soils are unlikely to be AASS or PASS;
  - The recording of at least one sample with a ΔpH greater than 1.0, PASS was indicated at all soil sampling locations, with the exception of TP15. However, with pH_F equal to or greater than 5.3 and pH_{FOX} values 4.7 or greater, and with mostly only slight reactions, the soils are unlikely to be AASS or PASS; and
  - Some association of PASS within coffee rock horizons was recorded at about 3mbgl;
- Sediments:
  - Moderate indication of PASS at BLSB2 and BLSN2 in all the samples. The sediment has the potential to oxidise further and produce sulphuric acid if exposed; and
  - Although all the other samples recorded a ΔpH greater than 1.0, the pH_{FOX} values were 4.4 or greater. The moderate reaction may have been caused by the organic matter. There is no clear indication of AASS or PASS in these samples.

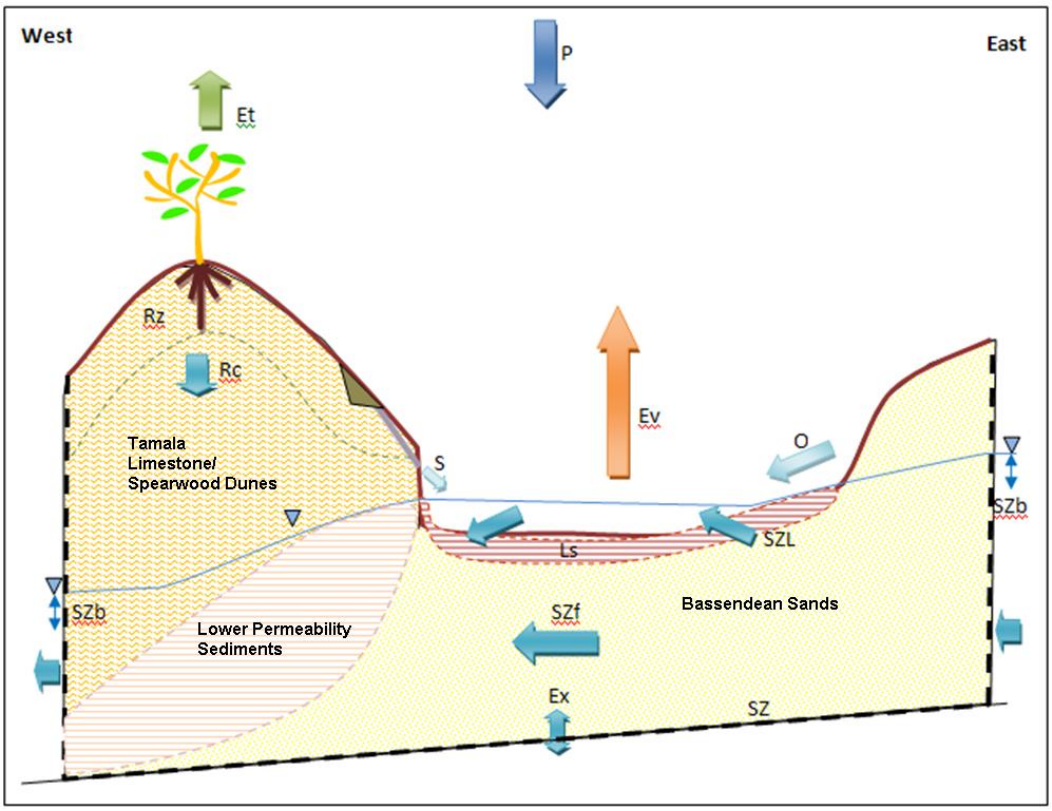
Table 5.5-1: Summary of ASS Laboratory Test Results

Field Observations			Field Test (Laboratory)			Action Criteria
Sample ID		Soil Description	pH_F	pH_{FOX}	$pH_F - pH_{FOX}$	Net Acidity (SPOCAS)
Sample Name	Sample Details (Depth in mgbl) / Interval of Soil Type		pH Units	pH Units	pH Units	mol H^+/t
Soil Samples						
TP13/2.6	2.6 m	SAND (SP): dark brown fine to coarse grained with coffee rock	5.5	3.1	2.4	64
TP14A/2.0	2.0 m	SAND (SP): orange brown fine to coarse grained	5.7	4.8	0.9	26
TP15/2.7	2.7 m	SILTY SAND (SM): dark brown fine to coarse grained with coffee rock	4.6	4.0	0.6	82
TP16/3.0	3.0 m	SAND (SP): grey fine to coarse grained. Some coffee Rock	6.0	4.6	1.4	33
TP17/2.0	2.0 m	SAND (SP): orange brown fine to coarse grained	5.9	4.7	1.2	<10
Sediment Samples						
BLS2	0.1–0.3m	Sediment	6.3–6.6	2.0–2.7	3.6–4.6	59–65
BLN2	0.1–0.3m	Sediment	4.8–4.9	3.2–3.3	1.5–1.7	643–763

mbgl - metres below ground level

5.6. Surface and Groundwater Movement

There is a seasonal hydrological cycle of winter inflows and summer drawdown on wetlands of the Swan Coastal Plain. Wetland water levels are influenced directly and indirectly (via groundwater) by the amount of rain that falls in winter and by evaporation rates and a lowering groundwater table during summer. General relationships between surface water, groundwater, evaporation and other relevant components of the hydrological cycle are illustrated in Figure 5.6-1. Specifically, the figure shows the stylised cross-section through Bibra Lake (with Bassendean Sands on the right, Bibra Lake centre of view and Spearwood Dunes underlain by Tamala Limestone on left of diagram).



Legend:

P	Precipitation	Ls	Lake sediments
Et	Evapotranspiration	SZ	Saturated zone
Ev	Evaporation	SZL	Saturated zone flow
O	Overland flow	SZb	Saturated zone boundary condition
S	Stormwater runoff piped from impervious urban areas to the lakes	SZf	Saturated zone flow driven by groundwater levels
Rc	Recharge	Ex	Exchange with groundwater
Rz	Root zone		

Figure 5.6-1: Hydrological Cycle

5.6.1. Climate

The climate of the south-western region of Western Australia is characterised as Mediterranean: experiencing hot, dry summers and cool to mild, wet winters. Due to the orographic effect (fast rising and condensing of moist air) on the Darling Scarp, passing fronts are intensified and rainfall increases at higher elevations. Occasionally, a weakened cyclone originating in seas off the northern portions of the State can provide rain, temporarily breaking the long summer drought (Bureau of Meteorology (BoM) 2011a).

The closest meteorological recording station to the project area is Jandakot Aero Weather Station, which commenced recording rainfall in 1972. This station is maintained by the BoM at the Jandakot Airport (station 009172). This station is located approximately 3.5km south-east of the eastern end of the project area, about five kilometres from Bibra Lake. Monitoring for weather statistics other than rainfall (e.g. temperature, wind and sunshine) commenced much later in 1989/1990. As a result, the recorded set of data is incomplete and has not been subject to quality control in the same way as official BoM weather stations (i.e. Perth Airport).

Mean monthly temperature (measured at 1500hrs local time) at Jandakot Aero ranges from 16.7ºC in July to 29.7ºC in February. Average minimum temperatures range from 6.8ºC in July and August to 16.8ºC in February. Average maximum temperatures vary between 17.8ºC in July to 31.3ºC in February. Winds near the project area primarily originate from the east in the morning, changing to mainly south-westerlies in the afternoon (BoM 2011b).

Long-term average wind roses from the BoM are provided in Figure 5.6-2 and Figure 5.6-3. Wind roses show the frequency of occurrence of winds by direction and strength. Overall, the wind roses from the nearest weather station indicate that there is a diurnal pattern in the wind directions, illustrated by the lighter inland winds (from the east and north-east) in the morning and a shift to stronger sea breezes (from the west and south-west) in the afternoon.

The mean annual rainfall at Jandakot Airport is approximately 826mm with the majority of rainfall occurring between May and September (BoM 2011b). The rainfall level recorded at Jandakot is approximately 15 percent more than rainfall recorded at Perth Airport (located 19km from Jandakot), with the greatest differences in rainfall being recorded between May and July.

While available data indicate that North and Bibra lakes have historically had similar water levels to current recorded levels, a declining trend in rainfall and water levels is apparent (Appendix W). This drying trend is consistent with observations in the south-west as a whole. Reduced rainfall and changes to other climate variables, including slight increases in mean temperature, may have affected available water for the wetlands. It is difficult to determine the extent of this impact, given the considerable amount of land development that has occurred in the last 50 years, including water extraction from the Jandakot groundwater mound.

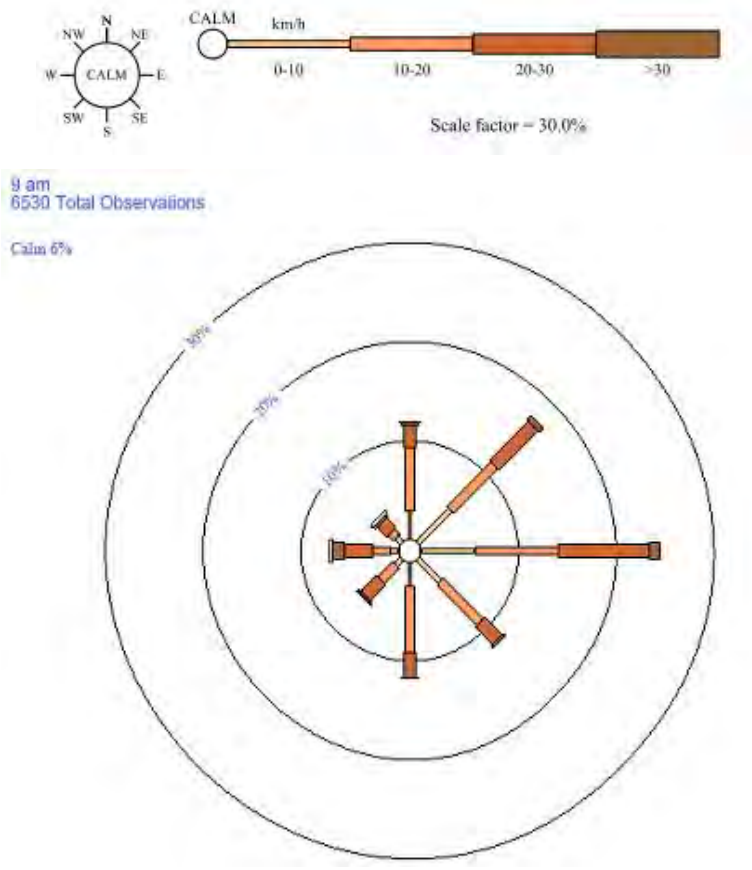


Figure 5.6-2: Average Wind Rose for Jandakot Airport, 0900hrs February 1989 to June 2008

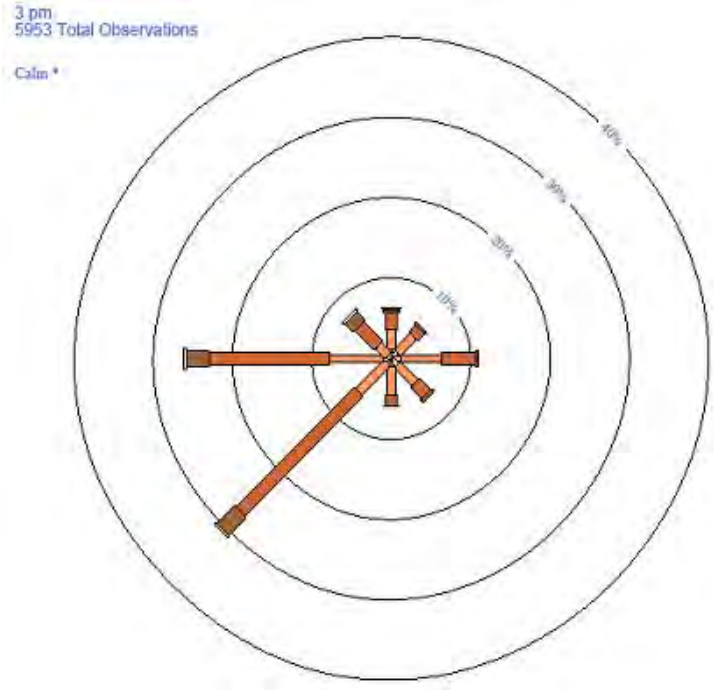
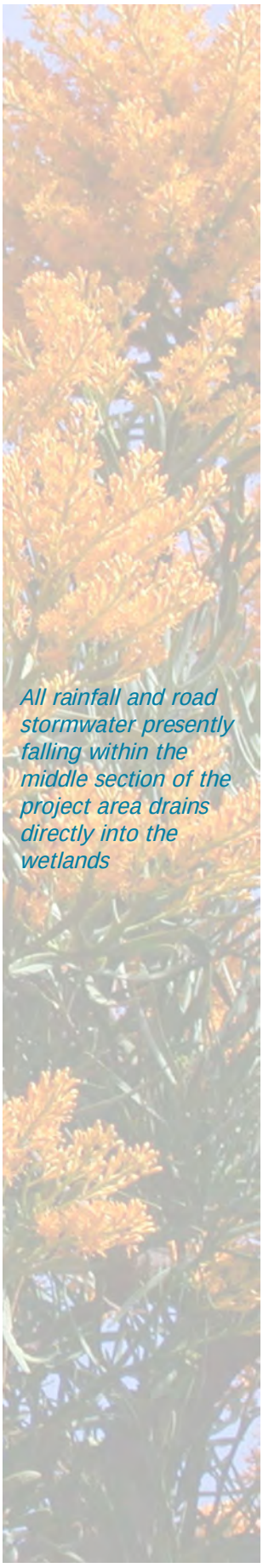


Figure 5.6-3: Average Wind Rose for Jandakot Airport, 1500hrs February 1989 to June 2008



All rainfall and road stormwater presently falling within the middle section of the project area drains directly into the wetlands

5.6.2. Catchment Hydrology and Drainage

The study area for evaluating surface water is defined as the catchment that contributes to the project wetland system, including the following water bodies, and is further discussed in Section 5.2.2.2:

- Bibra Lake;
- North Lake;
- Horse Paddock Swamp;
- Roe Swamp (i.e. Lower, Melaleuca and Roe swamps); and
- Murdoch Drain.

The project area intersects the catchment that contributes surface water runoff to each of these water bodies. This catchment has an area of approximately 730ha (Figure 5.6-4). Parts of the Roe Highway road reserve to the east and west of this catchment are generally self-contained with respect to surface water (i.e. surface water does not enter or leave the road reserve in these areas). These areas to the east and west of the catchment are referred to in terms of their proximity to existing local government drainage infrastructure.

The catchment surface area was calculated using a combination of Department of Land Administration (DOLA) topographic contours and City of Cockburn drainage information. The catchment does not include areas that may contribute to the wetland system through groundwater recharge. The surface water catchment for the project wetland system includes:

- Areas generating surface water flow that discharge directly into the project wetland system;
- Areas generating surface water flow from road drainage infrastructure;
- Areas generating surface water flow within residential areas that would contribute to road drainage infrastructure or overflow into the project wetland system during larger storm events;
- The area of water bodies receiving direct rainfall; and
- Areas generating surface water flow to existing City of Cockburn basins that overflow into the project wetland system during larger storm events.

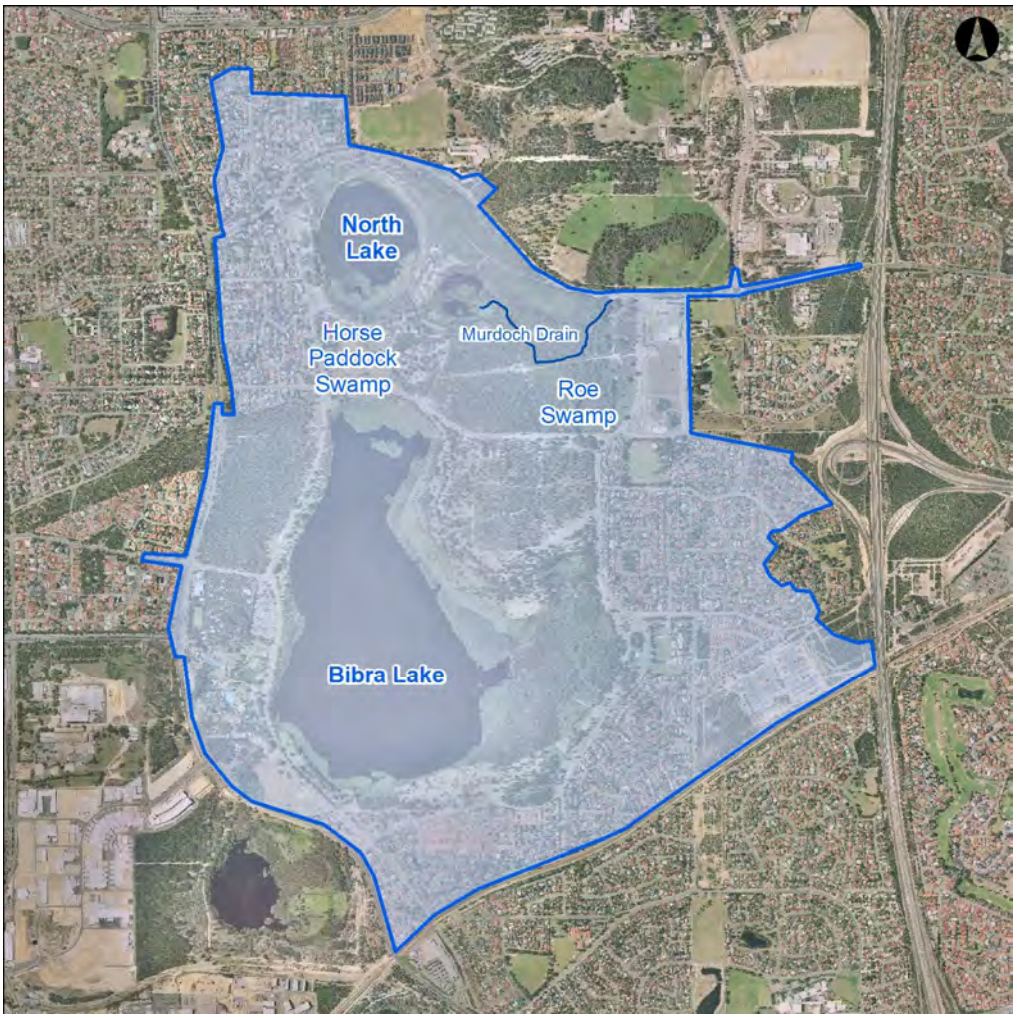


Figure 5.6-4: Wetland System Surface Water Catchment

5.6.2.1. Proportions of Surface Water Contributions

Approximately 46ha (six percent) of the surface water catchment (730ha) of the project wetland system comprises impervious road pavement. This runoff is predominantly captured through pit and pipe systems located within residential areas and on major roads. Minor roads situated closer to the wetlands are not kerbed; thereby allowing runoff to infiltrate locally or contribute to overland flow that drains into the wetlands and surrounding buffer areas during larger storm events.

Approximately 320ha (44 percent) of the surface water catchment to the project wetland system comprises vegetated areas, including the Beeliar Regional Park and adjacent parkland. The soil composition in these areas is predominantly Bassendean Sands with high hydraulic conductivity. Therefore, much of the incident rainfall infiltrates into the groundwater rather than becoming runoff. This is particularly the case in low intensity rainfall events, where soil moisture levels fail to achieve saturation resulting in infiltration rates matching rainfall intensity.

The area covered by North and Bibra lakes constitutes approximately 140ha (19 percent) of the study area. The remaining 224ha (30 percent) of the catchment is developed as residential and commercial areas.

Based on aerial photography, the average proportion of impervious areas (such as roof tops, driveways and paved areas) to pervious areas (ground surface) is 50 percent within residential lots. Typically, urban development policies have required that the 1-in-10-year Average Recurrence Interval (ARI) rainfall event is held within development lots in soak wells or constructed basins. Therefore, these areas effectively contribute to groundwater recharge rather than surface runoff, unless the 1-in-10-year ARI event is exceeded. Different areas of runoff contributions are shown in Figure 5.6-5.

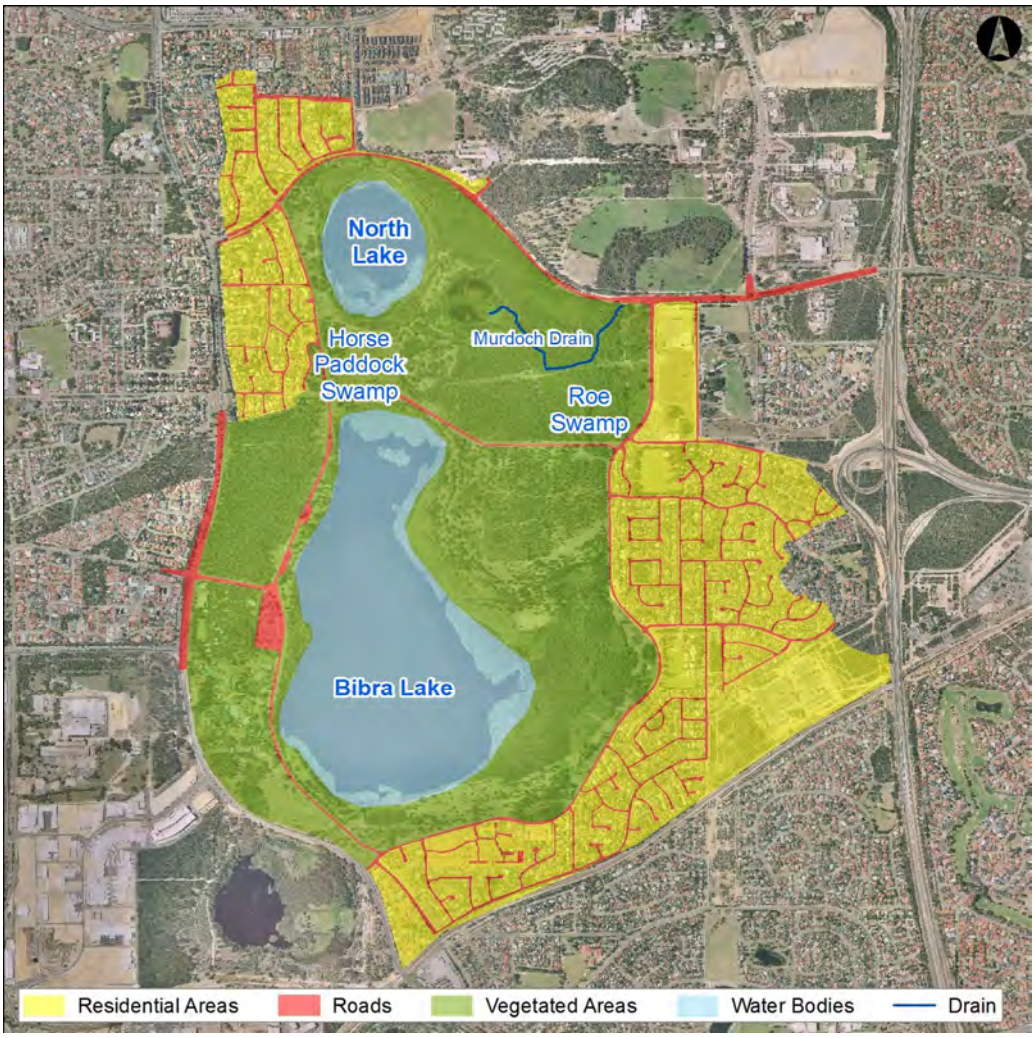


Figure 5.6-5: Surface Water Contributions

Historical aerial photography indicates that the majority of the contributing catchment before the mid-1970s comprised agriculture, vegetated surface and other undeveloped areas. Residential developments appeared in the mid-1970s and have continued to increase in density throughout the catchment since that time. Residential development occurred to the west of North Lake prior to the mid-1970s, but this is located outside of the catchment contributing to the wetland system. No residential development is shown to occur within the catchment or its fringes prior to 1960.

5.6.2.2. Surface Water Features

Surface water within the wetland system is a combination of groundwater expression and the result of surface water runoff. Site investigations and historical aerial photography have identified surface water at the following locations:

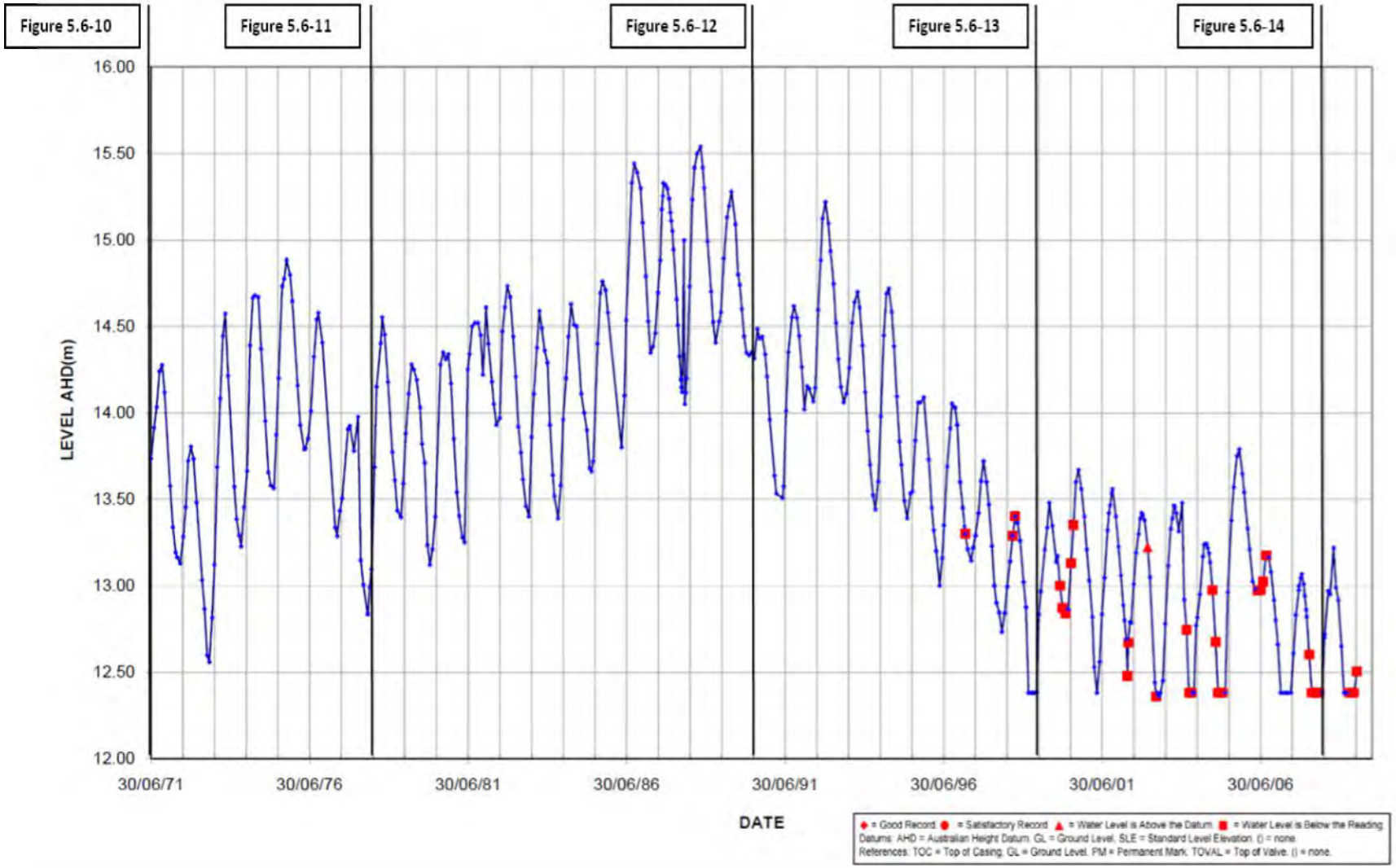
- Bibra Lake;
- North Lake;
- Horse Paddock Swamp;
- Roe Swamp; and
- Murdoch Drain.

The interactions between these water bodies, the surrounding topography and groundwater are typically spatially complex and temporally variable. A numerical model (MIKE SHE), representing water movement for above and below ground systems, has been developed and calibrated to further understand these interactions (Appendix G).

In addition to the water bodies identified through aerial photography or site investigations, there are other low lying areas that the MIKE SHE model has predicted as containing occasional surface water. This is supported by the groundwater and vegetation studies, which identified vegetation types that are typically supported by surface water or saturated surface soils in these areas.

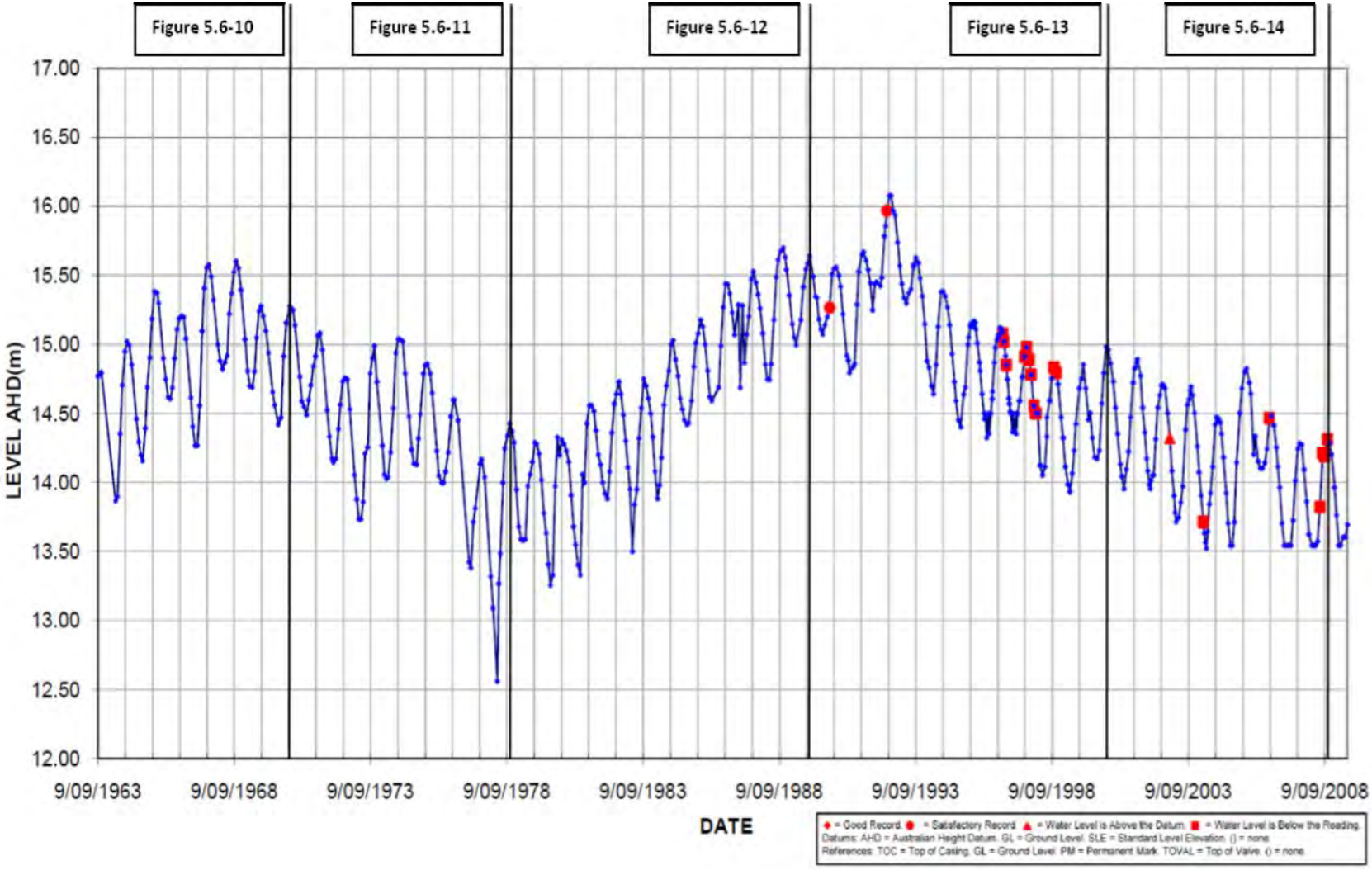
North and Bibra lakes are the largest water bodies within the studied part of the wetland system. The hydrology of these lakes, and the system as a whole, has been modified significantly over time, predominantly as a result of increased development within the catchment.

Water levels within North Lake have been consistently measured by the DoW since 1971 (with some errors appearing in the data, when the water levels fall below available gauge reading marks). Data associated with North Lake surface water levels are graphically represented in Figure 5.6-6. Similarly, water levels in Bibra Lake have been consistently measured by the DoW since 1963 (with some similar limitations in records). The data associated with Bibra Lake surface water are shown in Figure 5.6-7.



Source: DoW 2010; Easting = 388859.04 Northing = 6450358.82 Zone = 50 PM = 17.244mAHD WIN SITE ID = 13682

Figure 5.6-6: North Lake Surface Water Levels



Source: DoW 2010; Easting = 389289.00 Northing = 6448839.00 Zone = 50 PM = 15.503MAHD win site id = 13681

Figure 5.6-7: Bibra Lake Surface Water Levels

Water levels in Bibra Lake have maintained a repeatable pattern of highs and lows over the seasons, as well as within a 20-year cycle; however, there are not enough years of data to conclude whether this is a consistent pattern.

Historical aerial photography (Figure 5.6-8 through to Figure 5.6-14) shows various water levels in the lakes over time. The figures include the MRS road reserve boundary to provide context. Although taken at differing times of the year, the aerial images show that the water level in North and Bibra lakes has remained relatively similar over most years. During winter 2010, water levels were dry or low in the lakes. Low water levels indicated on aerial photography from 1978 (Figure 5.6-11) are consistent with the readings down to RL (Reduced Level) 12.5m Australian Height Datum (AHD) in 1978 (Figure 5.6-7). Variations in water level appear in the surrounding wetlands:

- Horse Paddock Swamp and Murdoch Drain had evident surface water in the 1947/1948, 1970 and 1989 photos;
- Lower Swamp and Roe Swamp had evident surface water in the 1978 photo, with only a small area of surface water in Horse Paddock Swamp and Murdoch Drain;
- None of the peripheral swamp systems showed obvious surface water in the 1958/1959 photo or the 1999 photo; and
- The only surface water showing in the 2008 historical aerial photograph was in the lower end of Murdoch Drain; there is no obvious surface water in the other peripheral swamp systems.

While the water levels in the lakes appear to have been relatively consistent, these variations in surface water within the peripheral systems indicate a shallow surface water system sensitive to groundwater expression and surface water contributions. Alternatively, it may be due to natural vegetative succession, as a result of changing land use practices.

Water levels in North and Bibra lakes appear less sensitive to change, possibly reflecting their larger storage volumes and deeper vertical profiles. Conversely, the peripheral swamps have smaller storage volumes, varying base levels and varying interfaces with the surrounding topography. Therefore, whether surface water shows or not depends on the rising groundwater intrusion through variably pervious wetland sediments and runoff generated in adjacent catchment areas.

Figure 5.6-8: Aerial Photo Showing Surface Water December 1947/January 1948

Figure 5.6-9: Aerial Photo Showing Surface Water August 1958/June 1959

Figure 5.6-10: Aerial Photo Showing Surface Water October 1970

Figure 5.6-11: Aerial Photo Showing Surface Water August 1978

Figure 5.6-12: Aerial Photo Showing Surface Water February 1989

Figure 5.6-13: Aerial Photo Showing Surface Water January/October 1999

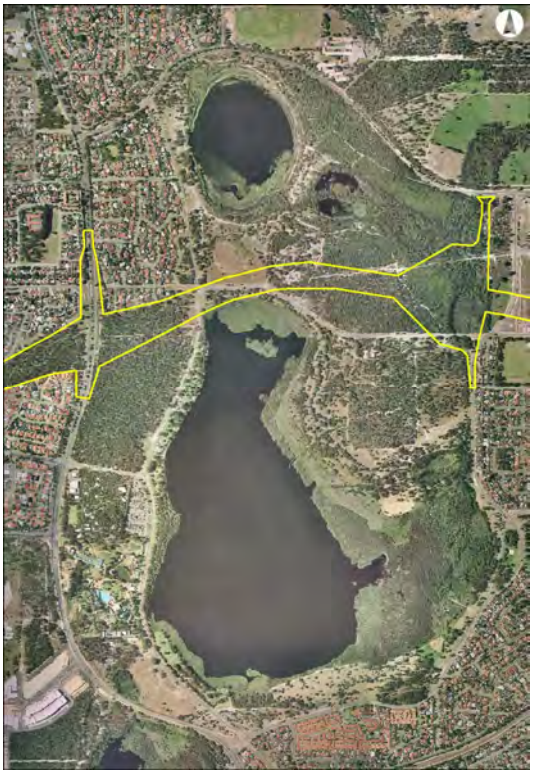


Figure 5.6-14: Aerial Photo Showing Surface Water March 2008

Roe Swamp and Murdoch Drain represent another surface and groundwater system, which has been modified over time by human activity and development with respect to hydrology and topography.

Roe Swamp and Murdoch Drain are indicated in the aerial photo captured in 1947/1948 (Figure 5.6-15). The current DoW hydrographical mapping (DoW 2010) is overlain on this figure to indicate that historical surface water extended beyond the existing pattern, as is evident by the vegetation extent. The DEC geomorphic wetland classification is also indicated.

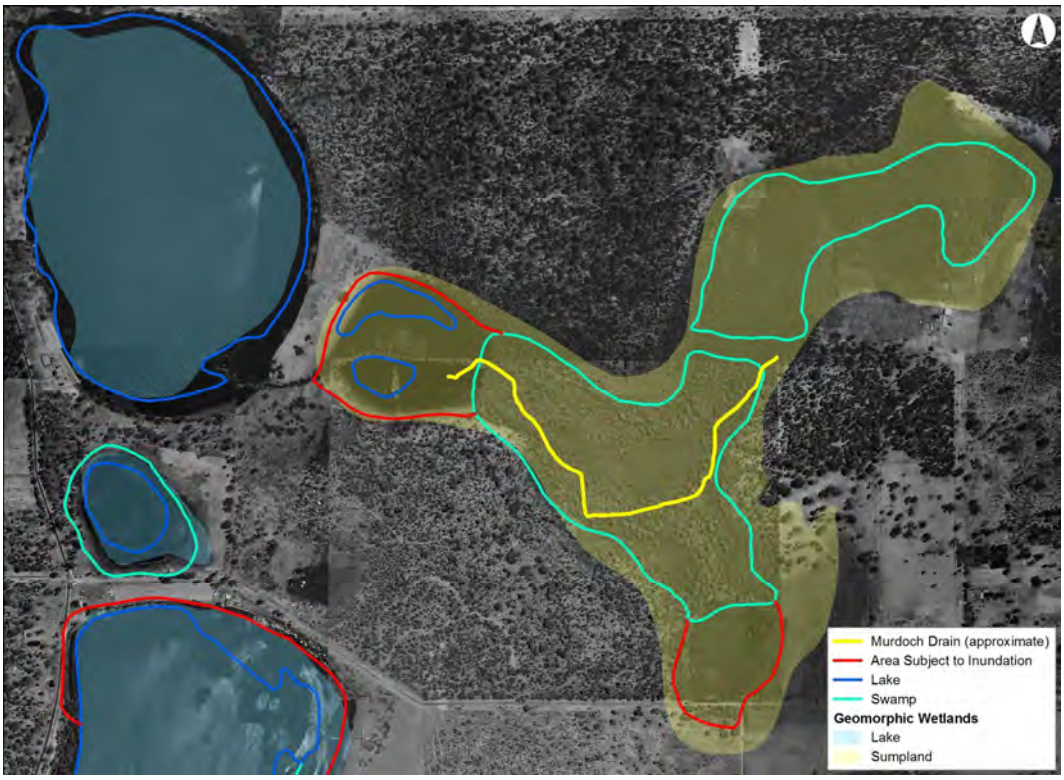


Figure 5.6-15: Murdoch Drain and Roe Swamp 1947/1948

An image of Roe Swamp that was captured in 1978 is shown in Figure 5.6-16. The current DoW hydrographical mapping is overlaid on this image and it is evident that the system is similar to the current vegetation pattern and hydrographical mapping, predominantly as a result of clearing that occurred prior to this time. Another interesting surface water feature of this aerial photo is the appearance of an access track on the current Farrington Road, as well as a man-made open channel system, which is shown in more detail in Figure 5.6-17. It is presumed that Murdoch Drain was formed in an attempt to drain the area of surface water to facilitate agricultural or urban development, such as road or residential construction activities.

Murdoch drain has a level grade. It flows westerly during heavy storm events

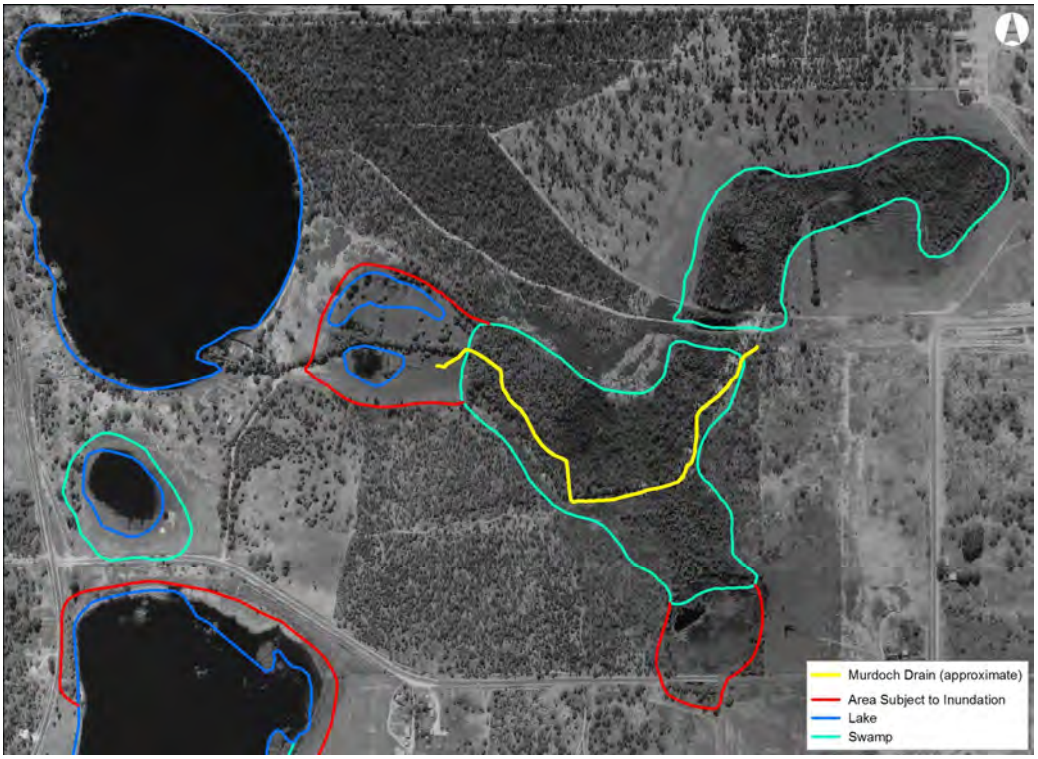


Figure 5.6-16: Murdoch Drain and Roe Swamp 1978

The alignment of the Murdoch Drain today is consistent with the 1978 aerial photography, although current survey information indicates that it does not currently function as a conveyance system. The presence of above-ground water is due to groundwater expression. The open drain does not have a positive grade falling in either direction, and its invert is at approximately 15m AHD, which is at least 1m below the DoW's maximum recorded groundwater levels (which vary between 16m AHD and 17m AHD in this area). The open channel receives surface water contributions from Farrington Road piped drainage, but it appears to require a considerable amount of flow from this contribution before it develops enough hydraulic grade to move in a westerly direction and discharge into North Lake.

In addition to the absence of grade, there is an obstruction in the form of a 1.5m high earth blockage within the drain, which appears to dam flows from moving further west without significant hydraulic head. There does not appear to be a culvert connecting either side; however, this possibility cannot be ruled out and if one exists, it is likely blocked. The purpose of the blockage is unclear, but it forms a makeshift bridge allowing pedestrian access from one side of the drain to the other.

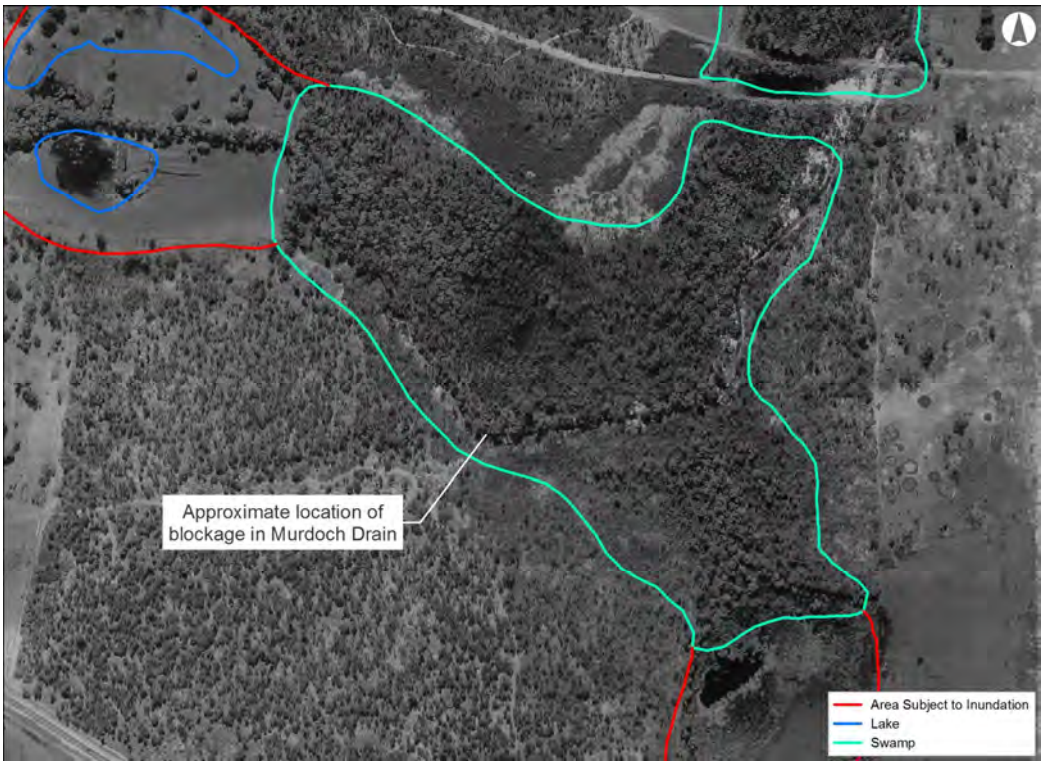


Figure 5.6-17: Man-made Murdoch Drain Open Channel 1978

5.6.2.3. Ministerial Statement 883

Ministerial Statement 883 *Jandakot Mound Groundwater Resources and Schedule 1 Proponent's Environmental Management Commitments* (WRC 2004) discusses the provision for environmental water requirements associated with resources within the Jandakot Mound, including North and Bibra lakes.

North Lake Staff Q6142521 has a preferred water level criterion of 13.29m AHD and an absolute minimum of 12.68m AHD, with additional criteria stating that water levels should not decline at a rate greater than 0.1 metres per year.

Bibra Lake staff Q6142520 has a preferred water level criterion of between 13.6m AHD and 14.2m AHD, with a preferred maximum of 15m AHD and an absolute minimum of 13.6m AHD, with additional criteria stating that the lake is not to dry more than 2 in every 3 years, and preferably less than 1 in every 3 years.

Analysis of water level information from DoW indicates a number of breaches of North and Bibra lakes preferred and absolute minimum water levels and rate of decline since 1997. When environmental water requirements are frequently not met, adverse impacts can occur. These may manifest as poor water quality, increased algal blooms, decreased species diversity and a general decline in the ecological health of the system.

5.6.2.4. Road Reserve Drainage

The project area to the west of the central wetland system is shown in Figure 5.6-18, with the City of Cockburn stormwater drainage infrastructure overlaid on a current aerial photo. Maximum groundwater contours are also indicated (DoW 2005) at one metre intervals, representing the height of maximum groundwater levels above AHD. The residential areas have their own stormwater systems that discharge into City of Cockburn's stormwater basins.

The MRS road reserve is contained with respect to surface water management and does not currently contribute to the City of Cockburn drainage infrastructure. As the MRS road reserve is undeveloped and largely covered by vegetation, stormwater falling within the area does not revert to significant runoff; but infiltrates into the sands to recharge groundwater. There is an existing, effectively contained road drainage system located on Stock and North Lake roads that does not contribute to the project road reserve.

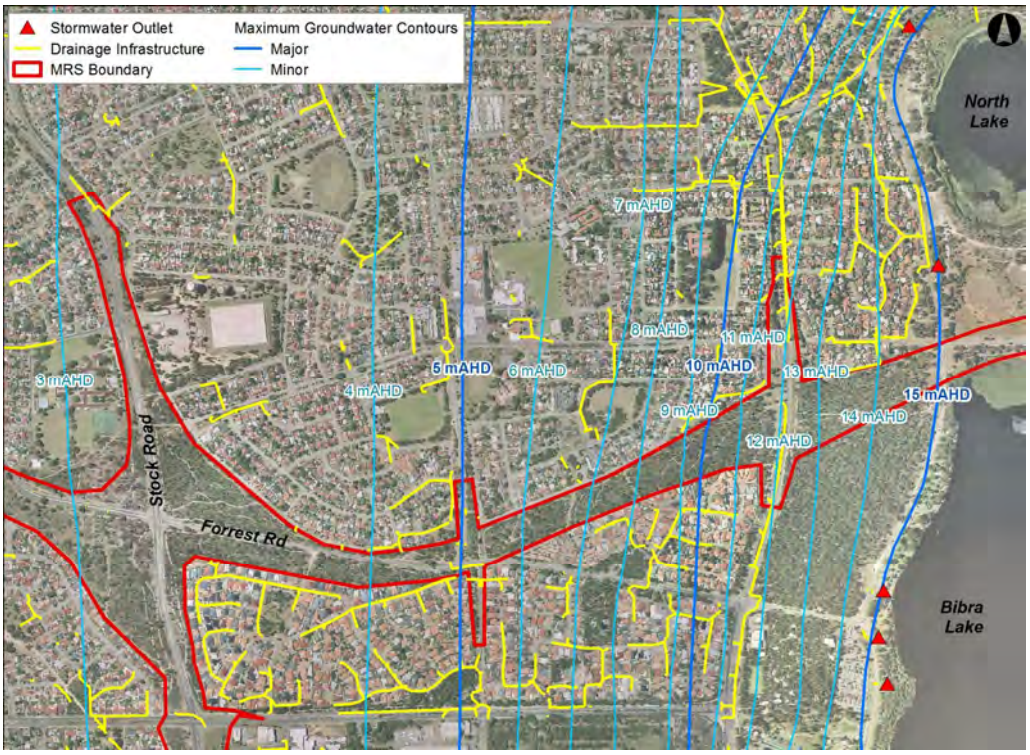


Figure 5.6-18: Existing Drainage Infrastructure West of Wetland System

The project area to the east of the central wetland system is shown in Figure 5.6-19, with the City of Cockburn stormwater drainage infrastructure overlaid on a current aerial photo and the MRS road reserve boundary also shown. The MRS road corridor in this section of the project is completely cleared to the east of Roe Swamp, except for portions of the Kwinana Freeway and Roe Highway interchange. The residential areas have their own stormwater systems that discharge into both the City of Cockburn stormwater basins and the buffer areas around the wetland system.

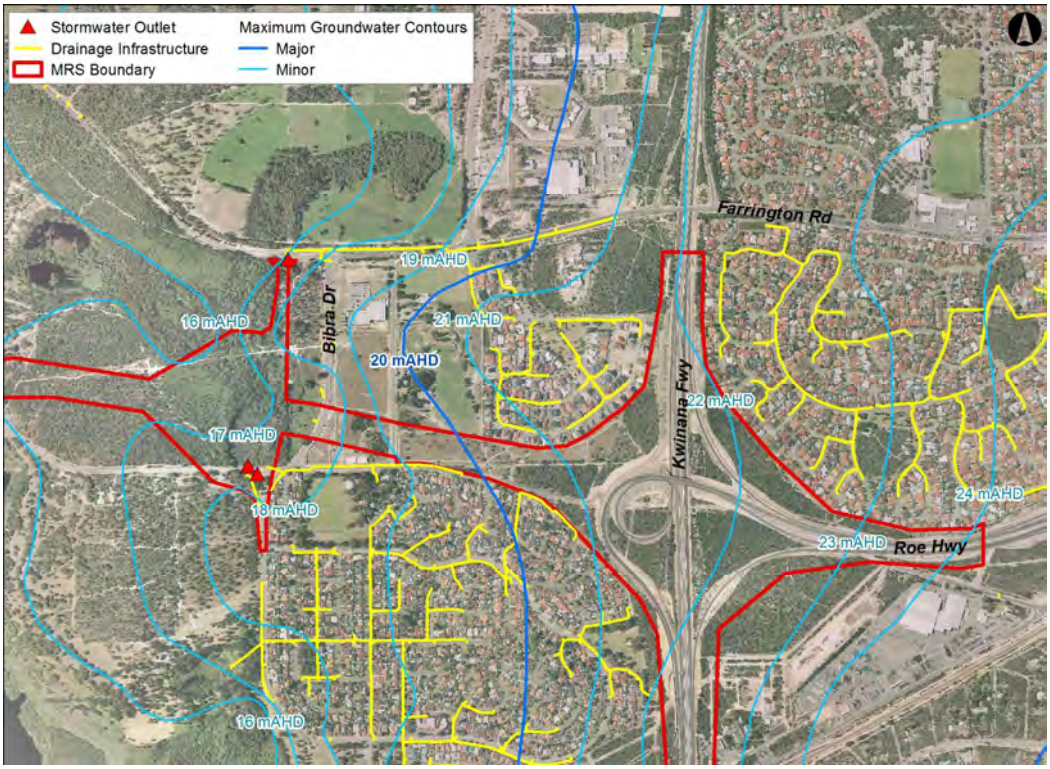


Figure 5.6-19: Existing Drainage Infrastructure East of Wetland System

The Farrington Road drainage system discharges into Murdoch Drain just near Farrington Road, as shown in more detail in Figure 5.6-20. There is further discussion on the water quality aspects of this stormwater in Section 5.7.

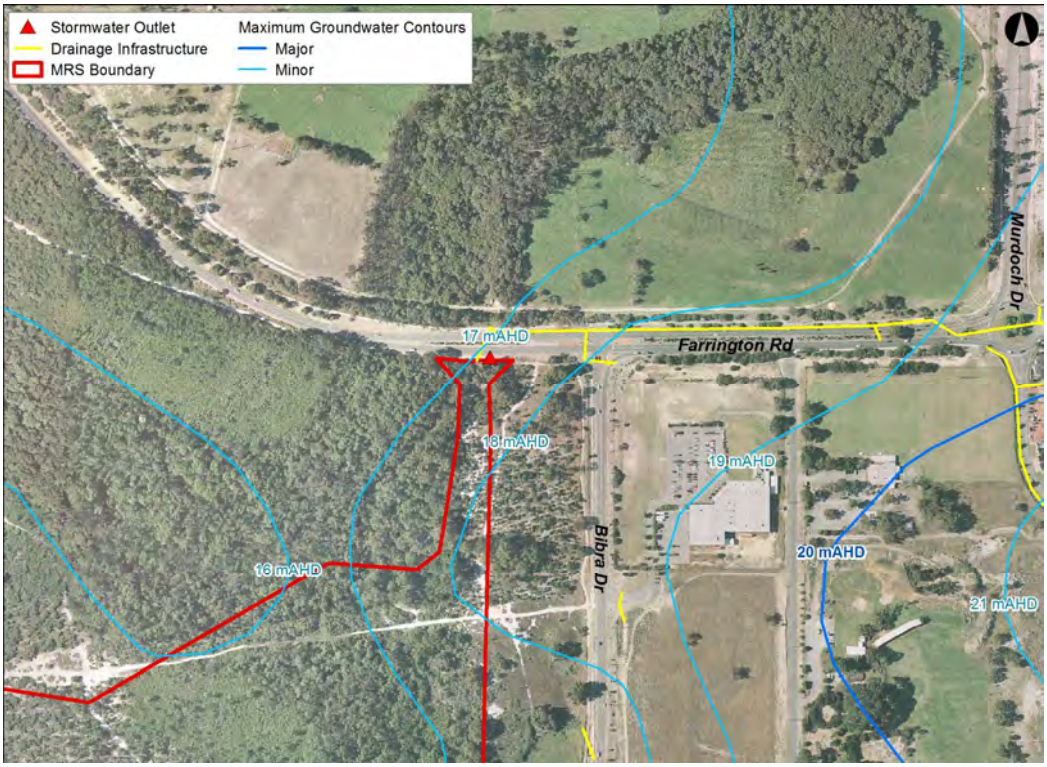


Figure 5.6-20: Farrington Road Runoff Discharges into Murdoch Drain

Several sections of Bibra Drive discharge directly into Roe Swamp, as indicated in Figure 5.6-21. The figure shows City of Cockburn stormwater infrastructure overlaid on a current aerial photo and the stormwater from the suburb of Bibra Lake discharging via the pipe network into Bond Swamp, located to the east of the Bibra Lake water body. Although the topography does not indicate that there is a direct overland flow route from this discharge point to the water body, there are certainly groundwater recharge connections, as well as the possibility of overland flow in extreme storm events.

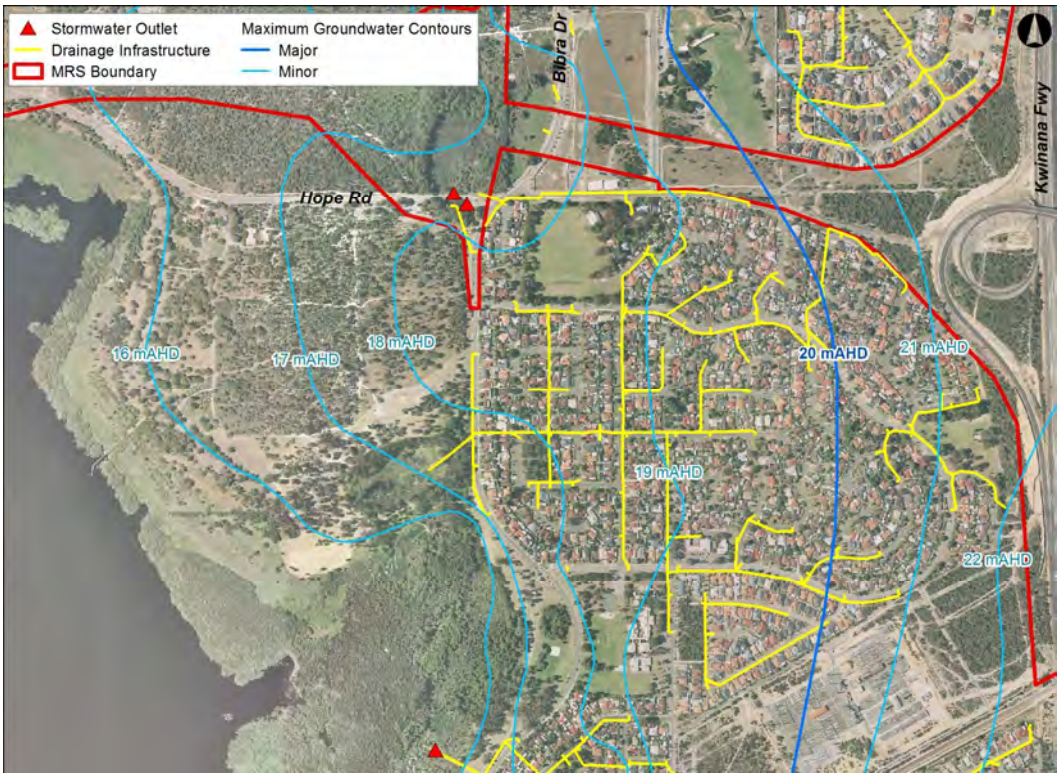


Figure 5.6-21: Bibra Drive and Bibra Lake Suburb Discharge into Roe Swamp and Bibra Lake

5.6.3. Groundwater Hydrology

This section discusses groundwater movement and recharge within the project area. Groundwater field studies began in March 2010 and concluded in February 2011. Given that 2010 was a low rainfall year, it is acknowledged that the results obtained may not be typical of water movement and levels. Nonetheless, the study results provide an understanding of the water cycle during a dry year, which has had fewer storm events and overall less rainfall (i.e. second driest on record). Previous studies were used to compare data between low and higher rainfall years in order to provide input into the project design and assessment.

The superficial aquifer that lies under the project area is approximately 40m thick

5.6.3.1. Regional Groundwater

The Jandakot Groundwater System is comprised of a superficial (unconfined) aquifer, the confined Leederville Aquifer and the confined Yarragadee Aquifer (Water Corporation 2008). The superficial aquifer is known as the Jandakot Mound. At the centre of the Jandakot Groundwater System, the saturated thickness of the superficial aquifer formation is approximately 40m (Water Corporation 2008). It comprises shallow sands and is unconfined, although ferricrete and coffee rock layers can locally impede groundwater or surface water, resulting in areas of ponding and perched aquifers. Generally, the thickness of the unconfined aquifer decreases towards the coast (Appendix D). It is believed that the Jandakot Mound has developed as a result of the rate of infiltration exceeding the rate of horizontal groundwater flow within the superficial aquifer (JAH 2009). During dry summer months, the rate of horizontal groundwater flow exceeds vertical infiltration resulting in a subsidence of the mound as the water table falls.

The Jandakot Mound is associated with wetland systems and groundwater dependent vegetation, as well as providing water for domestic and commercial supply. A confining shale layer (Osborne formation) beneath the majority of the northern portions of the superficial aquifer suggests that recharge to the underlying Leederville Aquifer occurs primarily in the southern extent of the Jandakot Mound. Most of the groundwater from this aquifer discharges to the Indian Ocean, the Swan-Canning River estuary system or other local river catchments (Water Corporation 2008).

5.6.3.1.1. Water Flow Levels

Groundwater levels within the study area fluctuate seasonally by approximately one metre and are generally highest during September and October (after winter rainfall recharge) and lowest during April and May (after summer) (Davidson 1983). Inspection of groundwater contour maps indicates that groundwater generally flows in a westerly direction from the Jandakot Mound to discharge in the near-shore marine environment of Cockburn Sound.

Groundwater contours indicate that the wetlands play a role in the flows of groundwater with water flows to and from wetland basins directed by wetland sediment. In the wetland basins, the sediment fill exhibits various thicknesses of mud, consequently forming an impedance to lateral groundwater flow into the wetlands and to vertical groundwater migration (Appendix D).

The measured groundwater contours of the area for 2010 are presented in Figure 5.6-22 (March 2010), Figure 5.6-23 (April 2010) and Figure 5.6-24 (August 2010). These figures indicate two westerly-trending groundwater plumes located north-west of North Lake and south-west of Bibra Lake. Due to access limitations, no piezometers were drilled in lake sediments of North or Bibra lakes and accordingly, no groundwater contours could be plotted beneath these lakes. On the eastern side in the delivery zone, there is a north-west plume between Roe Swamp and North Lake. In the same area, there were two local small mounds: one centred on Melaleuca Swamp and the other located between sites T4-C and T4-D on Hope Road.

Surface water levels in North Lake were 12.38, 12.38 and 12.60mAHD in March, April and August 2010, respectively. Bibra Lake surface water levels were 13.09 and 13.67mAHD in March and August 2010, respectively, with no level measured in April of the same year (DoW 2010).

Water tables across the Swan Coastal Plain commonly rise with the onset of winter rain and consequent groundwater recharge. This is represented on a hydrograph by a steep increase over initial months, followed by a matching sharp decline as evapotranspiration and lateral discharge commence. Few hydrographs representing groundwater levels within project piezometers exhibit the sinusoidal shape that typifies groundwater behaviour on the Swan Coastal Plain (Appendix D). Hydrographs up to July 2010 for the project area groundwater levels were relatively flat and did not approach the typical Swan Coastal Plain seasonal average rise in water level (0.7–1m). This is most likely as a result of the low rainfall in early winter, resulting in a small increase in groundwater level.

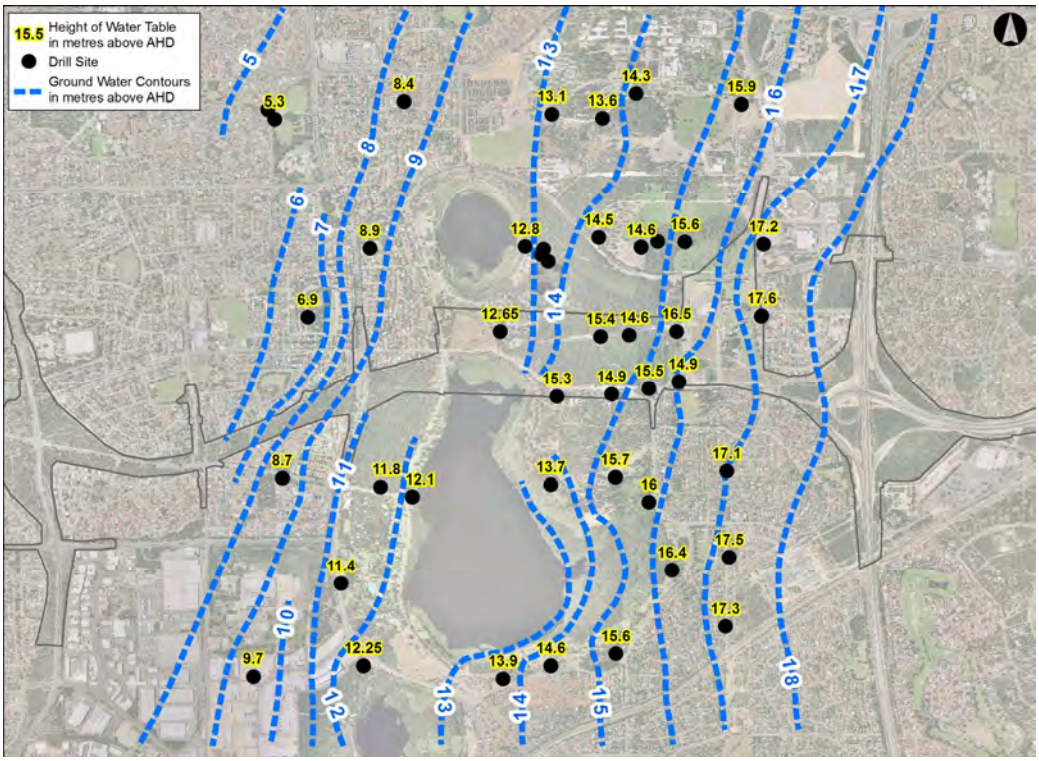


Figure 5.6-22: Regional Groundwater Contours Plotted from Lowest Bore Water Levels in March 2010

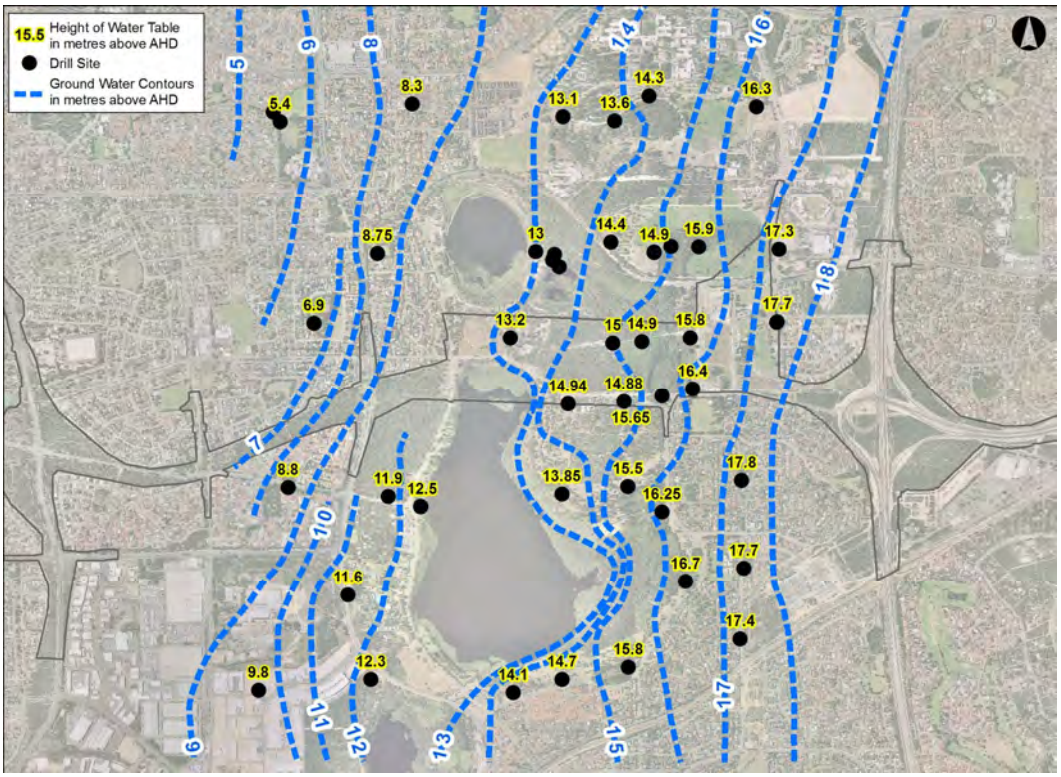


Figure 5.6-23: Regional Groundwater Contours Plotted from Recharged Water Levels in April 2010

Although horizontal hydraulic gradients are generally small (as low as 0.0002), steeper gradients (0.01) are evident west of the contact between the Bassendean Dunes and Spearwood Dunes (Tamala Limestone Sand). This could be attributed to a narrow band of lower permeability material along the formation contact (Smith and Hick 2001). Other variables may include the distribution of limestone tongues, limestone lenses, pinnacles, caves and yellow sands. Paleochannels, coarse sand layers and diagenesis have been identified as potentially contributing to variation within the general east-west groundwater flow within the project area (Appendix D).

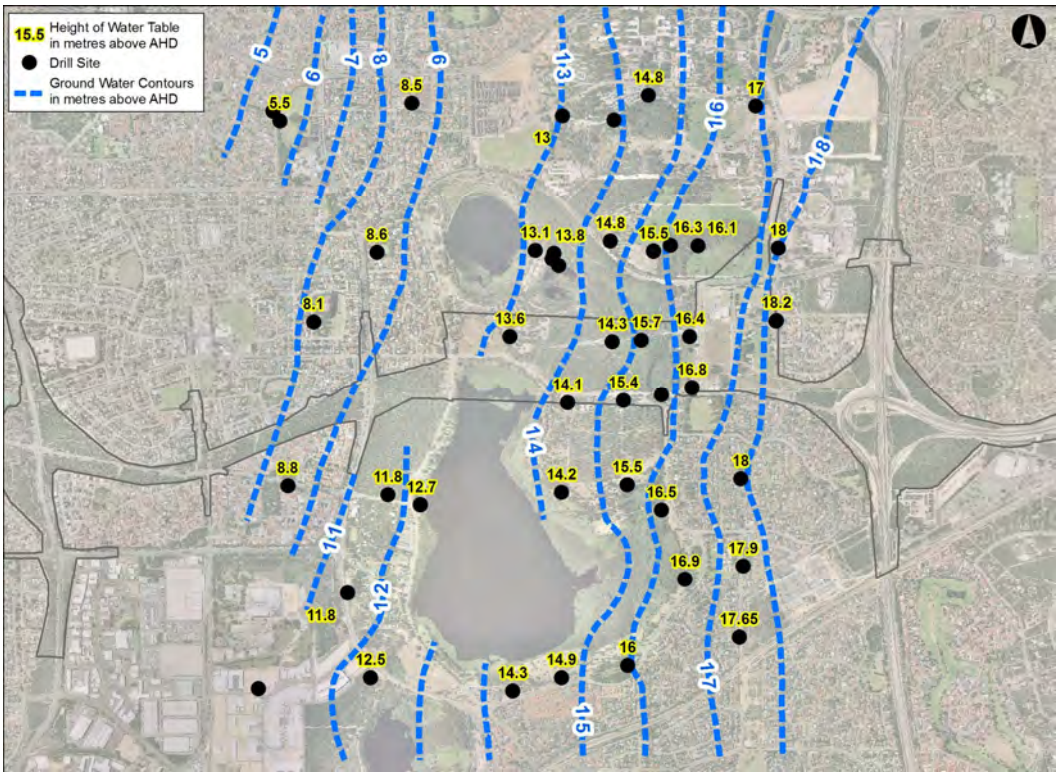


Figure 5.6-24: Regional Groundwater Contours from Highest Water Levels

5.6.3.1.2. Paleochannels

Geologic paleochannels are deposits of unconsolidated sediments or semi-consolidated sedimentary rocks deposited in currently inactive river and stream channel systems. The presence of muddy sands observed to be made up of combinations of diatom fragments, sponge spicules, phytoliths, quartz silt and kaolin clay in isolated limestone lenses suggests that paleochannels exist in the subsurface. Where they occur, these muddy sediments may impede lateral and/or vertical groundwater movement and rates of flow (Appendix D).

Paleochannels can act as hydrological conduits, resulting in non-uniform groundwater delivery pathways. Wetlands are usually low flow/low energy environments that tend to accumulate fine grained sediments, which act as relative barriers to groundwater flow. Deltaic deposits may be a combination of fined grained muds/clays and coarser deposits (remnant high flow channel). An example of this includes those areas containing buried wetland sediments and former paleochannels (Appendix D).

5.6.3.1.3. Coarse Sand Layers

Areas of coarse sand layers at the ground surface will tend to increase the rate of recharge to the water table. In the subsurface, these areas are also important in controlling groundwater pathways, discharge and through-flow rates in the local area.

5.6.3.1.4. Diagenesis

Diagenesis is the physical, chemical or biological alteration of sediments into sedimentary rock. The diagenetic alteration of sediments generally has an effect on wetlands and interaction with groundwater by affecting water flows, particularly within the wetlands and at the wetland margins. Some of the limestone lenses show evidence of having been calcretised and some sand deposits have been cemented by iron oxide. The process of calcretisation and cementation results in decreased permeability and porosity for the sediments thus affected.

5.6.3.2. Water Recharge and Movement

Recharge to the superficial aquifer occurs through direct vertical infiltration of rainfall, which migrates downward to the groundwater table or less permeable layers, at which point groundwater primarily flows laterally through the aquifer. Groundwater recharge is thought to be variable across the project area, depending on local soil properties and vertical hydraulic conductivities (Appendix D).

North and Bibra lakes are considered hydraulically connected with the unconfined superficial groundwater formation. The elevation of the water table on the eastern side of the lakes is higher than that of the lake bed, indicating discharge of groundwater into the lakes. On the western side of the lakes, the water table is lower than the lake level, which indicates outflow from the lakes to groundwater (Townley *et al*. 1993). This is also evident from regional east-west groundwater movement descriptions (Figure 5.6-22 to Figure 5.6-24). The Beeliar Wetlands in the western portion of the Jandakot Mound (including North and Bibra lakes) are through-flow lakes and expressions of the water table (CyMod 2009).

The depth of the upper surface of the superficial aquifer is at or near the topographic surface of the wetland bed sediments and surrounds. Where the water table is located near the surface, water is lost through evapotranspiration. In other areas, depth to groundwater is substantially deeper: for example, west of Bibra Lake (near Coolbellup Avenue), the water table is approximately 30 to 50 mbgl.

5.7. Water and Sediment Quality

The water levels in the Swan Coastal Plain wetlands are usually at a maximum in September and October and a minimum in March and April (Davis and Christids 1997). The quality of surface waters is often best during winter and spring, as a result of the increased freshwater inflows from winter rains, and poorest during late summer and autumn, when evaporative processes dominate and algal blooms occur (Davis and Christids 1997).

The seasonal hydrological cycle dominates wetland processes. Nutrients enter the wetland in groundwater inflows, precipitation and surface runoff during winter, while evaporation, coupled with little or no rainfall, results in the concentration of nutrients and salts during summer. Increased light and temperatures during summer, along with concentrations of nutrients, provide favourable conditions for algal growth and increased wetland productivity (Chambers and Davis 1988).

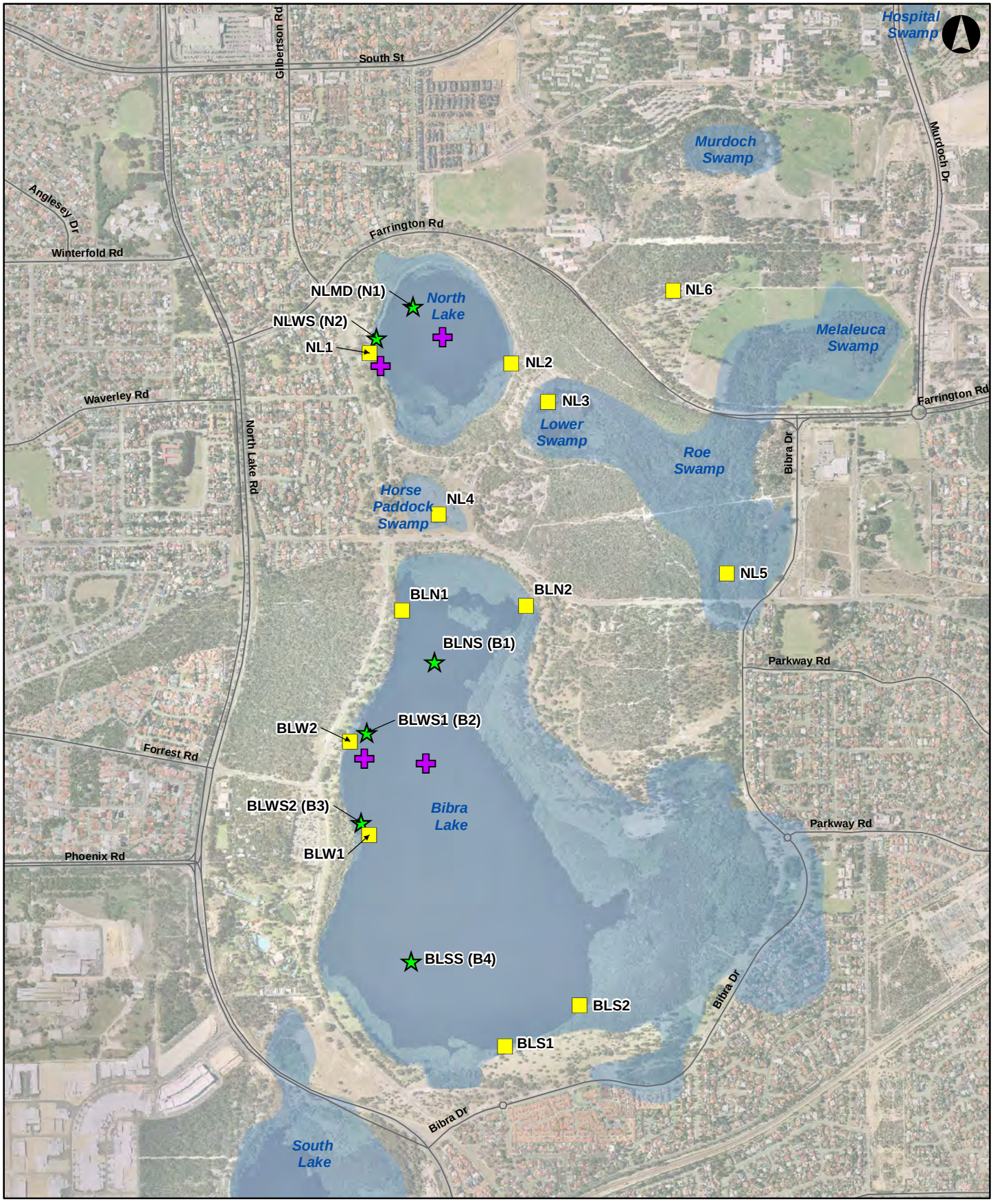
The project area lies within the surface water catchment contributing to Bibra Lake, North Lake, Roe Swamp, Horse Paddock Swamp and other adjacent swamps and damplands within the Swan Coastal Plain. To establish the possible impact of the proposed project on these wetlands, the following investigations were undertaken:

- Collection of baseline data to determine:
  - The current physical qualities of the wetlands;
  - The acceptable limits of change that may arise from the construction and operation of the proposed project; and
  - A baseline against which to assess effectiveness of the proposed road drainage design;
- Establishment of existing trophic and oxygen conditions in surface waters;
- Provision of a baseline for checking the relative benefits of infrastructure design solutions and operating conditions; and
- Assessment of performance and compliance.

Surface water and sediment samples were collected in North and Bibra lakes and surrounding areas (Figure 5.7-1). Stormwater catchments and stormwater sampling locations are indicated in Figure 5.7-2. Detail on the sampling locations, site details and the sampling techniques are presented in Appendix I. When possible, sampling in 2010 was undertaken to correspond with seasonal water fluctuations in the wetlands and drains during a period noted as the second driest winter on record for Perth.

Analytes that are most likely to be found in stormwater runoff were selected for testing. Landfill leachates and agricultural contamination from past activities have the potential to contribute pollutants, so nutrients, metals, organic compounds and hydrocarbons were analysed. Pesticides and herbicides were tested to identify contamination associated with residential or past agricultural land uses, after significant storm/rain events. The parameters measured limits of reporting (LOR) and laboratory methodologies are presented in Appendix I.

Due to their urban setting, there is a high risk of contamination of the modified ecosystems of North and Bibra lakes and surrounds. Stormwater and groundwater enter the project area wetlands (Bibra Lake, North Lake and Roe Swamp), which possess a high environmental value. A variety of methods were used to determine whether the concentrations recorded are usually found in a similar pristine ecosystem; this is detailed in Appendix I and summarised in this section.



Surface Water, Sediment & Algae Sample Sites

South Metro Connect

Figure 5.7-1

0 100 200 300 400 500

Metres

1:18,000 (A4)

- Surface Water
- Sediment
- Algae Sampling
- Wetlands

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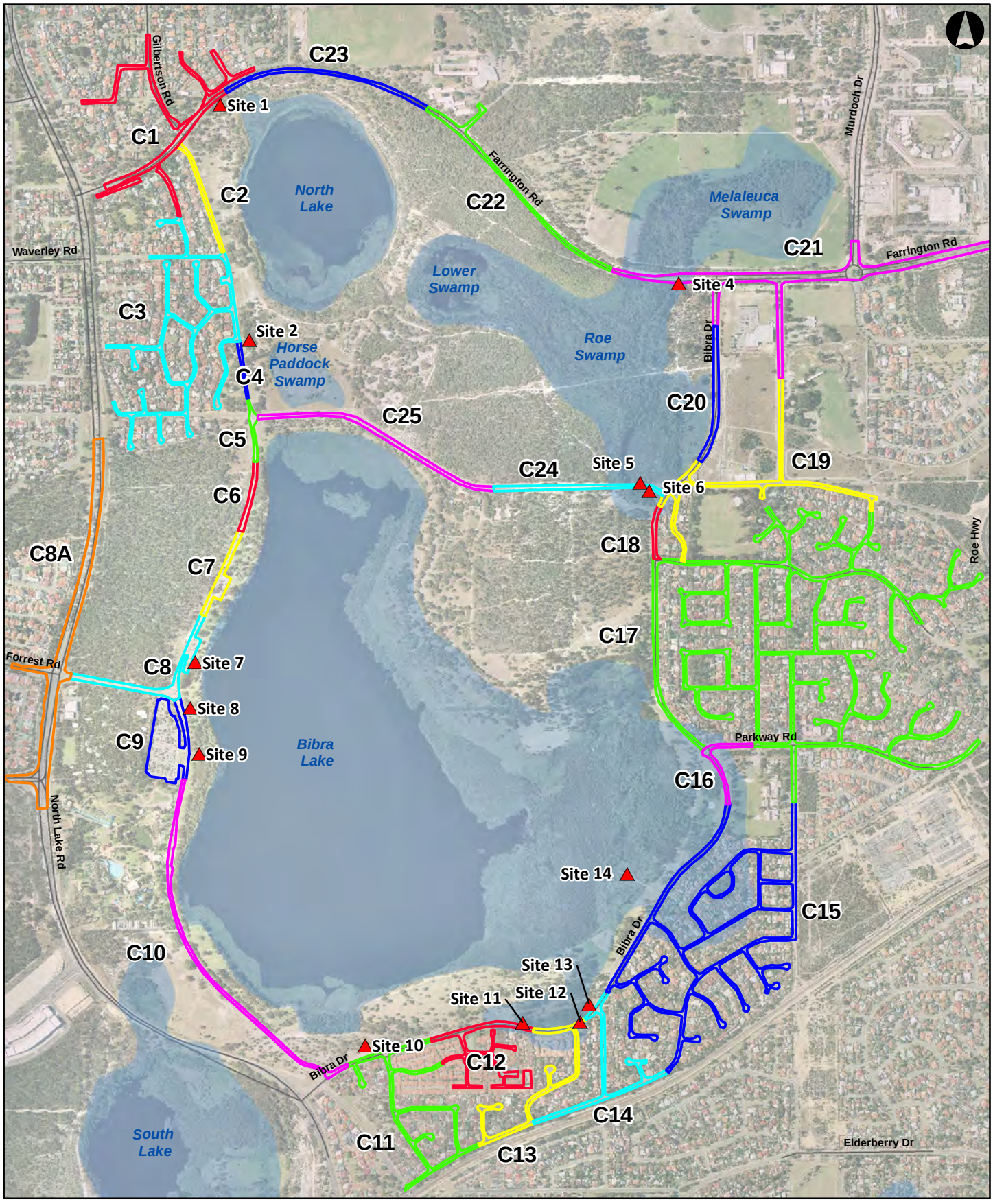

Stormwater Catchment Areas and Stormwater Outlets

South Metro Connect

Figure 5.7-2

0 100 200 300 400 500

Metres

1:16,000 (A4)

C1 - C25 Catchment ID

Stormwater Outlets

Wetlands

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5.7.1. Bibra Lake

5.7.1.1. Surface and Stormwater Quality

Water levels were found to vary seasonally in Bibra Lake, with some parts of the lake drying out in summer and refilling in winter. During the monitoring period, water in Bibra Lake was slightly alkaline with levels ranging from pH 8.17 to pH 8.75 (Figure 5.7-3). Although results were generally similar over all seasons sampled, pH values in February 2010 were higher than those measured in August 2010 and November 2009, likely because of increased algal photosynthetic activity (Lewis and McCutchan 2009). Increased photosynthetic activity is associated with the consumption of dissolved carbon dioxide, which leads to the production of hydroxyl ions (from chemical disassociation of water), which in turn leads to an increase in pH (Kinnear *et al.* 1997). This explains the slightly elevated pH results in February 2010 and is supported by the higher chlorophyll *a* levels obtained in Bibra Lake in February 2010 (which serves as an indicator of algal biomass).

The water was brackish with dissolved salt (measured as electrical conductivity, EC) ranging from approximately 1,300µS/cm in November 2009, 6,700µS/cm in February 2010 to 1,800 µS/cm in August 2010 (Figure 5.7-3). In February 2010, the lake water level dropped significantly and became isolated at the deeper western side of the lake. Increased temperature and insolation causing evaporative losses, no runoff inflows and reduced water level were likely the cause of the higher salts measured in February 2010.

The water in Bibra Lake appeared to be well oxygenated, with dissolved oxygen (DO) levels above 5mg/L during the monitoring period (Figure 5.7-3). The highest DO level was recorded in February 2010, likely due to the increased algal activity in the lake at this time. Diurnal sampling was not undertaken. However, as algal activity was high in February 2010, it is likely that the dissolved oxygen was much lower at night when photosynthetic activity ceased and only respiration occurred.

Biological oxygen demand (BOD, a surrogate measure of organic content in waters) was also measured to assist in understanding how much oxygen was available in the water column. In February 2010, BOD concentrations were 61mg/L and 69mg/L. The BOD suggests that the bacteria that break down the organic material will readily consume all of the oxygen in the water column. Lack of oxygen can have a number of effects on the system. The most obvious is the direct impact on the respiring biota beneath the lake's surface waters. Another is that the oxygen availability can influence the binding and releasing of contaminants and nutrients generally stored in lake sediments (Burkett 2005). This in turn can affect the amount and toxicity of contaminants in the water column. For instance, zinc is an essential element for plant metabolism, but can be toxic to algae and zinc's toxicity is increased by low dissolved oxygen concentration (Clarke *et al.* 1990).

Aluminium, arsenic, chromium, copper, lead and zinc concentrations were noted to be higher than guideline levels. These elements, in addition to hydrocarbons, were detected at their highest concentrations at sites close to a nearby car park (Figure 5.7-2). The presence of arsenic and zinc in the water suggests that pesticides and fertilisers used in the surrounding area may be transported into Bibra Lake (George *et al.* 1996).

Heavy metal concentrations in Bibra Lake were found to exceed guideline levels

Analysis of stormwater discharging into Bibra Lake indicates that this runoff contributes to the elements and total petroleum hydrocarbons (TPH) in lake waters. Aluminium, chromium, copper (Figure 5.7-4), lead (Figure 5.7-5) and zinc (Figure 5.7-6) were detected at elevated concentrations in all Bibra Lake drains. It was noted that drains on the western side of Bibra Lake (near the car park in Figure 5.7-2) contained comparatively higher TPH concentrations (Figure 5.7-7). Runoff into these drains is likely to be contributing to the poor water quality found in adjacent lake waters.

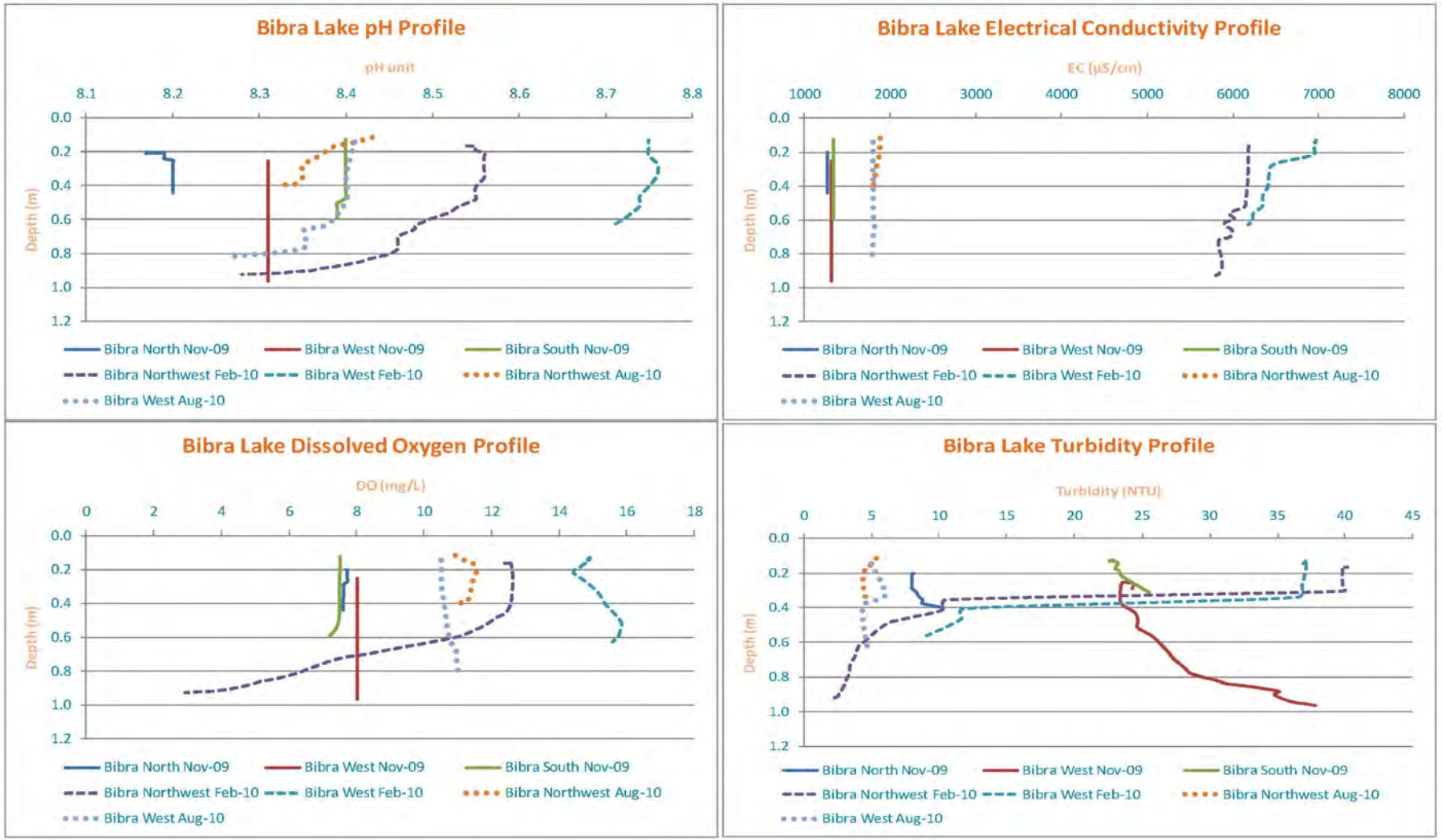
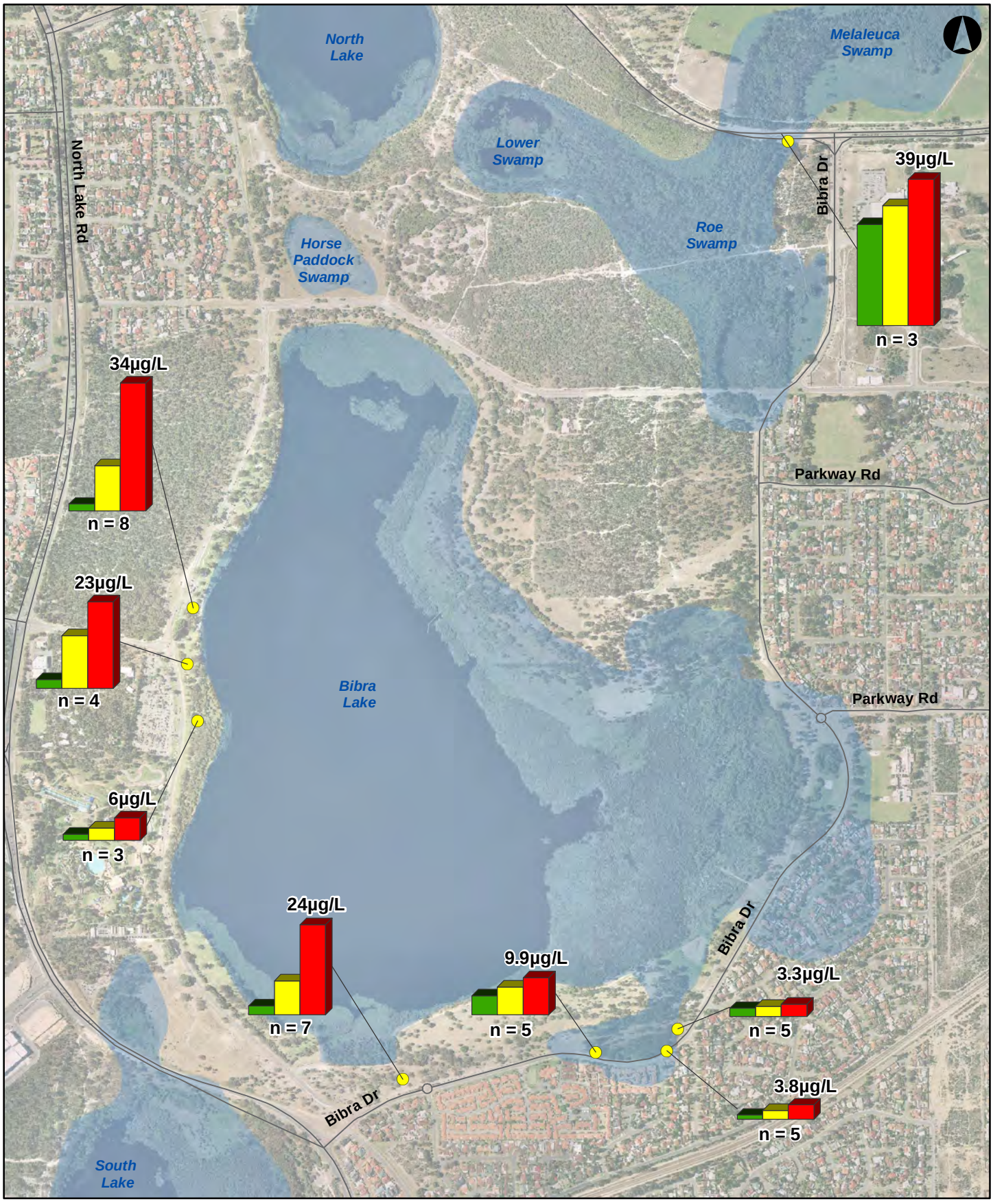


Figure 5.7-3: Water Profiles for Bibra Lake (late 2009 to mid 2010)



Copper Concentrations in stormwater entering Bibra Lake

South Metro Connect

Figure 5.7-4

0 100 200 300 400

Metres

1:13,000 (A4)

Stormwater Sampling Site

concentration

max

mean

min

n = number of samples above limit of reporting

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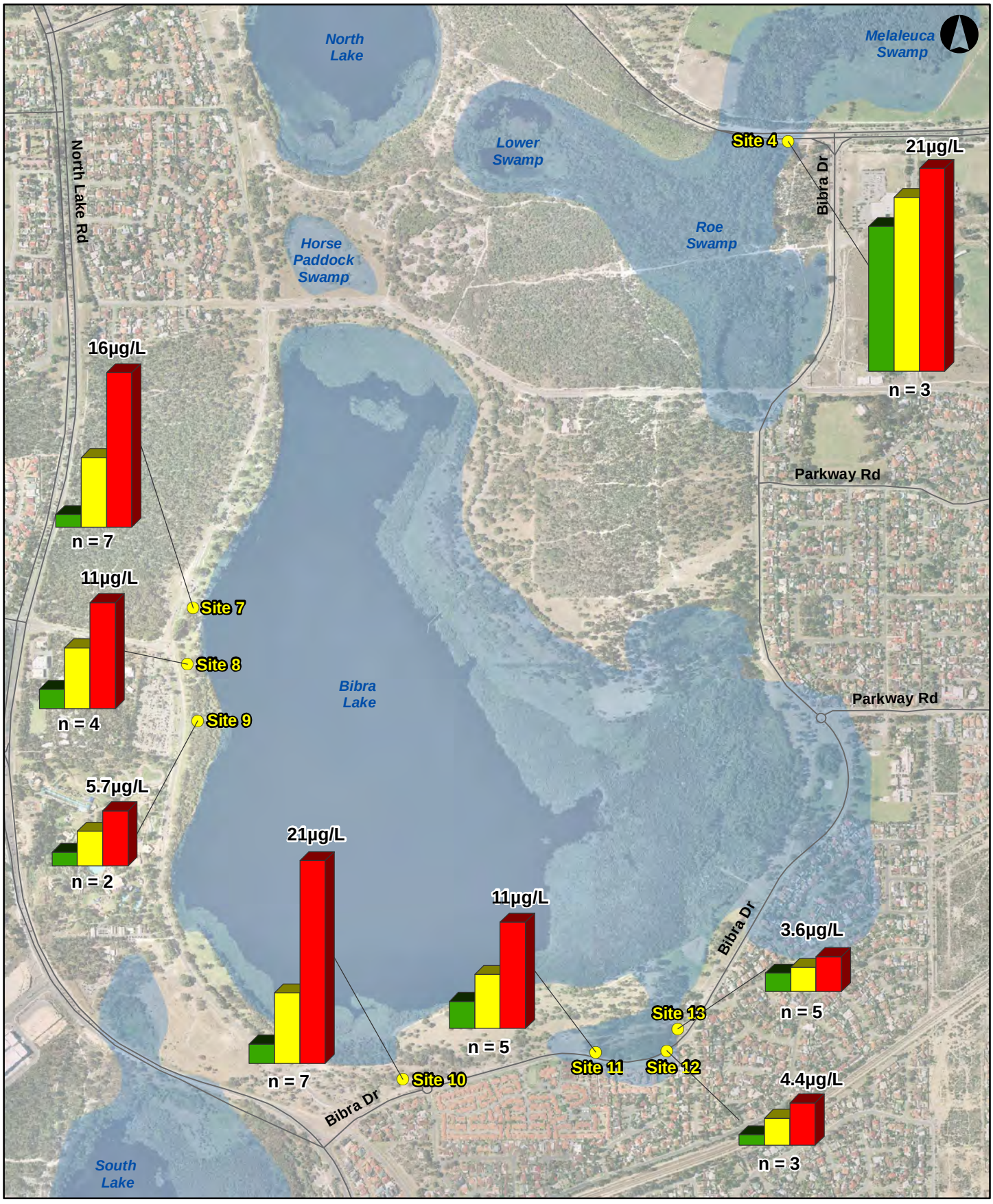


Lead Concentrations in stormwater entering Bibra Lake

South Metro Connect

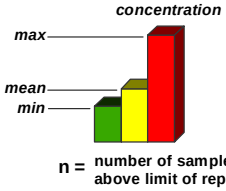
Figure 5.7-5

0 100 200 300 400

Metres

1:13,000 (A4)

Stormwater Sampling Site



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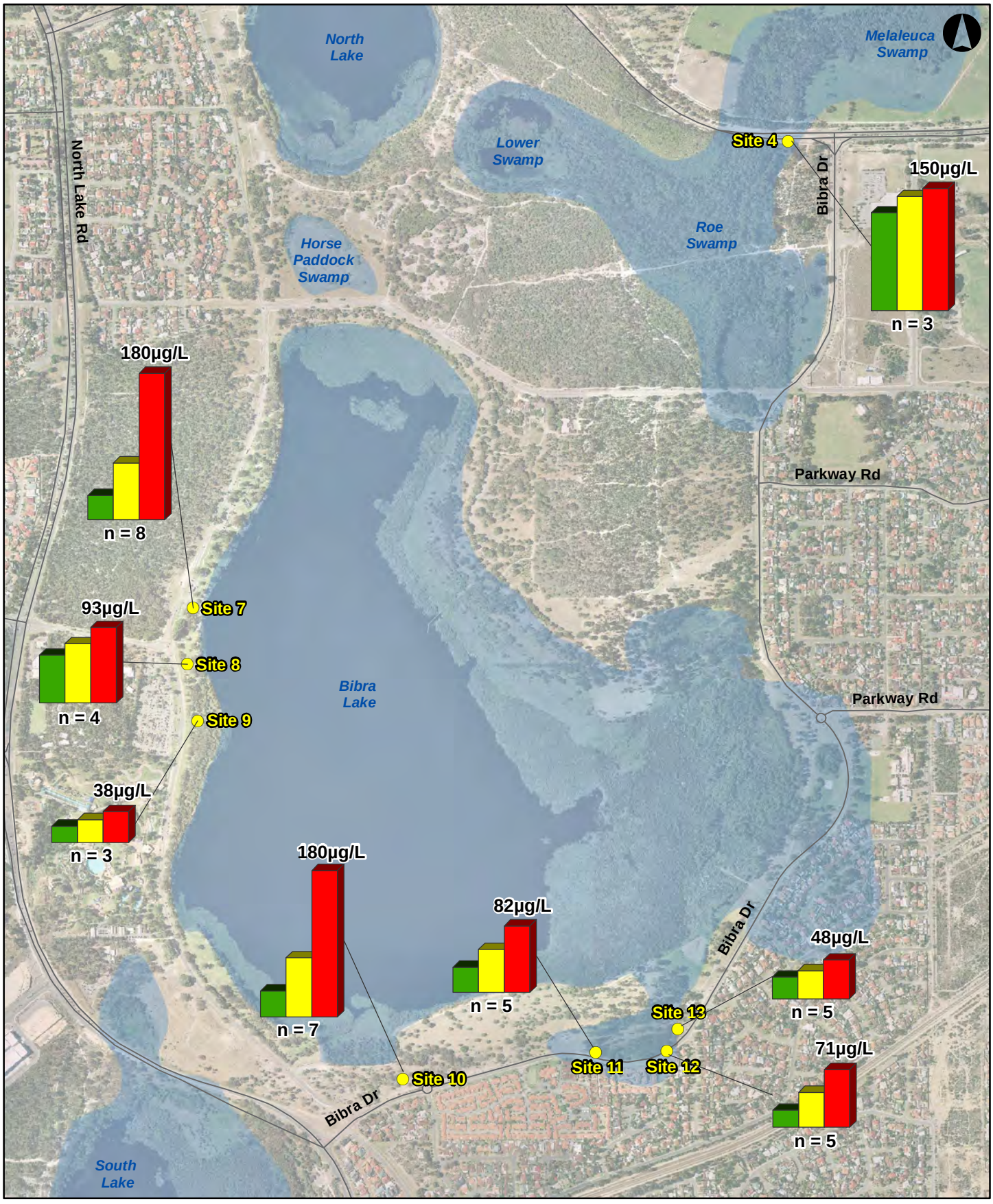

Zinc Concentrations in stormwater entering Bibra Lake

South Metro Connect

Figure 5.7-6

0 100 200 300 400

Metres

1:13,000 (A4)

Stormwater Sampling Site

concentration

max

mean

min

n = number of samples above limit of reporting

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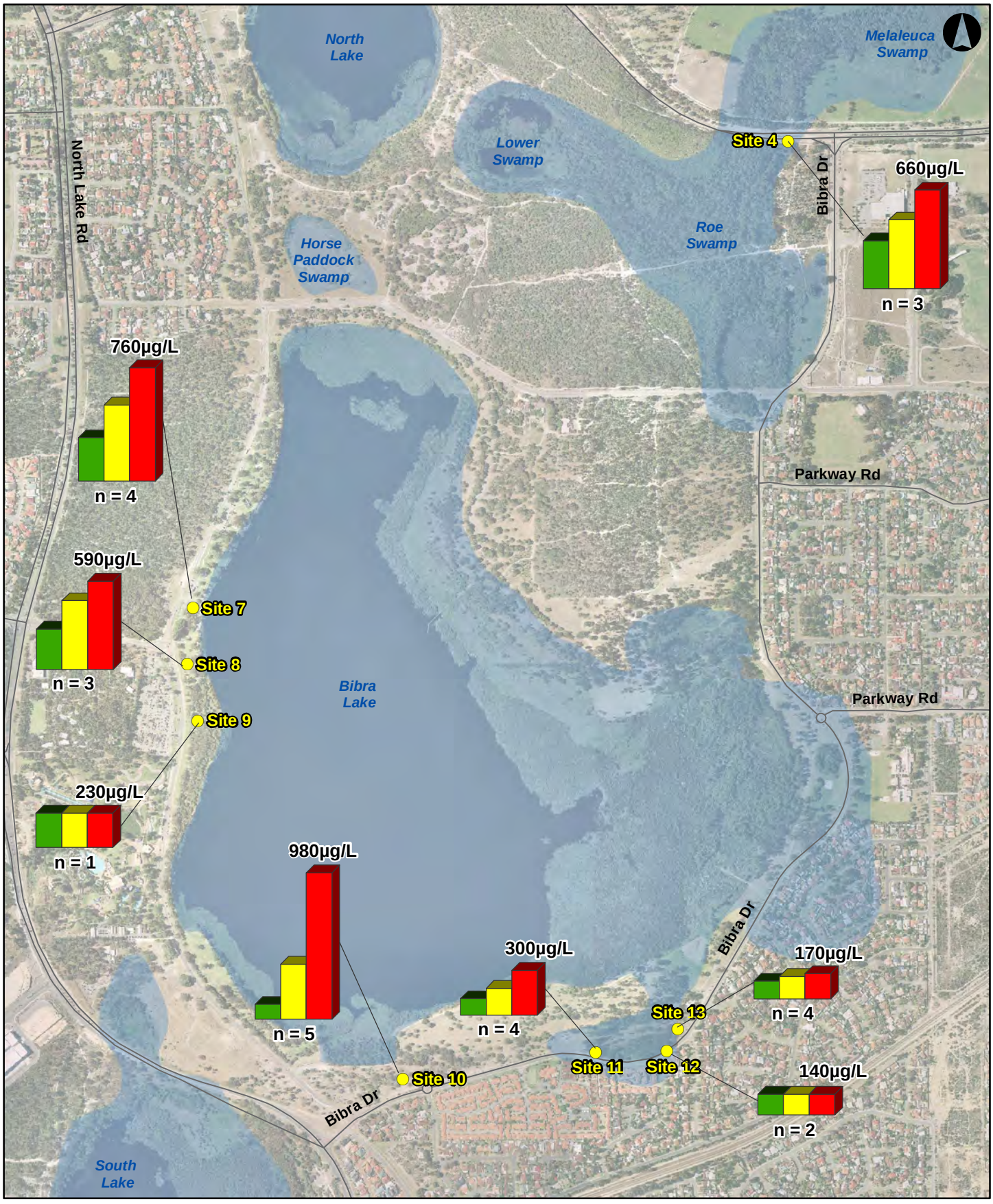

TPH Concentations in stormwater entering Bibra Lake

South Metro Connect

Figure 5.7-7

0 100 200 300 400

Metres

1:13,000 (A4)

Stormwater Sampling Site

concentration

max

mean

min

n = number of samples above limit of reporting

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Nutrient concentrations in Bibra Lake were found to exceed ANZECC guidelines

The presence of elements (such as zinc and lead) and hydrocarbons in stormwater is typical in urban drains, primarily due to the influence of vehicle traffic and built infrastructure. Concentrations of cadmium, chromium, lead, copper and zinc can be correlated with the volume of vehicle traffic on the road that drains to the stormwater drains (University of Wisconsin-Extension 1997). Vehicle wear and tear, which includes deterioration of brake pads and tyres, is a source of cadmium, copper, iron, lead and zinc in runoff. Lead concentrations in runoff may also be associated with historical exhaust fumes originating from vehicles fuelled with leaded petrol.

Galvanised gutters and downpipes in roofing are one of the main sources of zinc in urban runoff. Other sources of contaminants are paints and plated elements, which can contain cadmium and chromium. Considering the urbanised surroundings of the study area, these sources may explain the contaminants detected in Bibra Lake.

TPH detected in the surface water and stormwater runoff were primarily the longer chain fraction hydrocarbons, suggesting that the source may be diesel or heavy oil leaking from vehicles (Foulsham 2009). The existing car parking area at the western side of Bibra Lake represents a potential contributor of TPH input into Bibra Lake.

High concentrations of total phosphorus and total nitrogen, exceeding Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 guideline levels, were recorded in the surface water of Bibra Lake. These high nutrient concentrations were also found in the stormwater, which confirms that Bibra Lake receives nutrient inputs from runoff. This was also found in a study by Burkett (2005); however, that study indicated that the main controlling factor of nutrient concentrations in the water column is the nutrient release from the lake's sediment.

Seasonal changes in chlorophyll *a* (a method of estimating phytoplankton abundance) occurred with medium concentrations in November 2009, increasing to very high concentrations in February 2010 and then decreasing to low concentrations by August 2010, after winter conditions. This pattern was replicated in the phytoplankton abundance results.

Phosphorus is the major nutrient controlling cyanobacterial blooms in many regions of the world, although it can be nitrogen compounds. In contrast to planktonic algae, some cyanobacteria are able to escape nitrogen limitation by fixing atmospheric nitrogen. Thus, the availability of bioavailable nitrogen such as nitrate, ammonia or orthophosphate is an important factor in determining successional patterns and which algal species become dominant.

Within the study period, the total nitrogen to total phosphorus ratio (TN:TP) followed a similar pattern to chlorophyll *a* with ratios of 3:1 in November 2009 to 17:1 in February 2010. Based on data collected by City of Cockburn (1995-2009), nitrogen was identified as the main limiting factor during winter and spring months. As summer progresses, phosphorus becomes limiting to growth. The results obtained in this study were similar to long-term City of Cockburn results, with highest TN:TP ratios occurring during February 2010.

A low TN:TP ratio supports the development of cyanobacterial bloom. The optimum nitrogen to phosphorus ratio for cyanobacteria to bloom is 10 – 16:1 while for eukaryotic algae is 16 – 23:1 (Chorus and Bartram 1999). In spring, when nitrogen is the limiting factor, nitrogen-fixing algae such as species of cyanobacteria start to flourish and bloom as summer progresses.

5.7.1.2. Phytoplankton Assemblages

Phytoplankton was collected from Bibra Lake during the monitoring period in order to understand community composition changes through time. A characteristic pattern of seasonal succession of algal communities occurs in three distinct phases. In winter and spring, diatoms occur in association with rapidly growing small flagellates. In late spring and early summer, green algae flourish. In late summer and autumn, the predominant species are those which cannot easily be eaten by zooplankton, such as dinoflagellates, desmids and large yellow-green algae. In eutrophic and hypertrophic waters, cyanobacteria often dominate the summer phytoplankton. As winter approaches, in most water bodies, increasing turbulence and the lack of light during the winter leads to their replacement by diatoms (Chorus and Bartram 1999).

Algal blooms are frequently recorded in North and Bibra lakes

During November 2009, Chlorophyceae (green algae) were dominant in the lake, mainly *Mougeotia* and *Zygnemopsis*. These algae rarely occur in bloom, but are commonly found in patches in undisturbed wetlands (Chambers *et al.* 2005). Other Chlorophyceae such as *Chlamydomonas* and *Scenedesmus* were also present and these are odour causing species. Other potential taste and odour causing species were *Synedra* (diatoms), *Cryptomonas* (blue green algae), *Synechocyctis* (green algae) and *Euglena* (euglenoids). There were no potentially toxic species found during November 2009.

By February 2010, *Mougeotia* (green alga) and *Scenedesmus* (green alga) were not found in the phytoplankton, but other species such as *Kirchneriella* spp. (green algae), *Planktolyngbya contorta* and *Planktolyngbya subtilis* (blue-green algae) were abundant. Two potentially toxic cyanobacteria (blue-green algae), *Anabaena affinis* and *Anabaena spiroides*, were found. *Anabaena* spp. may produce a toxin called Anatoxin-a, which can cause respiratory arrest, liver and gastro-intestinal damage if consumed by vertebrates, including humans (Chambers *et al.* 2005). Other *Anabaena* species produce the cyclic peptide microcystin or saxitoxins, which can cause respiratory arrest and skin irritations that may lead to dermatitis (Chambers *et al.* 2005).

5.7.1.3. Sediment Quality

Elements in sediment were generally found in concentrations below ANZECC 2000 guideline levels. Lead was the only element detected above guideline levels in sediment from the north-east part of Bibra Lake (Figure 5.7-8). However, lead concentrations did not exceed the ISQG-High guideline value (ANZECC 2000) and is therefore unlikely to have a detrimental effect and does not warrant further investigation.

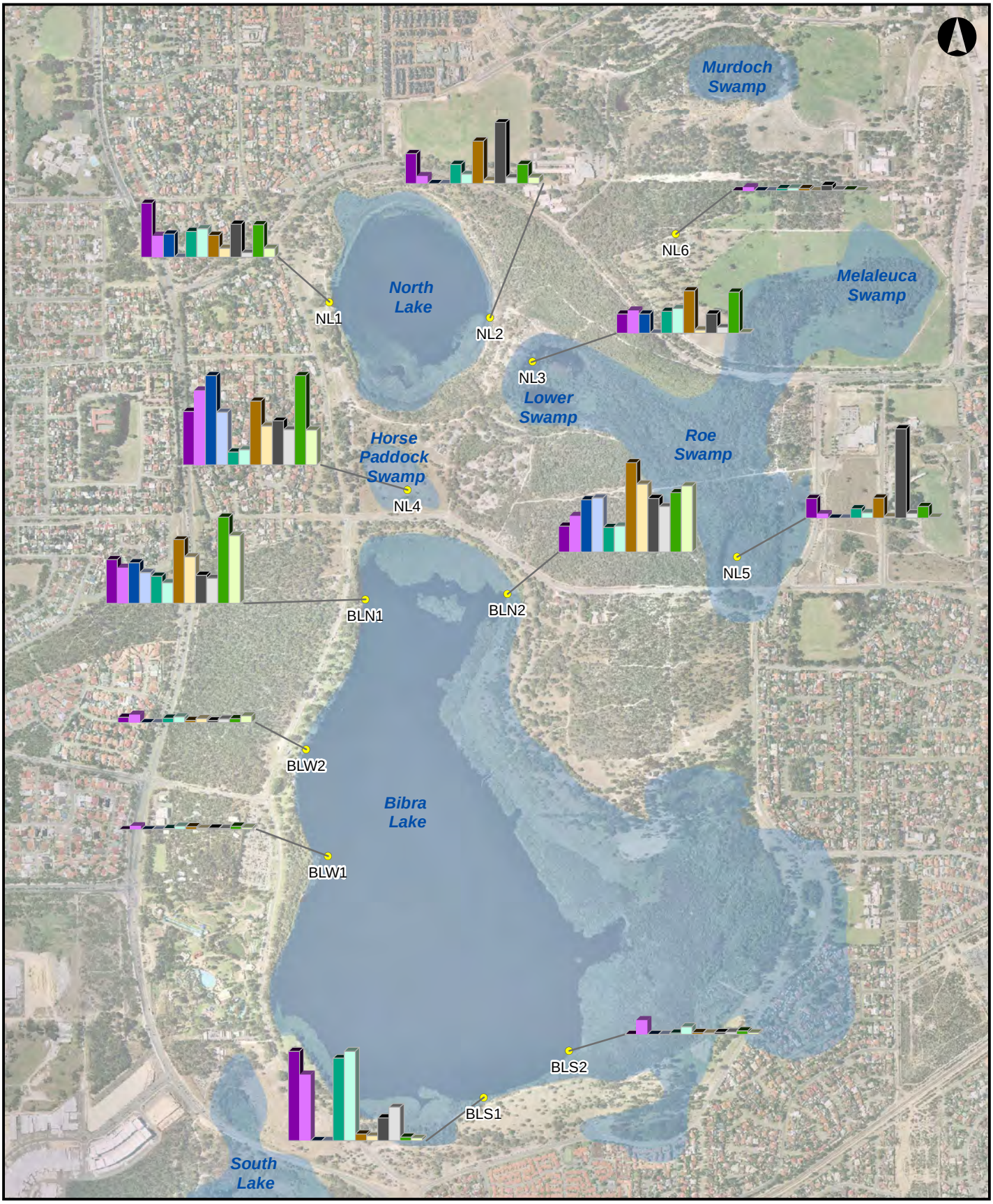
Elements in sediment were generally found to be below ANZECC guidelines

Aluminium and iron are naturally present in the sediment in high concentrations (DoW 2007a). Concentrations of elements in the sediment result from deposition of elements associated with suspended particles and geochemical precipitations from the water column. However, under certain conditions (e.g. acidic water, wetting-drying, aerobic-anaerobic), elements may be released back into the water.

High concentrations of arsenic and chromium detected in sediment in the south-west part of the lake (Figure 5.7-8) may be a result of past land uses in that area, such as landfill (EPA and Water Authority of Western Australia 1990). The northern part of the lake also contains higher concentrations of contaminants compared with the western and south-eastern parts of the lake (Figure 5.7-8).

Similar to surface water quality, TPHs were detected in sediment samples, mainly at the western side of Bibra Lake (Appendix I). Runoff containing petroleum products from vehicles may have contributed to TPH in lake sediments. Low concentrations of Polycyclic Aromatic Hydrocarbons (PAH) were detected in lake sediments, but not in surface water or stormwater. This suggests that there is no current measurable input of PAHs into the lake and PAHs present may be due to historical sources.

Sediments from the north and south-west sides of the lake contained a high proportion of total organic carbon, giving an indication of the capacity of the sediment to accumulate contaminants. Contaminants, such as PAHs and elements, are commonly bound to the organic content of the sediment, thereby reducing their availability to the biological and water compartments of the environment (DoW 2007a; Östman *et al.* 2005). High concentrations of lead detected in the north-eastern part of the lake indicates lead bound in the sediment, but not necessarily available. In contrast, at the west and south-east sides of the lake, the surface sediment generally contains less organic materials, so therefore contaminants may move through system compartments more rapidly than in other parts of the lake.



Wetland Sediment Quality

Arsenic, Cadmium, Chromium, Copper, Lead & Zinc Composition

South Metro Connect

Figure 5.7-8

0 100 200 300 400 500

Metres

1:16,000 (A4)

Datum: GDA94 Projection: MGA z50

	Arsenic	Cadmium	Chromium	Copper	Lead	Zinc
ANZECC/ARMCANZ 2000 - ISQG Low	20 mg/kg	0.5 mg/kg	80 mg/kg	65 mg/kg	50 mg/kg	200 mg/kg
Maximum Recorded Value	12 mg/kg	0.46 mg/kg	65 mg/kg	21 mg/kg	110 mg/kg	93 mg/kg
upper						
lower						

Sample Site

Wetlands

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5.7.2. North Lake

5.7.2.1. Surface and Stormwater Quality

Water levels of North Lake fluctuate greatly and the lake undergoes a drying and wetting cycle every year (Segal and Hale 2000). Davis and Rolls (1987) reported that North Lake retained water throughout the year, which is consistent with results in Section 5.6 from 1971 to1998 (refer to Figure 5.6-6). Conversely, North Lake dried up completely at the beginning of 2010. When North Lake was first sampled in November 2008 the water level was very low with a maximum water depth around 30cm. In February 2010, the lake was completely dry; it began to fill again in winter and reached a depth of around one metre in August 2010. This is consistent with the trend apparent at the end of the hydrograph that shows a drying phase in the last 12 years (Figure 5.6-6).

Water pH was near neutral with readings of pH 6.93 in November 2009 (Table 5.7-1). Historical data for North Lake indicated that the lake was neutral with a yearly mean of pH 7.1 ± 0.13 (Davis and Rolls 1987). Additionally, high pH levels of up to pH 9.7 were recorded during continuous cyanobacterial blooms in 1988–1989 (Balla and Davis 1993). However, during the August 2010 sampling event, the water was found to be acidic with levels ranging from pH 4.9 to pH 5.2 (Table 5.7-1).

Table 5.7-1: Water Profiles for North Lake (Late 2009 to Mid 2010)

Sampling Period	pH	EC (µS/cm)	DO (mg/L)	Turbidity (NTU)
November 2009	6.93	1700	6.2–8.3	4–9
August 2010	4.94–5.18	4600–4800	16–18	94–150

Consistent with the study undertaken by Davis and Rolls (1987), the lake's water was coloured during August 2010. The study suggested that this colouration (and slightly acidic pH levels) may be due to humic and fulvic acids, which are released during the decomposition of organic material.

The water in North Lake was brackish with dissolved salt (measured as EC) ranging from 1,700µS/cm in November 2009 to 4,800µS/cm in August 2010 (Table 5.7-1). The low water level and possible low dilution of surface salt is the likely reason that the readings were higher than the previous study by Davis and Roll (1987), which indicated that North Lake water stayed fresh throughout the year.

DO level was above the guideline level (5mg/L), with maximum daytime levels showing supersaturation (Table 5.7-1). The BOD level was below the guideline level (10mg/L) during both November 2009 and August 2010, indicating that oxygen in the water column is sufficient to support aerobic biological processes.

Stormwater runoff, where collectable, contained high concentrations of elements, nutrients and TPHs. The particular contaminants that are of interest for road runoff are displayed in Figure 5.7-4, Figure 5.7-5, Figure 5.7-6 and Figure 5.7-7. Surface water sampled from the western shore of North Lake recorded concentrations of aluminium, lead and zinc, exceeding guideline values. The presence of lead, in addition to traces of TPH, indicates that these pollutants are likely to have entered the lake via runoff from nearby sealed surfaces. Elevated zinc levels suggest that its use in galvanised building products from adjacent residential areas may also be a source via runoff into the lake.

Total phosphorus concentrations recorded in surface water samples from North Lake in both November 2009 and August 2010 were higher than guideline levels, as were some of the total nitrogen and chlorophyll *a* levels. This is consistent with measurements in North Lake in 1985 and 1986 (Davis and Rolls 1987).

The pollutants in North Lake have been identified as originating from urban runoff, agricultural runoff and groundwater (Bayley *et al.* 1989). Concentrations of pollutants in urban runoff are likely to reach their peak during the beginning of the rain season, when contaminants that have accumulated on the road surface are flushed by rain into the receiving water body. Agricultural runoff is mainly due to the application of fertiliser to the soil. A study by Bayley *et al*. (1989) identified that a large proportion of fertiliser applied on the area east of North Lake was leached into drainage leading to North Lake.

Segal and Hale (2000) found that, through a combination of microbiological processes and aerobic and anaerobic conditions, phosphorus, ammonium and nitrate are released from sediment when North Lake receives water. Ammonium and nitrate are only released from the lake sediment during the first flush (Segal and Hale 2000). Burkett (2005) suggested that most of the annual phosphorus load is retained in the sediment. However, under low oxygen and/or high pH conditions, sediment-bound phosphorus would be readily released back into the water column.

5.7.2.2. Phytoplankton Assemblages

In November 2009, *Mougeotia* (green algae) was found to be the dominant genera in the lake, similar to Bibra Lake's algal assemblage. Other genera such as *Fragilaria* (diatom) and *Chlamydomonas* sp. (green algae) were abundant in North Lake while *Naviculla* (diatom), *Cosmarium* (green alga) and *Zygnemopsis* (green alga) were abundant in boundary areas of North Lake.

Several algae known to have the potential to cause taste and odour problems were also present in North Lake, such as *Synedra* (diatom), *Ankistrodemus* (green alga), *Chlamydomonas* (green alga), *Scenedesmus* (green alga), *Pseudanabaena* (blue-green alga), *Synechocytis* (blue-green alga) and *Euglena* (euglenoid). In addition to these algae, one potentially toxic blue alga (*Anabaena aphanizomenioides*) was found in the middle and boundary areas of the lake.

Stormwater drains were found to contribute to heavy metals and hydrocarbons into North and Bibra lakes.

Concentrations of heavy metals and some nutrients in North Lake were found to exceed guideline levels. Lead and hydrocarbons were also present

Heavy metal concentrations were found to be elevated in Horse Paddock and Roe swamp sediments

In August 2010, assemblages were less diverse than at other sampling events and potentially toxic species were not found. However, potential odour causing species were present, such as *Synechocystis* spp. (blue-green algae), *Glenodinium* spp. (dinoflagellates) and *Euglena* spp (euglenoids). Algae such as *Trachelomonas* (euglenoid) are known to cause a brown water colouration when in bloom (Chambers *et al.* 2005). *Trachelomonas* was dominant and 'in bloom' (the chlorophyll *a* concentration was 175µg/L) during August 2010 and would have also contributed to the water colouration, along with leachates from soil humus.

5.7.2.3. Sediment Quality

Sediments in North Lake contained elevated concentrations of lead and detectable TPH fractions. Lead was measured in concentrations above the ISQG-Low guideline levels on the eastern side of North Lake (Figure 5.7-8). However, lead concentrations did not exceed the ISQG-High guideline value (ANZECC 2000) and it is therefore unlikely to have a detrimental effect and does not warrant further investigation.

Elevated concentrations of other elements in sediments, such as aluminium and iron, are considered to be naturally occurring (DoW 2007a). TPH presence in the sediment indicates low level man-made contamination that can be associated with vehicle use on nearby roads or past land uses.

The longer chain TPH fractions (C_{15}–C_{28} and C_{29}–C_{36}) found in North Lake sediments may have accumulated over a period of time, due to the tendency of the larger molecular weight constituent to absorb to sediment and remain relatively immobile (Agency for Toxic Substances and Disease Registry 1999).

5.7.3. Surrounding Sumplands (Roe Swamp, Murdoch Drain, Melaleuca Swamp and Horse Paddock Swamp)

The water depths in Roe Swamp, Murdoch Drain, Melaleuca Swamp, Horse Paddock Swamp and surrounding sumplands were very low or completely dry during the 2009–2010 study period; consequently only sediment samples were collected (Figure 5.7-1). Elevated concentrations of aluminium and iron were measured in sediments, which are considered to be naturally occurring. Elements such as chromium, copper, nickel, lead and zinc tended to be higher in Horse Paddock and Roe Swamps than the other sumplands (Figure 5.7-8). These sites are in close proximity to the road and may receive road runoff, accounting for the concentrations.

Lead concentrations above the guideline level at Horse Paddock Swamp and Roe Swamp may be attributed to high total organic content of the sediment. However, at Roe Swamp in August 2010, high concentrations of lead and zinc were recorded after adjustment for the organic carbon content of the sediment. This indicates that lead and zinc were not bound in the sediment and may be the result of some recent input of lead and zinc, which could be due to stormwater runoff from nearby sealed surfaces (refer to Figure 5.7-5 and Figure 5.7-6).

Low levels of some organochlorine pesticides were detected in Horse Paddock Swamp and Roe Swamp surface sediments, although not detected in the bed sediments of other waterways. Traces of dichlorodiphenyldichloroethylene (DDE) were found in sediment collected from Horse Paddock Swamp (Appendix I). DDE is a breakdown product of dichlorodiphenyltrichloroethane (DDT), an organochlorine pesticide banned in Australia since 1987 (DEWHA 1997). DDE half-life is recorded to be more than 20 years in temperate region soils (Agency for Toxic Substances and Disease Registry 2002). Traces of trans-chlordane were also detected in sediments from Horse Paddock Swamp and Roe Swamp (Appendix I). Chlordane was once registered as insecticide, termiticide, wood preservative and herbicide; however, its use was discontinued in 1997 (Australian Pesticide and Veterinary Medicines Authority n.d.). The trace concentrations of trans-chlordane found in the sediment may also be due to historical use of the pesticide, since chlordane potentially persists in soil for more than 20 years (Agency for Toxic Substances and Disease Registry 1997).

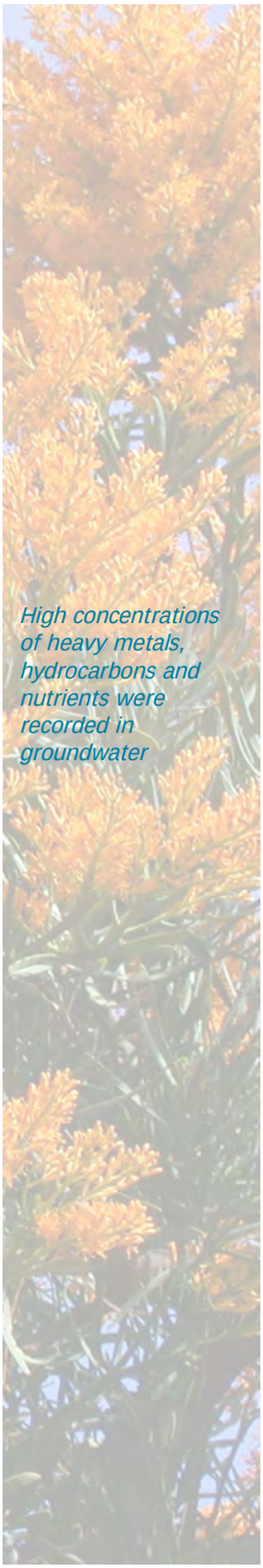
Pesticide constituents were detected in Horse Paddock Swamp and Roe Swamp sediments

5.7.4. Groundwater Quality

Groundwater samples were collected from a number of bores/piezometers around the wetlands, in order to determine baseline quality (Figure 5.2-3 and Figure 5.2-4). Groundwater contains a range of natural chemical species as well as those resulting from anthropogenic activities. Groundwater in the superficial aquifer is mostly fresh with salinities ranging from about 250 to 1,000 parts per million (ppm or milligrams per litre, mg/L). Groundwater in the North and Bibra lakes area can be defined as fresh with dissolved salt contents ranging from less than 150 to 1,000mg/L at most sites. Groundwater with dissolved salt content of 1,000 to 2,000mg/L was recorded in the wetland area south-west of Bibra Lake (Appendix I).

The source waters that enter wetlands are generally of low salt content, within the range of 89 to 260mg/L, while the groundwater in close proximity to lake and wetland areas had a slightly higher salt content, 150–330mg/L. The highest salt content was found in the groundwater sampled in the impoundment/water storage area, where salt concentrations varied from 440 to 1700mg/L. During the study period, there was little evidence of salt accumulation or export (Appendix D; Appendix I). Low groundwater flushing rates during the study period could be attributed to the low rainfall recorded in 2010 with a very small increase in the groundwater level, particularly during early winter (Appendix D).

The pH values in groundwater in the North and Bibra lakes area were generally between pH 5.4–7.2. In the source or water/delivery zone, levels varied from slightly acidic to close to neutral (pH 5.4–6.8). In the wetlands, groundwater pH fluctuated with time, lying at approximately pH 7, but increased after each rainfall event and after sediment flushing. In the impoundment zone/water storage area pH levels were slightly higher than the other two hydrological zones. The pH level in this zone was approximately neutral to slightly alkaline (pH 6.7–7.2).



High concentrations of heavy metals, hydrocarbons and nutrients were recorded in groundwater

Nested piezometers were installed at locations within the study area, to determine if there were detectable vertical impediments to groundwater movement. Groundwater in the deeper piezometers exhibited consistently higher pH readings over the monitoring period. The greatest difference occurred in April 2010, when the shallow piezometer recorded pH 5.8 and the deeper piezometer recorded pH 7.5. Groundwater in the shallow bores was slightly acidic, ranging between pH 5.4 and pH 6.6; while the groundwater in deeper bores was neutral, ranging between pH 6.6 and pH 7.6 (Appendix D).

Aluminium and iron were detected in high concentrations in the groundwater. These elements are naturally occurring at elevated concentrations in the sediment and may be released into groundwater. Iron is present due to the hydrolysis and oxidation of dissolved ferrous iron and the presence of organic acids. Groundwater from the upper portions of the unsaturated aquifer contain concentrations of total dissolved iron generally in excess of 1mg/L and may be greater than 5mg/L in discharge zones of wetlands (Cargeeg *et al.* 1987). The current study found similar results with the concentration of total dissolved iron generally less than 1mg/L. However, concentrations in excess of 1mg/L were recorded in the delivery zone (eastern side of North and Bibra lakes, Figure 5.2-3 (Appendix I)).

Arsenic was detected in elevated concentrations at one site at the margin of Murdoch Drain (Figure 5.7-8) and in lower concentrations at several other sites (Appendix D; Appendix I). The low concentration of arsenic found in the groundwater may be due to adsorption by hydrous iron oxide (Hem 1985), given that the groundwater and the surrounding wetland sediment contain high levels of iron.

Chromium in groundwater was elevated at one of the bores, but generally undetected at most of the sites. Zinc was found in elevated concentration at a site close to North Lake Road (Figure 5.7-6) and was found consistently at other sites throughout the monitoring periods. It is likely that chromium and zinc concentrations may originate from stormwater runoff from urban catchments that eventually leach out into the groundwater. This is supported by elevated concentrations of chromium and zinc in runoff from drains in the Bibra Lake and North Lake areas (Appendix I).

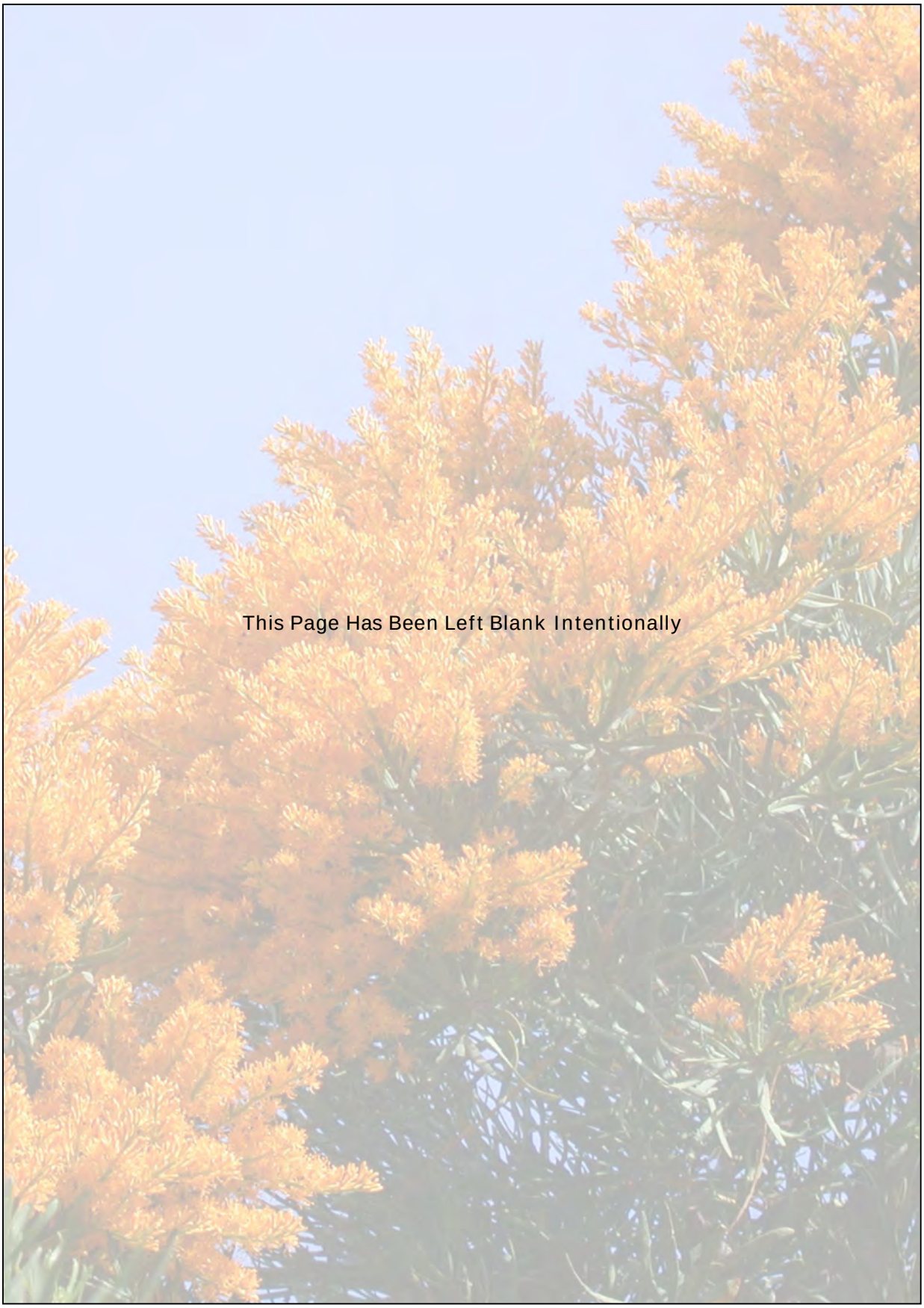
Lead was found in detectable concentrations in groundwater both close to and far from roadways. Elevated concentrations of hydrocarbons were recorded in the groundwater at different sites in the study area. The majority of the sites were within or close to urban and industrial areas (Appendix D; Appendix I).

The majority of nitrogen measured in groundwater was in the form of nitrate, which may originate from septic tank leakage and/or fertiliser use (Burkett 2005). The concentration of nitrate ions in groundwater commonly exceeds 0.1mg/L within an urban area (Cargeeg *et al.* 1987) and less outside it, depending on catchment use. The highest nitrate concentration (and elevated total nitrogen) recorded in this study was 3.2mg/L at a bore in the groundwater delivery zone situated up gradient from the central wetlands zone (Appendix I).

5.7.5. Conclusion

The project area and surrounds have been modified from a landscape dominated by agriculture, vegetated surfaces and other undeveloped areas in the mid-1970s to mainly residential developments prevalent today. As a result of past and current land use practices which generate contaminants, the wetlands are not pristine. Elevated concentrations of heavy metals, hydrocarbons and nutrients were recorded in the groundwater, stormwater, surface water and wetland sediment within the project area. Algal blooms were recorded in the lakes during the study period and previous studies have frequently reported blooms dominating large areas of North and Bibra lakes.

As a result of past and current land uses which generate contaminants, the wetlands are not pristine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5.8. Flora and Vegetation

The Commonwealth of Australia and State of Western Australia regulate potential impacts on flora in regards to vegetation clearing as well as declared rare, priority and threatened species. Applicable legislation and regulations are described in Section 4. In addition to conservation significant species, flora can also be considered to be important if they are significant either regionally and/or in the Perth metropolitan region, or if they are of other interest.

The Commonwealth and State also regulate impacts on vegetation communities in regards to locally and regionally significant vegetation, Threatened Ecological Communities (TECs) and Priority Ecological Communities (PECs). TECs are biological assemblages that are subject to threatening processes and are therefore protected under the *EPBC Act.* The *EP Act* provides protection for State TECs not listed on the Commonwealth register. Environmentally Sensitive Areas, which include Bush Forever sites, are also protected under this State legislation by way of the Environmental Protection (Environmentally Sensitive Areas) Note 2005.

This section of the PER also considers the distribution of introduced flora (weeds) and the plant disease *Phytophthora cinnamomi*, which present a potential threat to floral values of the project area. The section ends with a discussion of the Groundwater Dependent Ecosystems within and surrounding the project area.

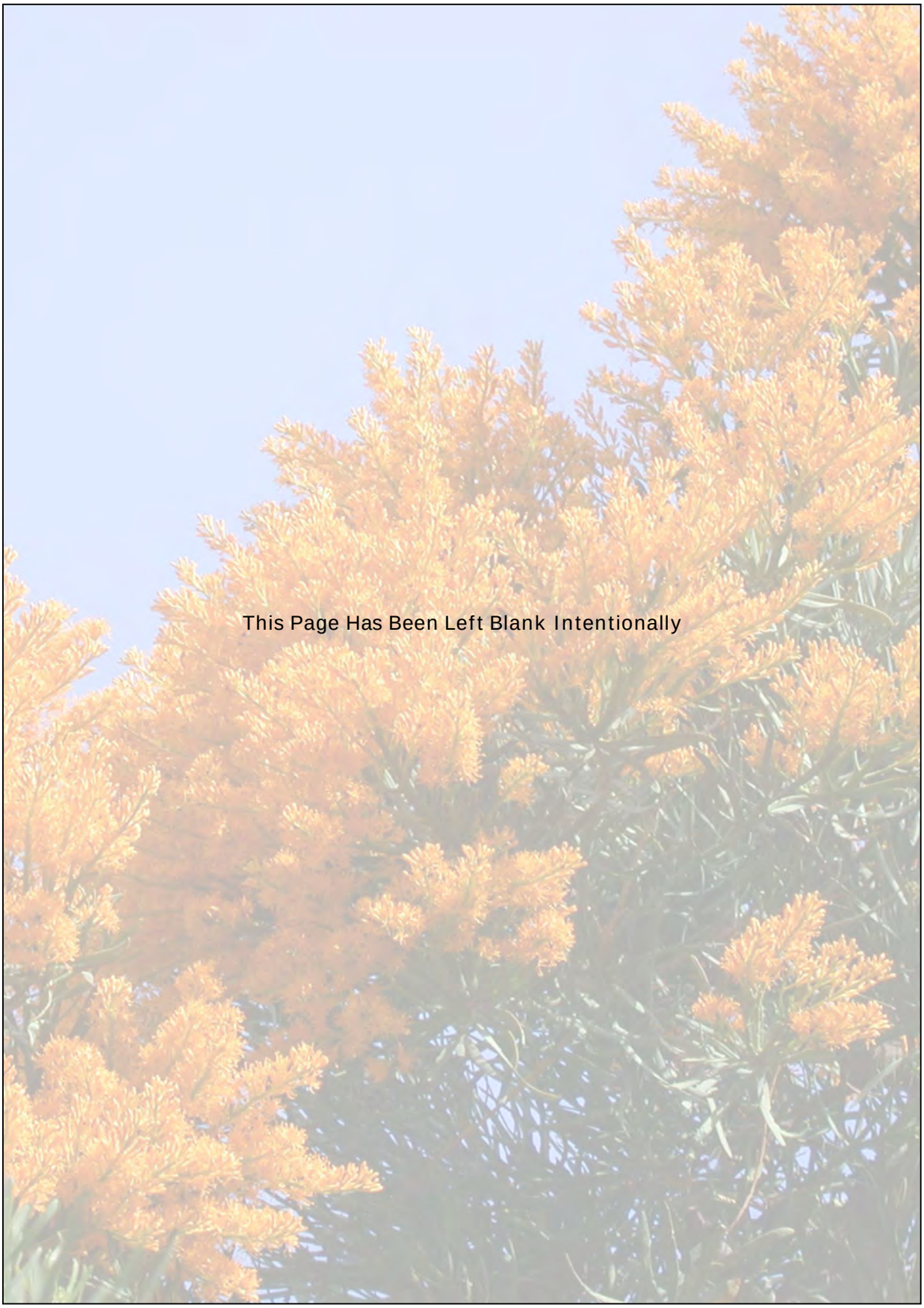
5.8.1. Protected Flora Species of the Region

The potential for significant flora and vegetation values to be supported by the project area was determined by a search of the DEC Threatened and Priority Flora Database. It identified the previous occurrence of 18 Priority Flora species within the vicinity of the project area (Table 5.8-1), including five Declared Rare Flora (DRF) and 13 Priority species.

Table 5.8-1: Declared Rare and Priority Flora Potentially Occurring in the Local Area by Jurisdiction

Species	Conservation Code		Habitat	Flowering Period	Likelihood of Occurring in Project Area
	Commonwealth	State			
Caladenia huegelii	Endangered	Declared Rare	Grey or brown sand, clay loam	September to October	Likely (but not found)
Darwinia foetida (formerly known as *Darwinia* sp. Muchea (B.J.Keighery 2458))	Critically Endangered	Declared Rare	Grey, brown, black sand or peaty sandy clay, winter wet lowlands	July to November	Unlikely
Drakaea elastica	Endangered	Declared Rare	White or grey sand. Low-lying situations adjoining winter-wet swamps	October to November	Likely (but not found)
Drakaea micrantha	Vulnerable	Declared Rare	White-grey sand	September to October	Unlikely
Lepidosperma rostratum	Endangered	Declared Rare	Peaty sand, clay	May to August	Possible (but not found)
Acacia lasiocarpa var. *bracteolata* long peduncle variant (G.J. Keighery 5026)	Not applicable (n/a)	Priority 1 (P1)	Grey or black sand over clay, swampy areas, winter wet lowlands	May to August	Possible
Hydrocotyle striata	n/a	P1	Clay, springs	September to November	Unlikely
Bossiaea modesta	n/a	Priority 2 (P2)	Soils derived from granite, damp areas close to stream	October to December	Unlikely
Byblis gigantea	n/a	P2	Sandy-peat swamps, seasonally wet areas	September to January	Possible
Angianthus micropodioides	n/a	Priority 3 (P3)	Saline sandy soils, river edges, saline depressions, claypans	November to February	Unlikely
Jacksonia gracillima	n/a	P3	Wetlands, winter wet flats, grey peaty sand	October to November	Recorded in project area
Phlebocarya pilosissima	n/a	P3	White or grey sand, lateritic gravel	August to October	Unlikely
Stylidium longitubum	n/a	P3	Sandy clay, clay, seasonal wetlands	October to December	Possible
Dodonaea hackettiana	n/a	Priority 4 (P4)	Sand, outcropping limestone	July to October	Recorded in project area
Microtis quadrata	n/a	P4	Wetlands, sandy clay/loam, peaty soil	unknown	Possible
Anthotium junciforme	n/a	P4	Sandy clay, clay, winter-wet depressions, drainage lines	November to March	Unlikely
Hydrocotyle lemnoides	n/a	P4	Swamps	August to October	Unlikely
Jacksonia sericea	n/a	P4	Calcareous and sandy soils	December to February	Possible

Source: DEC DRF and Priority Flora search conducted on 22 July 2009 (AECOM 2009a)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434 species of flora from 244 genera were recorded within the project area

No flora species listed under the EPBC Act or as State DRF were recorded

Six species of State Priority Flora were recorded

5.8.2. Protected Flora of the Project Area

Detailed flora and vegetation surveys across the project area were conducted in spring 2009 and spring 2010, in accordance with Level 2 surveys as described in Guidance Statement No. 51, *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004a).

A total of 434 species from 244 genera and 80 families were recorded within the project area from the baseline assessment and subsequent seasonal monitoring events. Families with the highest representation were Myrtaceae, Fabaceae, Asteraceae and Poaceae, a floristic composition typical for the Swan Coastal Plain.

An analysis of habitat preferences, location and previous records indicated that three DRF species have the potential to be supported by the project area. These species are the Grand Spider Orchid (*Caladenia huegelii*), Glossy-leaved Hammer Orchid (*Drakaea elastica*) and *Lepidosperma rostratum*. Ground searches for DRF were carried out via foot traverses using a gridding technique to examine areas of native bushland determined to be suitable habitat. Monitoring quadrats were established within the project area and assessed for the purposes of seasonal flora and vegetation monitoring. Details of survey methodology and results are provided in Appendix K.

5.8.2.1. Significant Flora

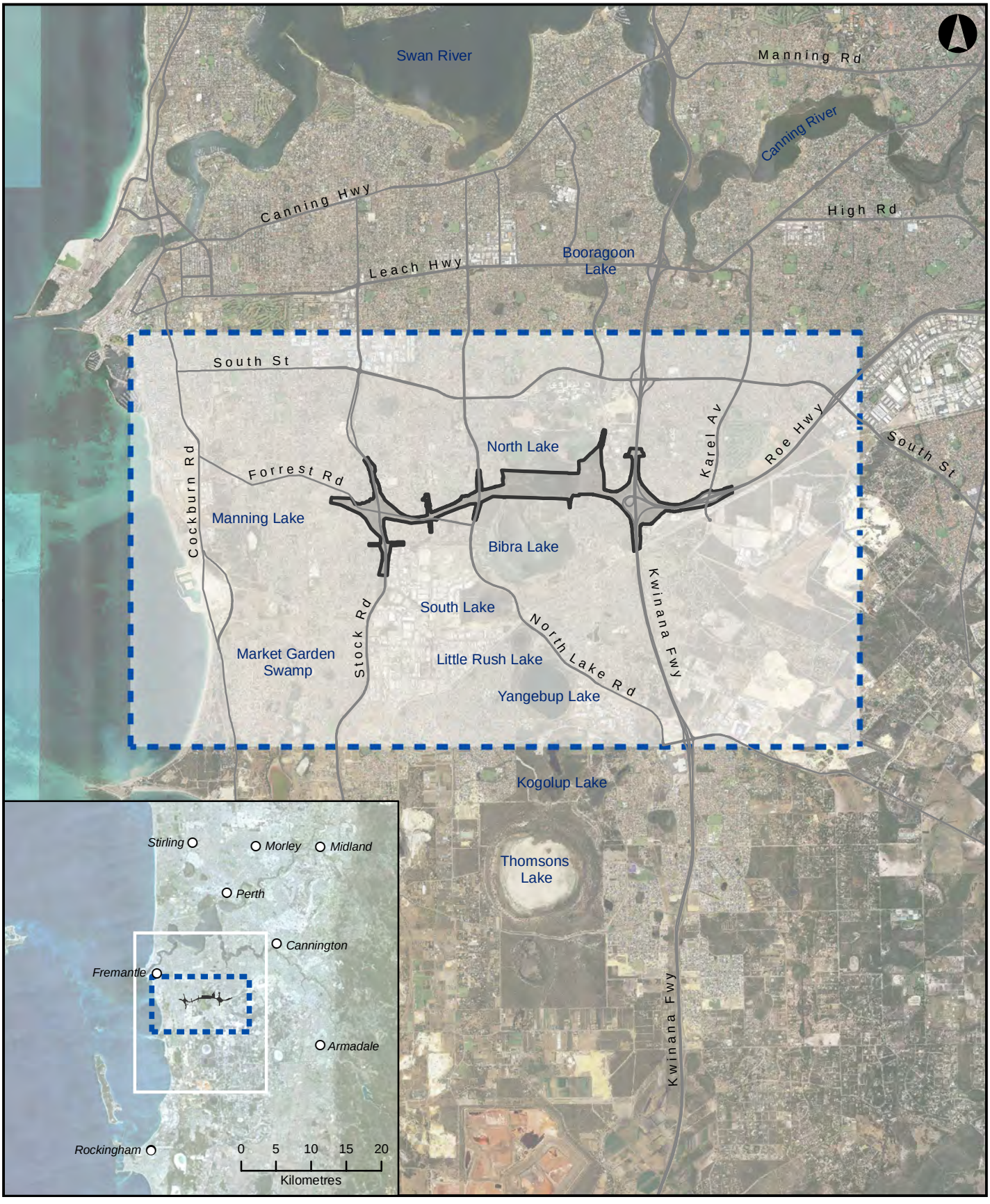
The project area was surveyed for significant flora within two extents: a detailed study area and a local study area in the surrounding region. Figure 5.8-1 defines these study areas. Within these areas, significant flora species were searched for, to gather a regional perspective of local populations. Flora can be considered significant for a range of reasons, including:

- State and/or Commonwealth conservation significance;
- Regionally significant and/or significant in the Perth metropolitan region; and
- Other interest (e.g. new species).

5.8.2.2. Flora of Conservation Significance

None of the five flora listed in the *EPBC Act* that have the potential to occur within the project area (Table 5.8-1) were recorded during the 2009 or 2010 surveys. *Calothamnus rupestris* (P4) was recorded from roadside plantings during the survey; however, it does not occur naturally in the area. No species listed as DRF pursuant to the *WC Act* were recorded during the 2009 and 2010 surveys; however six species of State Priority Flora were recorded within the project area. These species included:

- *Dampiera triloba* (P1);
- *Tetraria* sp. *Chandala* (P2) (G.J.Keighery 17055);
- *Cyathochaeta teretifolia* (P3);
- *Jacksonia gracillima* (P3);
- *Eryngium pinnatifidum* subsp. *palustre* (ms) (P3); and
- *Dodonaea hackettiana* (P4).



Flora and Vegetation Study Area

South Metro Connect

Figure 5.8-1

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Kilometres

1:100,000 (A4)

Datum: GDA94 Projection: MGA z50

Local Study Area (LSA)

Detailed Study Area (DSA)

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Nine species were identified as significant flora of the Perth metropolitan region

5.8.2.3. Regionally Significant Flora

Two species of regional significance were identified during spring surveys in 2009 and 2010: *Gastrolobium ebracteolatum* and *Ixiolaena viscosa*. *G. ebracteolatum* is significant, as the type of damp habitat that it is associated with is rare on the Swan Coastal Plain. *Ixiolaena viscosa* occurs in dampland sections of basin wetlands. The presence of *I. viscosa* indicates that vegetation within the project area is more intact and in better condition than other wetlands on the Swan Coastal Plain (Keighery 2010). For further details on each of the individual species of significance recorded within the project area, refer to Appendix K.

5.8.2.4. Significant Flora of the Perth Metropolitan Region

One hundred and seventy eight vascular plant taxa (species, subspecies or varieties) recorded on the Swan Coastal Plain are of particular interest, as they are (locally) rare, poorly known, restricted in distribution or have some other distinctive feature (WAPC 2000a).

During the 2009 and 2010 surveys, nine species were identified as significant flora of the Perth metropolitan region. The categories of significance considered relevant for each of the significant flora are listed in Table 5.8-2. *Chamelaucium uncinatum* is not considered to be a significant species in relation to this project, because it was recorded from roadside plantings and does not occur naturally in the area.

Table 5.8-2: Significant Flora of the Perth Metropolitan Region

Species	State Conservation Code	Commonwealth Significance Code
Agonis flexuosa	n/a	r, s
Chamelaucium uncinatum	n/a	r, s
Conostephium minus	n/a	s, e
Cyathochaeta teretifolia	P3	p, s
Dodonaea hackettiana	P4	p, s, e
Eryngium pinnatifidum subsp. *palustre* ms	P3	n/a
Hibbertia cuneiformis	n/a	r, s
Lechenaultia linarioides	n/a	p
Melaleuca lanceolata	n/a	d, s

Source: WAPC 2000a.

r – populations at the northern or southern limit of their known geographic range

s – significant populations (applies to DRF and priority taxa)

p – considered to be poorly reserved (applies to DRF and priority taxa)

e – taxa endemic to the Swan Coastal Plain

d – populations disjunct from their known geographic range

n/a – not applicable

5.8.2.5. Flora of Other Interest

Some flora, although not necessarily of conservation significance, are of interest and can represent important floristic value. Four species of interest requiring taxonomic review were recorded within the project area. These species have generally been classified as complex variances of the *Lepidosperma squamatum* group (Barrett R 2010). *L. squamatum* is not of conservation significance, although the *Lepidosperma* and Cyperaceae groups (including the *L. squamatum* group) are the subject of ongoing significant taxonomic review.

5.8.3. Vegetation Community Types of the Region

The project area is located within the Drummond Botanical Sub-district of the South West Botanical Province, which is typically characterised by low *Banksia* woodlands with *Melaleuca* swamps and woodlands of Tuart (*Eucalyptus gomphocephala*), Jarrah (*Eucalyptus marginata*) and Marri (*Corymbia calophylla*) (Beard 1990).

There are 85 recognised Interim Biogeographical Regionalisation of Australia (IBRA) regions across Australia. Western Australia supports 53 IBRA subregions and the project area lies within the Swan Coastal Plain IBRA region and, on a finer scale, within the Perth subregion. The Swan Coastal Plain is a low lying coastal plain, mainly covered with woodlands, dominated by *Banksia* or Tuart on sandy soils (McKenzie *et al*. 2002). The Perth subregion is composed of colluvial and aeolian sands, alluvial river flats, coastal limestone, heath and/or woodland of Tuart on limestone, *Banksia* and Jarrah-*Banksia* woodlands on Quaternary marine dunes of various ages, Marri on colluvial and alluvials, and includes a complex series of seasonal wetlands (McKenzie *et al*. 2002).

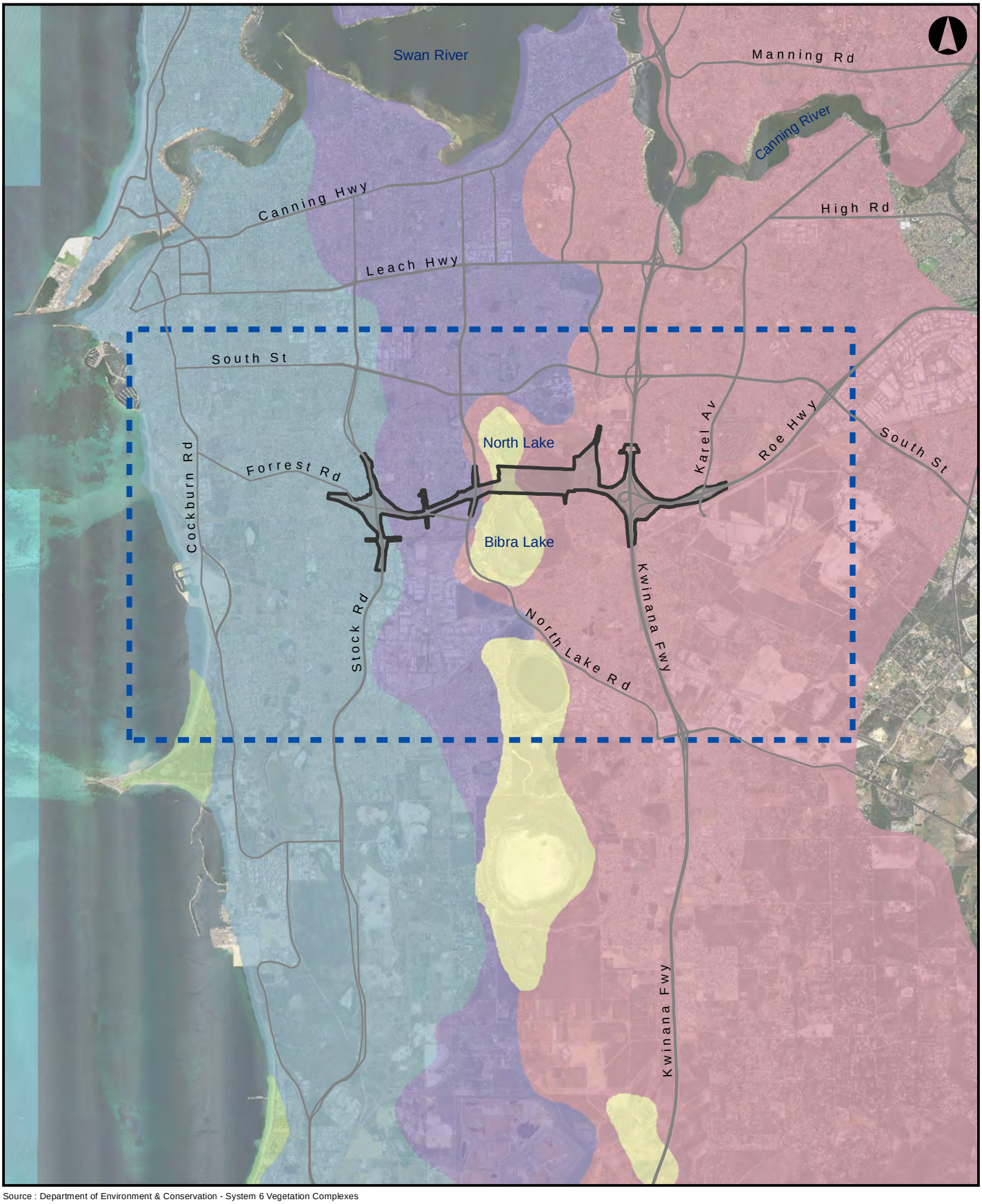
At a finer regional scale within the project area, the broad vegetation complexes that occur, as defined within the *Atlas of Natural Resources, Darling System, Western Australia* (Heddle *et al*. 1980), are summarised in Table 5.8-3 and shown in Figure 5.8-2. The complexes are based on vegetation in association with landforms and geology.

Table 5.8-3: Vegetation Complexes

Heddle Vegetation Complex[1]	Description[1]	Pre-European Extent (ha)[2]	Current Remaining Area (ha)[2]	% of Pre-European Extent Remaining (ha)
Bassendean Complex – Central and South (44)	Woodland of Jarrah-Marri with well defined second storey of Pink Summer Calytrix (*Calytrix fraseriana*) and Bull Banksia (*Banksia grandis*) on the deeper soils and a closed scrub on the moister sites. The understorey species reflect similarities with the adjacent vegetation complexes	46,220	10,919	24
Herdsman Complex (53)	Sedgelands and fringing woodland of Flooded Gum (*Eucalyptus rudis*) and *Melaleuca* species	6,509	2,017	31
Karrakatta Complex – Central and South (49)	Predominantly open forest of Tuart-Jarrah-Marri and woodland of Jarrah and *Banksia* species	34,532	6,275	18
Cottesloe Complex – Central and South (52)	Mosaic woodland of Tuart and open forest of Tuart-Jarrah and Marri, closed heath of the limestone outcrops	34,439	12,362	36

[1]Source: Heddle *et al.* 1980. Numbers in brackets refer to vegetation codes

[2]Source: WAPC 2000a



Source : Department of Environment & Conservation - System 6 Vegetation Complexes

System 6 Vegetation Complexes

South Metro Connect

Figure 5.8-2

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Kilometres

1:100,000 (A4)

Datum: GDA94 Projection: MGA z50

- Local Study Area
- Detailed Study Area
- Bassendean complex - Central and South
- Cottesloe complex - Central and South
- Herdsman Complex
- Karrakatta complex - Central and South
- Quindalup complex

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40 vegetation communities have been defined

Four vegetation types have been described within the project area by the Department of Agriculture report *Land Use and Vegetation in Western Australia* (Beeston *et al.* 2002) and are summarised in Table 5.8-4.

Table 5.8-4: Coverage of Vegetation Associations

Vegetation Association No.	Beard Code	Description	Current Extent (ha)	Pre-European Extent (ha)	Remaining (%)
6	e_2, 4Mi	Medium woodland; Tuart and Jarrah	22,168	67,429	32.88
126	Fl	Bare areas; freshwater lakes	204,323	220,518	92.66
998	e_4Mi	Medium woodland; Tuart	17,332	48,946	35.41
1001	e_2Mb cbLi	Medium very sparse woodland: Jarrah with low woodland; *Banksia* and *Casuarina*	16,758	64,799	25.86

Source: Beeston *et al.* 2002.

5.8.4. Vegetation within the Project Area

Vegetation within the project area is predominantly made up of *Banksia* woodland and areas of wetland vegetation with varying levels of disturbance and integrity. A total of 40 vegetation communities were recorded during the 2009 spring survey consisting of 25 woodlands, two shrublands, two herbland/sedgelands and eleven other classifications of mapped areas (excluding open water, tracks and roads). These communities are described in Table 5.8-5 and spatially presented in Figure 5.8-3 and Figure 5.8-4. A comprehensive list of vascular flora species and the vegetation communities in which they occur, as well as data from individual quadrats, is presented in Appendix K.

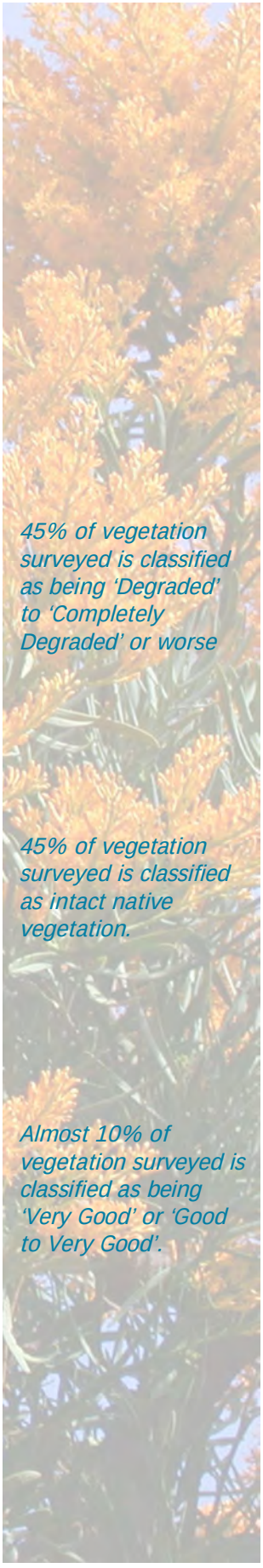
Table 5.8-5: Vegetation Communities Including Percent Cover

Vegetation Community Code	Percent of Project Area	Vegetation Community Descriptions
Woodlands		
AfBKgS	0.40	Low woodland *of Allocasuarina fraseriana, Banksia menziesii, Banksia attenuata* and *Banksia ilicifolia* over a low open shrubland of *Kunzea glabrescens* over an open herbland of *Phlebocarya ciliata, Dasypogon bromeliifolius* and *Loxocarya cinerea* on grey sand
AfKgS	0.32	Open forest of *Eucalyptus rudis* with occasional *Corymbia calophylla* over tall open scrub of *Agonis flexuosa* with occasional *Kunzea glabrescens* and *Astartea scoparia* over Tall Shrubland of *Melaleuca preissiana* over introduced species.
BahS	0.81	Low open woodland of *Banksia attenuata* and *Banksia menziesii* over a tall shrubland of *Regelia ciliata* over a low shrubland of *Allocasuarina humilis* and *Hibbertia hypericoides* over an open sedgeland of *Mesomelaena pseudostygia* on grey sand

Vegetation Community Code	Percent of Project Area	Vegetation Community Descriptions
BaNfW	0.14	Low woodland of *Banksia attenuata* and *Nuytsia floribunda* with occasional *Banksia ilicifolia* over a low open shrubland of *Xanthorrhoea preissii* with emergent *Kunzea glabrescens* over an open herbland of **Zantedeschia aethiopica* on grey-brown sandy loam
BaTs	9.12	Low open woodland of *Banksia attenuata* and *Banksia menziesii* with occasional *Eucalyptus marginata* over an open heath of *Allocasuarina humilis, Conostephium minus* and *Eremaea pauciflora* over an open grassland/sedgeland of *Amphipogon turbinatus* and *Mesomelaena pseudostygia* on grey sand
BHhW	6.09	Low open woodland of *Banksia attenuata* and *Banksia menziesii* with occasional *Eucalyptus marginata* and *Nuytsia floribunda* over a shrubland of *Allocasuarina humilis* and *Hibbertia hypericoides* with occasional *Allocasuarina fraseriana* and *Jacksonia furcellata* over a grassland of **Ehrharta calycina* and *Mesomelaena pseudostygia* on pale brown sand
BiSiH	1.02	Low open woodland of *Banksia ilicifolia* over a tall open shrubland of *Kunzea glabrescens* over an open herbland of *Scholtzia involucrata* and **Carpobrotus edulis* on grey sand
BXpW	5.97	Low open woodland of *Banksia attenuata* and *Banksia menziesii* with occasional *Eucalyptus marginata* over an open heath of *Hibbertia hypericoides* and *Xanthorrhoea preissii* over an open sedgeland of *Mesomelaena pseudostygia* on grey sand
CcAf	0.01	Low Open Woodland of *Corymbia calophylla* over a tall shrubland of *Allocasuarina fraseriana* over a Very Open introduced Grassland of **Ehrharta calycina* and **Ehrharta longiflora* in brown sand
CcBKgS	1.75	Low open forest of *Corymbia calophylla, Banksia attenuata* and *Banksia ilicifolia* over a tall shrubland of *Kunzea glabrescens* over a low shrubland of *Xanthorrhoea preissii* with occasional *Macrozamia riedlei* over a herbland of *Lomandra* sp. and *Dasypogon bromeliifolius* on grey sand
CcXpDdS	3.67	Open woodland of *Eucalyptus marginata* and *Corymbia calophylla* over a low open shrubland of *Xanthorrhoea preissii, Macrozamia riedlei, Daviesia divaricata* and *Hibbertia hypericoides* over an open grassland of **Ehrharta calycina* on grey sand over yellow sand
CcXpMrS	11.78	Woodland to open woodland of *Eucalyptus marginata* and *Corymbia calophylla* over an open to low shrubland of *Xanthorrhoea preissii*, *Macrozamia riedlei* and *Hibbertia hypericoides* over an open herbland of **Oxalis pes-caprae* and *Sowerbaea laxiflora* over an open grassland of **Briza maxima* and **Ehrharta calycina* on brown sandy loam
EgXpS	9.31	Open woodland of *Eucalyptus gomphocephala* and *Eucalyptus marginata* over a low open woodland of *Banksia attenuata* over a tall open shrubland of *Xanthorrhoea preissii* over an open sedgeland of *Mesomelaena pseudostygia* on yellow sand
EmApS	3.11	Open woodland to low open woodland of *Eucalyptus marginata* and *Banksia attenuata* over low shrubland of *Acacia pulchella, Hibbertia hypericoides, Macrozamia riedlei* and *Xanthorrhoea preissii* over **Briza maxima* on yellow sand
EmBaS	0.69	Open woodland of *Eucalyptus marginata* over a low open woodland of *Banksia attenuata* and *Banksia menziesii* over a low open heath of *Allocasuarina humilis, Xanthorrhoea preissii* and *Hibbertia hypericoides* over an open sedgeland of *Mesomelaena pseudostygia* on grey-yellow sand

Vegetation Community Code	Percent of Project Area	Vegetation Community Descriptions
EmKgS	1.25	Low woodland of *Eucalyptus marginata* with occasional *Corymbia calophylla* and *Banksia menziesii* over a tall shrubland of *Kunzea glabrescens* with occasional *Allocasuarina fraseriana* over a closed herbland of **Carpobrotus edulis* on grey sand
EmXpS	2.71	Low open woodland of *Eucalyptus marginata, Banksia attenuata* and *Banksia menziesii* over a low open shrubland of *Xanthorrhoea preissii* with occasional *Banksia sessilis* in degraded areas on brown-yellow sand
ErCtS	1.00	Low woodland to open forest of *Eucalyptus rudis, Banksia attenuata* and *Melaleuca preissiana* over low open shrubland of *Taxandria linearifolia*, *Gastrolobium ebracteolatum* and *Pteridium esculentum* over closed sedgeland of *Cyathochaeta teretifolia* (P3) on brown sandy loam
ErMpAfS	0.97	Low open forest of *Eucalyptus rudis* and *Melaleuca preissiana* over a tall open shrubland of *Astartea fascicularis* and *Kunzea glabrescens* over an open shrubland of *Pteridium esculentum* over a sedgeland of *Lepidosperma* sp. on brown clayey-loam flats
ErMpGeS	0.30	Low open forest of *Eucalyptus rudis* and *Melaleuca preissiana* with occasional *Banksia attenuata* over a tall shrubland of *Gastrolobium ebracteolatum* and *Kunzea glabrescens* over a low open shrubland of *Taxandria linearifolia* over a sedgeland of *Baumea preissii* subsp. *laxa* on black clay flats
ErMpH	5.03	Open woodland to low open woodland of *Eucalyptus rudis* and *Melaleuca preissiana* over open herbland of **Carpobrotus edulis, *Zantedeschia aethiopica* and **Oxalis pes-caprae* on grey sand
EtKgS	0.32	Low open woodland of *Eucalyptus todtiana* with occasional *Eucalyptus rudis* over a tall open shrubland of *Kunzea glabrescens* over an open herbland of **Carpobrotus edulis* on grey sand
MpBaS	1.96	Open forest of *Corymbia calophylla, Eucalyptus rudis* and *Banksia littoralis* over a tall shrubland of *Melaleuca preissiana* and *Kunzea glabrescens* with occasional *Melaleuca rhaphiophylla* over a closed sedgeland of *Baumea articulata* fringing wetlands on brown sandy loam
MpKgS	0.60	Low open woodland of *Melaleuca preissiana* and occasional *Eucalyptus rudis* over a closed tall scrub of *Kunzea glabrescens* over occasional *Lepidosperma* sp. over an Open Herbland of **Zantedeschia aethiopica* over **Aira caryophyllea* and **Gallium murale* on brown sandy-loam
BaBmBi	0.76	Low woodland *of Banksia attenuata, Banksia menziesii* and *Banksia ilicifolia* with occasional *Nuytsia floribunda, Allocasuarina fraseriana, Melaleuca preissiana* and *Eucalyptus marginata* over a shrubland dominated by *Xanthorrhoea preissii, Melaleuca thymoides* and *Acacia pulchella* over a low shrubland of *Patersonia occidentalis*, *Platysace compressa, Dasypogon bromeliifolius* and *Bossiaea eriocarpa* on grey sand
Planted Shrublands		
LlHpS	1.11	Low shrubland of **Leptospermum laevigatum* and *Hakea prostrata* over a mixed grassland/herbland of introduced species in association with disturbed roadsides
JfKgE	0.95	Tall open scrub of *Jacksonia furcellata* and *Kunzea glabrescens* over introduced grasses including *Ehrharta *longiflora, *Ehrharta calycina* and **Briza maxima* in disturbed roadside areas

Vegetation Community Code	Percent of Project Area	Vegetation Community Descriptions
Introduced Herbland/Sedgelands		
TBS	0.66	Closed sedgeland of **Typha orientalis, Baumea vaginalis* and *Baumea articulata* on brown sandy loam
T1	2.56	Herbland of ** Typha orientalis* with scattered *Juncus pallidus* surrounded by fringing wetland vegetation comprising of but not limited to *Melaleuca teretifolia*, *Eucalyptus camaldulensis*, *Melaleuca rhaphiophylla* and *Corymbia calophylla* on grey sand
Other Areas (Including Non-endemic or Planted Species)		
R1	9.32	Tall open shrubland of *Regelia ciliata, Stirlingia latifolia, Allocasuarina humilis* and *Adenanthos cygnorum* over introduced grasses and weeds on rehabilitated road batters
R2	0.99	Planted low open woodland of *#Eucalyptus conferruminata, #Eucalyptus erythrocorys* and *#Eucalyptus platypus* with scattered *Corymbia calophylla* and *Eucalyptus marginata* over a tall open shrubland of *#Melaleuca nesophila, #Acacia iteaphylla, Jacksonia furcellata* and *#Callistemon phoeniceus* with scattered **Callitris* sp. and occasional thickets of ** Leptospermum laevigatum* over introduced grasses dominated by ** Cynodon dactylon, *Ehrharta calycina* and ** Eragrostis curvula* on brown sand
R3	0.49	Planted open heath to tall open shrubland dominated by *#Calothamnus rupestris* with dominance alternating between *Acacia cochlearis, Acacia saligna* (narrow form) and scattered *#Corymbia maculata;* and *#Chamelaucium uncinatum* over introduced grasses dominated by ** Ehrharta calycina* and ** Eragrostis curvula* in association with rehabilitated road batters
R5	0.02	Planted low open woodland of *Corymbia calophylla* with scattered *Eucalyptus marginata* and *Banksia menziesii* over a tall shrubland of *Kunzea glabrescens* and *#Calothamnus rupestris* over introduced grasses
Pa1	0.35	Cleared parkland consisting mainly of **Araucaria heterophylla, Eucalyptus gomphocephala*, *Melaleuca viminea, Xanthorrhoea preissii*, *#Melaleuca nesophila* and *#Callistemon phoeniceus* over grasses dominated mainly by ** Cynodon dactylon* and ** Pennisetum clandestinum*
Pa2	1.26	Cleared parkland comprising, but not limited to, *Melaleuca preissiana*, *#Eucalyptus camaldulensis*, *Corymbia calophylla* and *Xanthorrhoea preissiana* over introduced grasses dominated by ** Pennisetum clandestinum, *Cynodon dactylon* and ** Eragrostis curvula*
Pa3	9.79	Cleared areas comprising, but not limited to, *Eucalyptus marginata*, *#Eucalyptus camaldulensis*, *#Eucalyptus macrocarpa* subsp. *macrocarpa, Corymbia calophylla, Acacia saligna* and *#Callistemon phoeniceus* over an open grassland dominated by ** Eragrostis curvula* and ** Ehrharta calycina* on grey sands
Pa4	0.17	Pasture community dominated by ** Cynodon dactylon* and ** Pennisetum clandestinum* with scattered *Melaleuca preissiana* and *Corymbia calophylla* on grey sands
Pa5	2.02	Cleared parkland of ** Cynodon dactylon* and ** Pennisetum clandestinum* with road edges comprising but not limited to *Corymbia calophylla*, *#Eucalyptus conferruminata* and *#Eucalyptus platypus* on grey sands



45% of vegetation surveyed is classified as being 'Degraded' to 'Completely Degraded' or worse

45% of vegetation surveyed is classified as intact native vegetation.

Almost 10% of vegetation surveyed is classified as being 'Very Good' or 'Good to Very Good'.

Vegetation Community Code	Percent of Project Area	Vegetation Community Descriptions
Pa6	0.06	Cleared areas comprising of, but not limited to *Corymbia citriodora*, *Eucalyptus platypus*, *Eucalyptus erythrocorys*, *Agonis flexuosa*, *Callistemon phoeniceus*, *Melaleuca rhaphiophylla*, *Melaleuca preissiana*, *Corymbia calophylla*, *Corymbia ficifolia*, *Melaleuca nesophila*, *Callitris* sp. over an introduced grassland dominated by *Cynodon dactylon* and *Ehrharta calycina*.
Pa7	0.05	Parkland of *Corymbia calophylla* and *Corymbia citriodora* over a lawn of introduced grasses

Source: Appendix K
*Denotes introduced (weed) species
#Denotes non-endemic or planted species

5.8.4.1. Vegetation Condition

In order to map the vegetation condition of the project area, the condition was determined at a range of detailed recording sites and in between, as necessary, where condition changed. The categories of vegetation condition used were consistent with a combination of methods developed by Keighery (1994) and the Braun-Blanquet Scale (Mueller-Dombois and Ellenberg 1974). These categories range from 'Completely Degraded' to 'Excellent' condition. The methodology is explained in detail in Appendix K. Effective measures of bushland condition are both the amount of change in community structure and the proportion of weeds present.

The project area has historically been cleared for urban activities and market gardens. However, there is remnant native vegetation within the project area, particularly associated with the wetlands (Conservation Commission 2001). The recreational aspects of the parklands and wetlands have contributed to disturbance and, as a result, 45 percent of the project area was found to be in the condition rated as 'Degraded to Completely Degraded' or worse. More than 20 percent of the vegetation was recorded to be in 'Good' condition, while approximately 10 percent of the areas surveyed were recorded as 'Very Good' or 'Good to Very Good' condition. Native vegetation rated as 'Degraded to Good' condition or better has been defined as intact native vegetation. One hundred and fifteen hectares (45 percent) of intact native vegetation occurs within the project area.

The assessed vegetation condition of the vegetation communities across the project area is summarised in Table 5.8-6 and illustrated in Figure 5.8-5 and Figure 5.8-6.

Table 5.8-6: Vegetation Condition Rating

Condition Rating*	Area (ha)	% Total Area Surveyed
Very Good	3.50	1.4
Good to Very Good	20.25	8.0
Good	45.09	17.8
Degraded to Good	46.36	18.3
Degraded	24.44	9.6
Degraded to Completely Degraded	58.11	22.9
Completely Degraded	55.93	22.0
TOTAL	253.69	100

Source: Appendix K

*after Keighery 1994

Vegetation Communities 1

South Metro Connect

Figure 5.8-3

0 100 200 300 400 500

Metres

1:20,500 (A4)

- AfBKgS
- AfKgS
- BAhS
- BHhW
- BXpW
- BaBmBi
- BaNfW
- BaTs
- BiSiH
- CcAf
- CcBKgS
- CcXpDdS
- CcXpMrS
- EgXpS
- EmApS
- EmBaS
- EmKgS
- EmXpS
- ErCtS
- ErMpAfS
- ErMpGeS
- ErMpH
- EtKgS
- JfKgE
- LlHpS
- MpBaS
- MpKgS
- Pa1
- Pa2
- Pa3
- Pa4
- Pa5
- Pa6
- Pa7
- R1
- R2
- R3
- R5
- T1
- TBS
- Water

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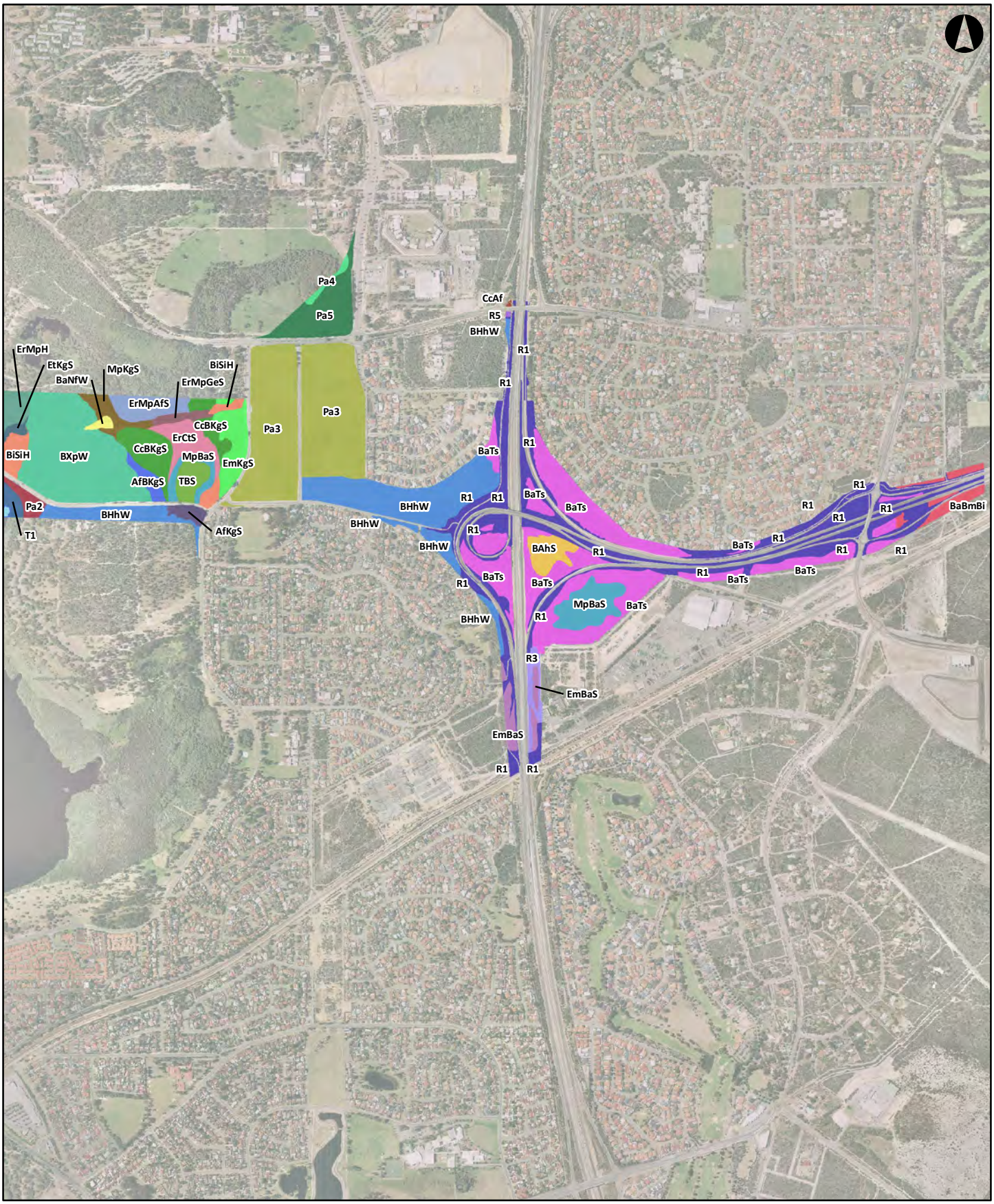

Vegetation Communities 2

South Metro Connect

Figure 5.8-4

0 100 200 300 400 500

Metres

1:20,500 (A4)

- AfBKgS
- AfKgS
- BAhS
- BHhW
- BXpW
- BaBmBi
- BaNfW
- BaTs
- BiSiH
- CcAf
- CcBKgS
- CcXpDdS
- CcXpMrS
- EgXpS
- EmApS
- EmBaS
- EmKgS
- EmXpS
- ErCtS
- ErMpAfS
- ErMpGeS
- ErMpH
- EtKgS
- JfKgE
- LlHpS
- MpBaS
- MpKgS
- Pa1
- Pa2
- Pa3
- Pa4
- Pa5
- Pa6
- Pa7
- R1
- R2
- R3
- R5
- T1
- TBS
- Water

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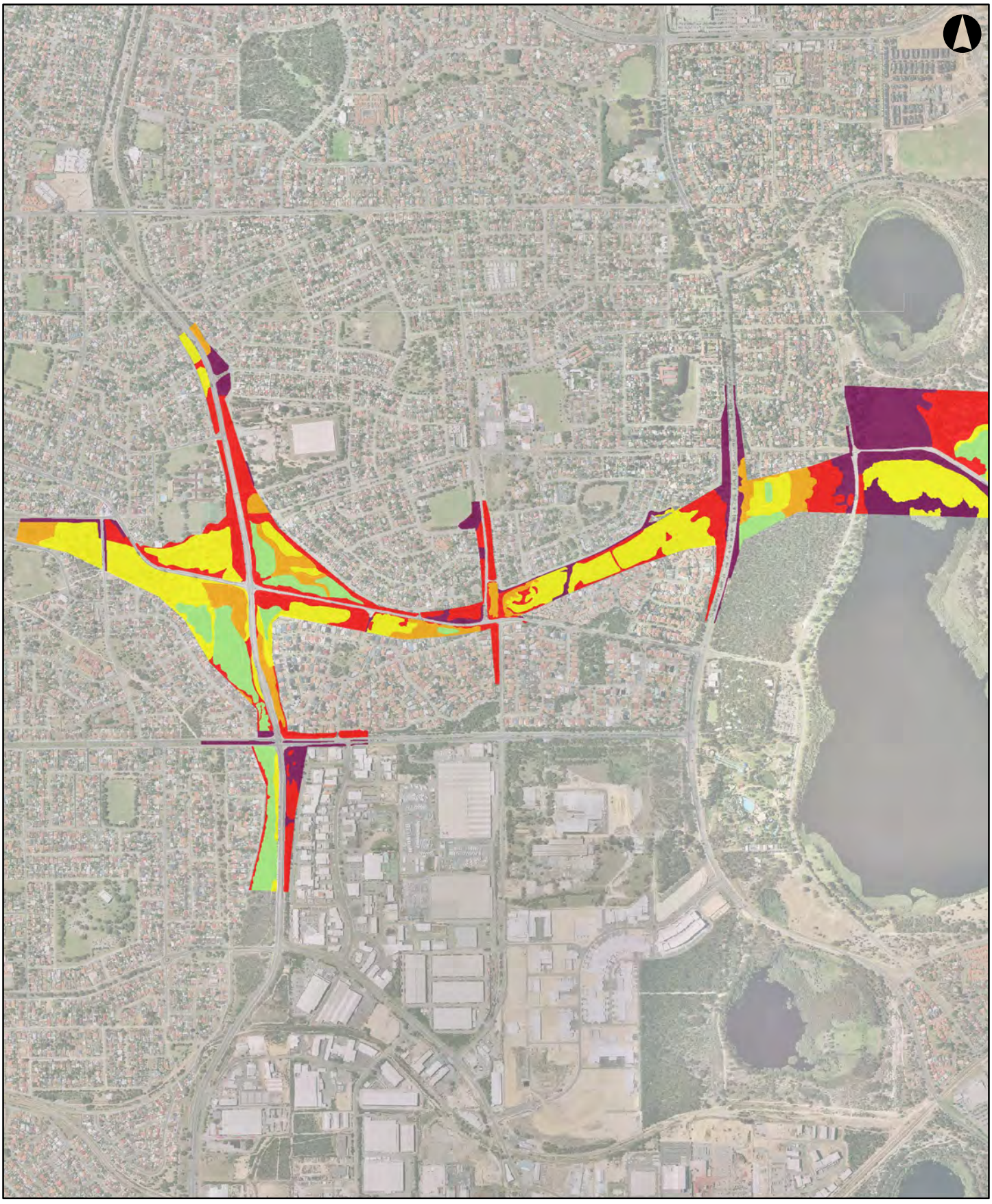

Vegetation Condition 1

South Metro Connect

Figure 5.8-5

0 100 200 300 400 500

Metres

1:20,500 (A4)

- Completely Degraded
- Degraded - Completely Degraded
- Degraded
- Degraded - Good
- Good
- Good - Very Good
- Very Good

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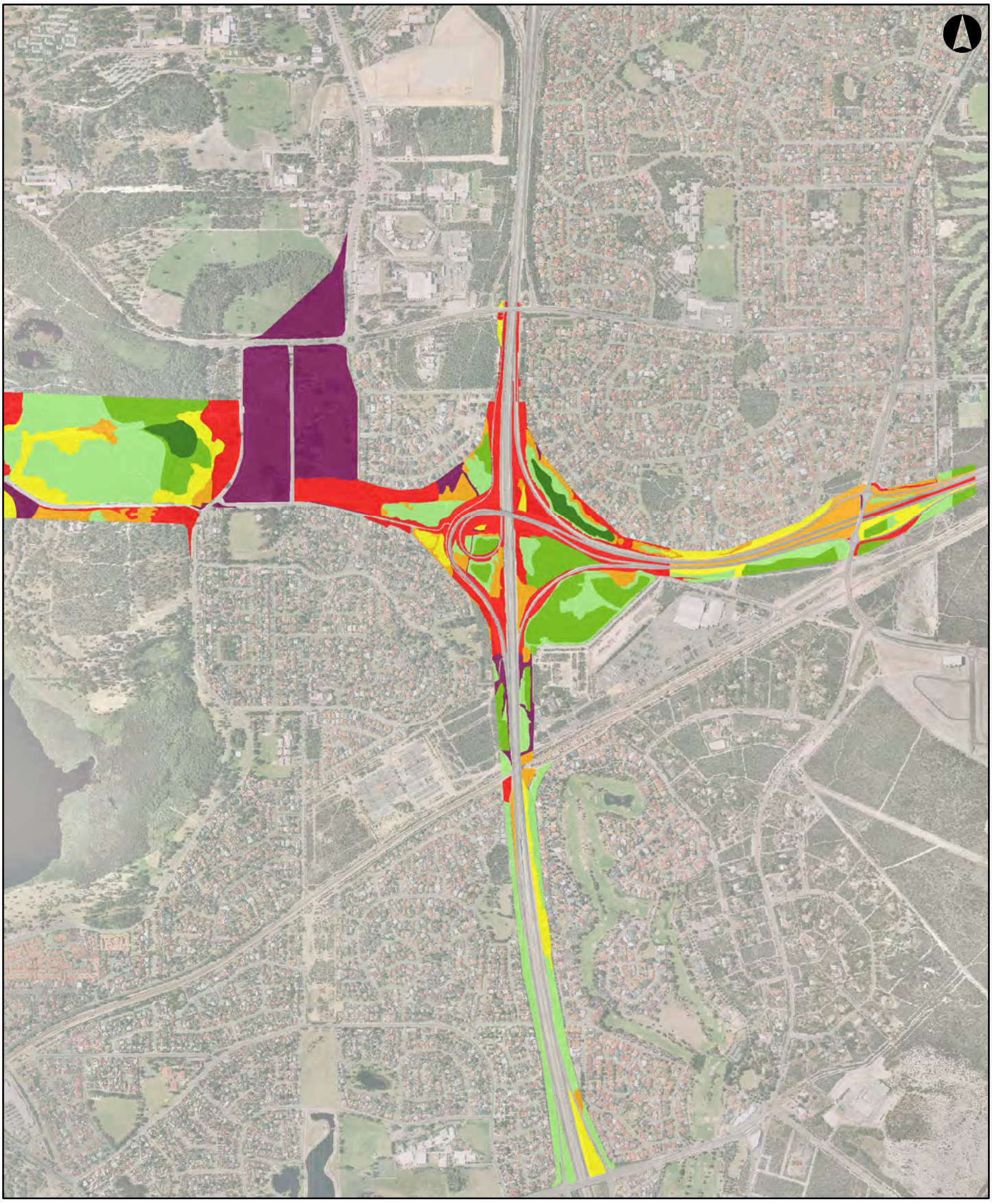

Vegetation Condition 2

South Metro Connect

Figure 5.8-6

0 100 200 300 400 500

Metres

1:20,500 (A4)

- Completely Degraded
- Degraded - Completely Degraded
- Degraded
- Degraded - Good
- Good
- Good - Very Good
- Very Good

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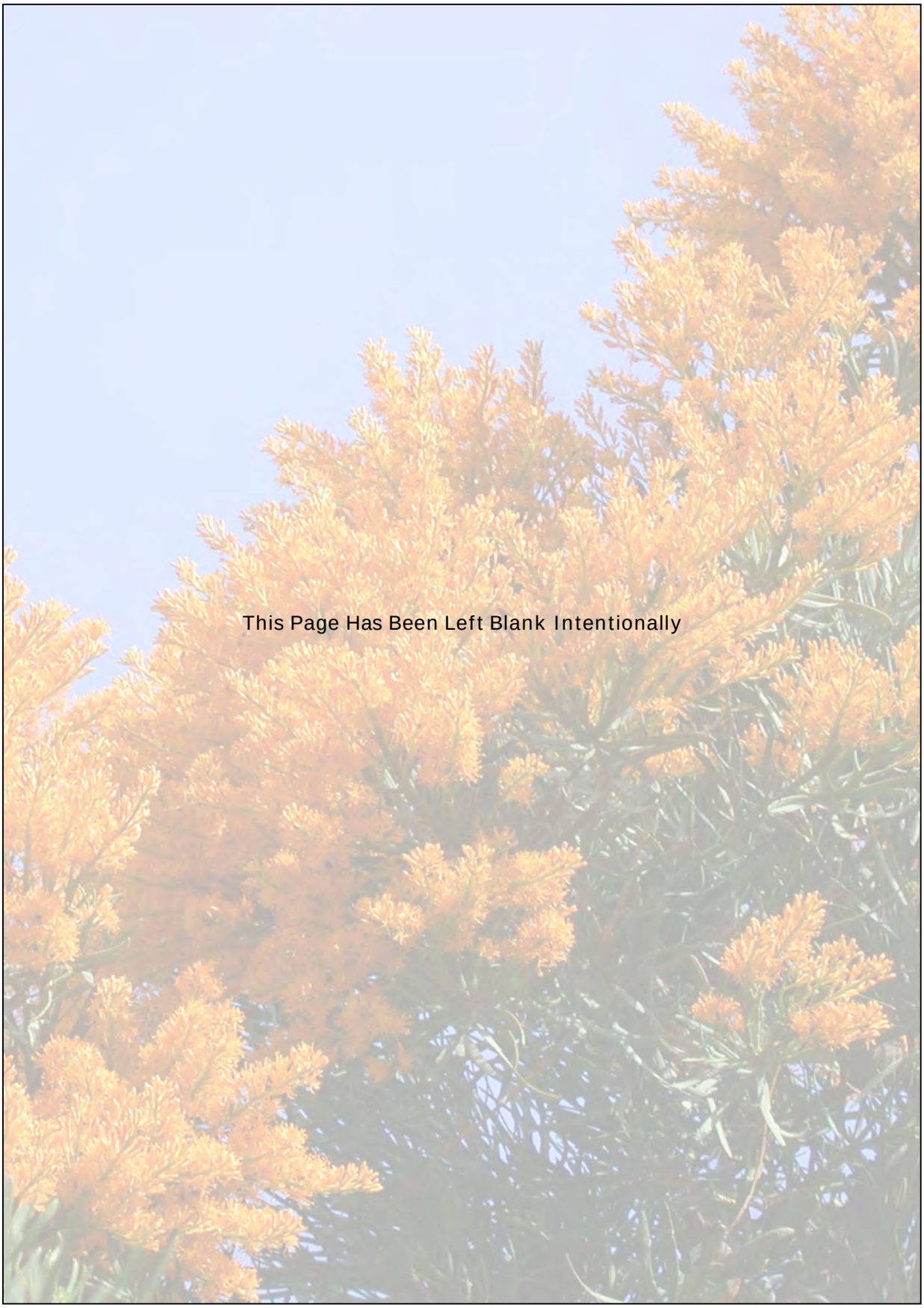
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5.8.4.1.1. Introduced Flora (Weeds)

There are 96 weed species occurring within Western Australia that are listed as Declared Plants (pest weeds), pursuant to the *Agriculture and Related Resources Protection Act 1976*. These species are subject to restrictions on movement or sale. During the spring surveys, 129 introduced or non-endemic species were identified within the project area. Three of these species are listed as Declared Plants:

- Arum Lily (*Zantedeschia aethiopica);
- Bridal Creeper (**Asparagus asparagoides*); and
- One-leaf Cape Tulip (**Moraea flaccida*).

129 weeds were identified, including three Declared Plants.

Weed invasion is relatively high throughout the project area, due to its urban nature and history of development. Generally, weeds are introduced and establish in areas of human activity and disturbance, such as walking trails, road reserves and drainage channels. Past land uses of the site and surrounds, including grazing and market gardens, have also contributed to weed invasion (Conservation Commission 2001).

5.8.4.1.2. Dieback

Dieback is a plant disease caused by a soil borne fungus. In Western Australia, the most common and destructive species is *Phytophthora cinnamomi*. The pathogen is a microscopic root-rot fungus that lives in the soil. It passively spreads through surface and groundwater, but may spread over long distances through the movement of infected soil carried by vehicles, bushwalkers or animals. In susceptible plant species, infection leads to decline of the canopy and eventually death of the infected plants.

Proteaceae and Ericaceae plant species are particularly vulnerable to the effects of dieback. Horticultural and crop species are also affected. The disease occurs discontinuously throughout the south-west of Western Australia.

A dieback assessment was undertaken within the project area. Methodology and assessment techniques used are detailed in Appendix L, along with detailed results. No infestations of *P. cinnamomi* were identified within the project area, with all samples analysed returning negative laboratory test results (Table 5.8-7). The majority of the project area was unmappable due to significant levels of disturbance and a lack of indicator species, or uninterpretable because of the presence of the Spearwood Dune association west of Progress Drive. *P. cinnamomi* typically does not 'express' on these alkaline soils. In simple terms, this means that the pathogen may actually be present within the soil, but it will subsist as an organism, rather than proliferate and manifest as visible disease symptoms (Appendix L). Other areas were uninterpretable due to the presence of wetlands, where associated vegetation is naturally void of reliable indicator species.

No infestations of Phytophthora cinnamomi were recorded

Historical studies have recorded other *Phytophthora* species adjacent to the project area; however these types of fungus are not known to be potentially destructive like *P. cinnamomi* (Brown 2010).

Table 5.8-7: Results of Dieback Assessment

Category	Area (ha)	% of Total Area Surveyed
Infested	0	0
Uninterpretable	144.5	54.0
Uninfested (*P. cinnamomi* free)	42.5	15.9
Unmappable	80.5	30.1
Total Area	267.5	100

Source: Appendix L

Note: For definitions of categories refer to Appendix L

5.8.4.2. Significant Vegetation

Vegetation that is considered to be significant is important in either a local, regional or national context. Vegetation communities are referred to as locally significant where they:

- Support populations of Priority Flora species;
- Extend the geographic range of particular taxa from previously recorded locations;
- Are restricted to only one or a few locations;
- Occur as small isolated communities; or
- Exhibit unusually high structural and species diversity (Mattiske 2000).

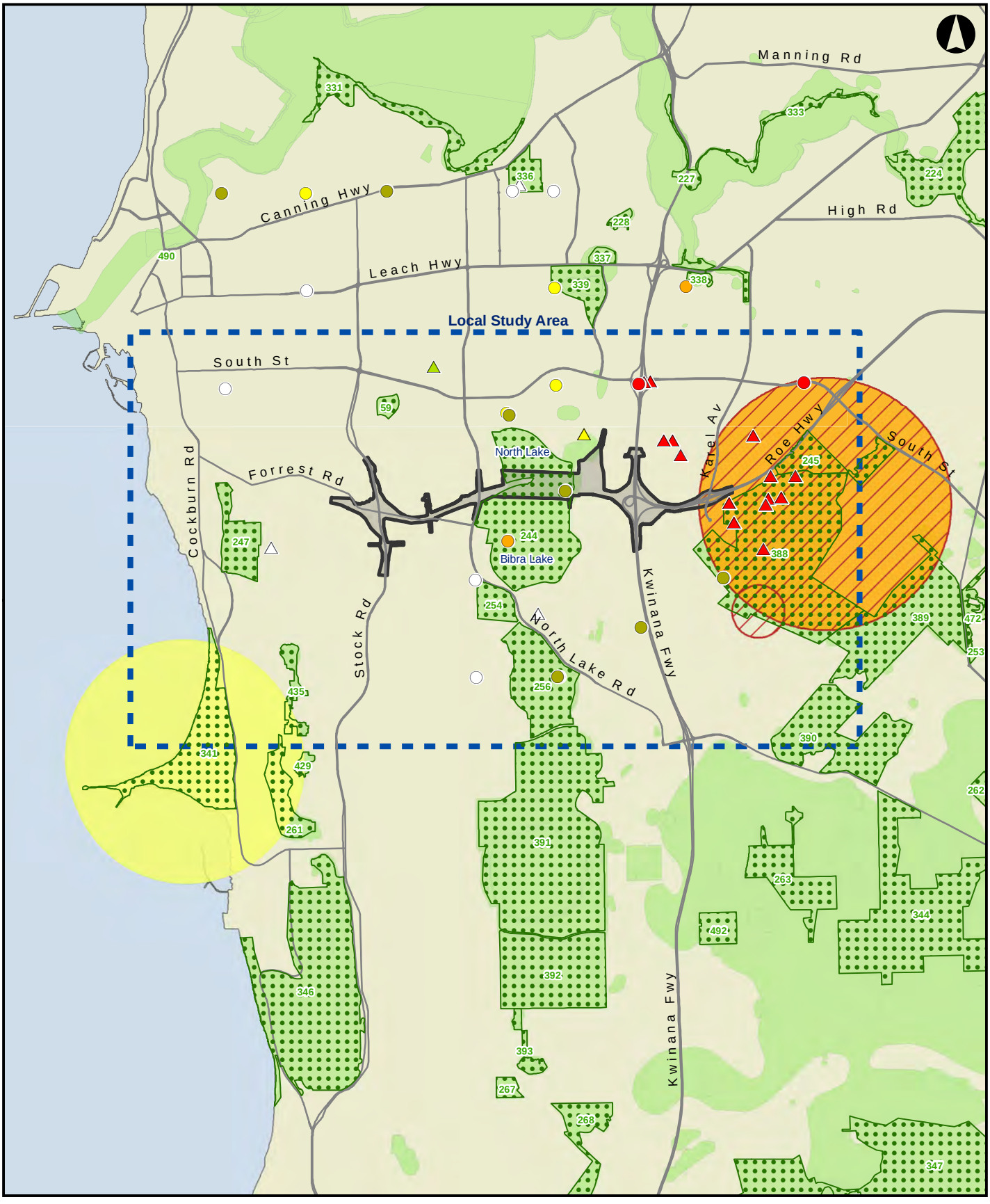
5.8.4.2.1. Threatened and Priority Ecological Communities

TECs are naturally occurring biological assemblages that occur in a particular type of habitat, which are subject to processes that threaten to destroy or significantly modify the assemblage across its range (DEC 2001).

TECs are protected under the *EPBC Act*. The TECs on the Commonwealth register are also listed on the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) website (www.environment.gov.au). For those State TECs not listed on the Commonwealth register, land clearing legislation under the *EP Act* provides protection for TECs from clearing. A database of State-listed TECs is available for online searches via the DEC website (www.dec.wa.gov.au). For further details on criteria of the various levels of Priority for PECs, refer to Appendix K.

Known TECs and PECs

Prior to field assessments, a search of the DEC TEC/PEC database was conducted for the project area. This search did not identify known occurrences of TECs within the project area or nearby. The buffer of one DEC-defined P3 PEC is recorded to intersect the project area. This PEC, Low lying *Banksia attenuata* woodland or shrubland, is equivalent to Floristic Community Type (FCT) 21c (Gibson *et al*. 1994). A P2 PEC, *Banksia ilicifolia* woodlands, is located near the project area, its buffer occurring approximately 1.7km south-east of the project area (Figure 5.8-7). The locations of PECs are represented spatially by point data, based on confirmed study plots assessed by the DEC.



Conservation Status Flora & Vegetation

South Metro Connect

Figure 5.8-7

0 1 2 3

Kilometres
1:100,000 (A4)
Datum: GDA94 Projection: MGA z50

DEC Rare Flora
- Declared Rare Flora
- Priority P2
- Priority P3
- Priority P4

WA Herbarium
- Declared Rare Flora
- Priority P1
- Priority P2
- Priority P3
- Priority P4

- Bush Forever Site
- Clearing Regulations - ESA

TEC/PEC Buffer
- PEC - Priority 2
- PEC - Priority 3
- TEC - Vulnerable

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No TECs or PECs exist within the project area

TEC/PEC Status of Recorded Vegetation Communities

None of the vegetation communities recorded within the project area have been determined to be equivalent to State TECs under the DEC listings or Commonwealth TECs protected under the *EPBC Act*. In addition, determination of the Floristic Community Types relevant to the recorded vegetation communities did not suggest that PECs are supported by the project area.

Consultation with the DEC in 2010 indicated that there are 21 PECs on the Swan Coastal Plain. None of the project area vegetation communities are considered to be equivalent to PECs under the DEC listings. A combination of information regarding specific boundaries and distributional extent of PECs in the Swan Coastal Plain, as well as species composition, soil types and position in the landscape, were used to characterise the mapped vegetation communities. These characteristics were considered in terms of their equivalence to the P3 PEC Low lying *Banksia attenuata* woodland or shrubland and the P2 PEC *Banksia ilicifolia* woodlands.

5.8.4.2.2. Vegetation Supporting Significant Flora

Eighteen communities mapped within the project area during the 2009 and 2010 spring surveys are considered locally significant as they support populations of Priority Flora, regionally significant species and significant flora of the Perth metropolitan region. These communities and the significant flora they support are listed in Table 5.8-8.

Vegetation communities AfKgS, CcAf and JfKgE and TBS have not been included in this assessment as they represent degraded variants of original intact native communities. Communities Pa1, Pa2, Pa3, Pa4, Pa5, Pa6, Pa7, R1, R2, R3 and R5 have not been included in further assessments, because they are not intact native vegetation assemblages and mainly comprise rehabilitated, cleared or degraded areas. Intact native vegetation is classified as native vegetation that is in 'Degraded to Good' condition or better.

Table 5.8-8: Locally Significant Vegetation Communities

Vegetation Community	Community Significance
AfBKgS*	Supports Priority Flora (*Jacksonia gracillima* (P3)) and a flora species significant for Perth metropolitan region (*Conostephium minus*) Limited local representation (locally significant)
AfKgS	Supports a flora species significant for Perth metropolitan region (*Agonis flexuosa*)
BaBmBi, BahS, BaNfW	Limited local representation (locally significant)
BATs, BHhW	Supports flora species significant for Perth metropolitan region (*Chamelaucium uncinatum*, *Conostephium minus*)
BiSiH*	Supports Priority Flora (*Jacksonia gracillima* (P3)) Limited local representation (locally significant)
BXpW	Supports Priority Flora (*Jacksonia gracillima* (P3))
CcBKgS*	Supports Priority Flora (*Jacksonia gracillima* (P3), *Cyathochaeta teretifolia* (P3) and *Dampiera triloba* (P1)) and a flora species significant for Perth metropolitan region (*Conostephium minus*)
CcXpMrS	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3), *Tetraria* sp. Chandala (G.J.Keighery 17055) (P2)) and a flora species significant for Perth metropolitan region (*Chamelaucium uncinatum*)
EgXpS	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3) and *Jacksonia gracillima* (P3) a species that is Priority listed and significant for Perth metropolitan region (*Dodonaea hackettiana* (P4)) and a species that is significant for Perth metropolitan region (*Lechenaultia linarioides*)
EmApS	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* ms (P3))
EmKgS, ErMpH*,	Supports a flora species significant for Perth metropolitan region (*Hibbertia cuneiformis*)
EtKgS*	Limited local representation (locally significant) Supports a flora species significant for Perth metropolitan region (*Hibbertia cuneiformis*)
EmXpS	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3)) and a species significant for Perth metropolitan region (*Chamelaucium uncinatum*)
ErCtS*	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and *Jacksonia gracillima* (P3) and a regionally significant flora species (*Gastrolobium ebracteolatum*)
ErMpAfS*	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and *Jacksonia gracillima* (P3) and a regionally significant flora species (*Gastrolobium ebracteolatum*)
ErMpGeS*	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and *Jacksonia gracillima* (P3) and a regionally significant flora species (*Gastrolobium ebracteolatum*)
JfKgE	Supports flora species significant for Perth metropolitan region (*Agonis flexuosa*, *Chamelaucium uncinatum*)
MpBaS	Supports Priority Flora (*Cyathochaeta teretifolia* (P3) *Dampiera triloba* (P1) *Jacksonia gracillima* (P3))

Vegetation Community	Community Significance
MpKgS*	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1) and a regionally significant flora species (*Ixiolaena viscosa)*
Pa2, Pa5	Supports a flora species significant for Perth metropolitan region (*Agonis flexuosa*)
R2	Supports flora species significant for Perth metropolitan region (*Agonis flexuosa*, *Melaleuca lanceolata*)
R3, R5	Supports a flora species significant for Perth metropolitan region (*Chamelaucium uncinatum*)

Source: Appendix K

*Located entirely or almost entirely within Environmentally Sensitive Areas (ESAs)

Two of the four vegetation complexes identified in the project area already have less than 30% of their pre-European extents remaining.

10 vegetation communities may be considered significant due to limited local representation.

5.8.4.2.3. Vegetation Representation

A range of factors determine the significance of native vegetation communities. The most important factor is the degree of representation in the local and regional areas. That is, vegetation communities are considered significant if they are inadequately represented elsewhere.

The EPA Position Statement No. 2 lays out a series of objectives that relate to the conservation of biodiversity. One of the objectives is to protect at least 30 percent of the original pre-clearing extent of each vegetation type, as defined by Beard (1990) (provided in Table 5.8-4). Finer scale mapping of vegetation complexes (Heddle *et al.* 1980) is available for the Swan Coastal Plain (Table 5.8-3). Of the vegetation complexes identified within the project area, both the Herdsman Complex and the Cottesloe Complex – Central and South (Figure 5.8-2) were above the 30 percent retention target at the time of last survey, with 31 and 36 percent of their pre-European extent remaining respectively (WAPC 2000a). Conversely, both the Bassendean Complex – Central and South (24%) and Karrakatta Complex – Central and South (18%) currently have less than 30 percent of their pre-European extents remaining (WAPC 2000a).

Determining vegetation representation on a local level involves assessing the proportionate extent of each recorded community in the local context (often within the project area). Ten vegetation communities (AfBKgS, BahS, BaBmBi, BaNfW, BiSiH, ErCtS, ErMpAfS, ErMpGeS, EtKgS and MpKgS) may be considered significant, due to limited representation in the local context. Representation of less than one percent of the total surveyed area is adopted as limited representation.

Vegetation communities AfKgS, CcAf, JfKgE, LlHpS and TBS have not been included in this assessment, because they represent degraded variants of their original intact native communities. Additionally, other classifications of mapped areas (namely Pa1, Pa2, Pa3, Pa4, Pa5, Pa6, Pa7, R1, R2, R3, R5, T1 and Water) have not been included in this assessment because they are not intact native vegetation assemblages and they consist of rehabilitated, cleared or degraded areas and open water bodies.

5.8.4.2.4. Vegetation within Environmentally Sensitive Areas

Environmentally Sensitive Areas (ESAs) are areas that require special protection due to aspects such as landscape, wildlife or historical value (Naturenet 2010). They are based on the *Western Australian Environmental Protection (Environmentally Sensitive Areas) Notice 2005* which was gazetted on 8 April 2005. Exceptions offered for clearing under Regulation 5 of the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* do not apply within ESAs. ESAs are selected for State or Commonwealth environmental values and, in this situation, include:

- Declared World Heritage properties (*EPBC Act*);
- Areas included on the National Estate Register;
- Defined wetlands and associated buffers;
- Vegetation within 50m of rare flora;
- Threatened Ecological Communities (discussed in Section 5.8.4.2.1);
- Bush Forever sites;
- Areas covered by the Environmental Protection (Gnangara Mound Crown Land) Policy 1992 and the Environmental Protection (Western Swamp Tortoise) Policy 2002;
- Wetlands covered by the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992; and
- Areas fringing native vegetation as defined in the Environmental Protection (Swan and Canning Rivers) Policy 1998.

Part of Bush Forever Site 244 occurs within the project area (Figure 5.8-7). It includes vegetation associated with Bibra Lake, Roe Swamp and surrounding sumplands (UFIs 14425 and 15240), and Horse Paddock Swamp, which together constitute an ESA. The vegetation within the wetlands, wetland buffers and Bush Forever site is regionally significant in terms of its structural complexity, floristic assemblages and ecological patterns.

The Bush Forever strategy is a ten year plan that formally commenced in 2000 to protect approximately 51,200ha of regionally significant bushland within about 290 Bush Forever Sites. This represents, where achievable, a retention target of at least 10 percent of the original extent of the 26 vegetation complexes of the Swan Coastal Plain within the Perth metropolitan region (WAPC 2000b).

It is an EPA objective to ensure that regionally significant flora and vegetation communities in Bush Forever sites are adequately protected. However, the Bush Forever *Site Implementation Guidelines, Practice Notes* recognise that the primary purpose of road reserves identified in the MRS or local Town Planning Schemes is to accommodate vital transport infrastructure, and that the construction authority has the right to undertake the required works for transport and associated infrastructure.

Vegetation within the wetlands, wetland buffers and Bush Forever Site 244 is regionally significant

Sixteen of the 40 vegetation communities recorded within the project area are located entirely or almost entirely within ESAs. These communities and their inferred FCTs have been determined to be well represented outside of the project area and elsewhere in the region, including within other Bush Forever sites: Thomsons Lake Nature Reserve (Bush Forever Site 391) and Jandakot Airport (Bush Forever Site 388). Accordingly, vegetation communities occurring within ESAs that are part of Bush Forever Site 244 within the project area are not considered significant in the regional context.

5.8.5. Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are ecosystems that rely on the use of groundwater at some stage of their life cycle and would be significantly altered (and even irreversibly degraded) if groundwater availability was altered beyond its normal range of fluctuation (Colvin *et al*. 2003).

A GDE investigation of the study area was undertaken in conjunction with an assessment of the underlying stratigraphy of the project area, which aimed to characterise the soils and groundwater that influence the occurrence of GDEs (Appendix D). The study area comprises approximately 467ha and the extent of survey is defined in Figure 5.8-8.

GDEs are also defined as ecosystems that require groundwater input to maintain their current position, function and composition (Eamus *et al*. 2006). Such ecosystems were determined based on the floral composition (i.e. if groundwater dependent/indicator flora species were observed to be supported within an ecosystem, that ecosystem was mapped to be a GDE).

Figure 5.8-8: GDE Study Area

Vegetation of the project area has been classified as groundwater dependent, based on the presence of known regional groundwater dependent flora species, referred to as GDE indicator species. By mapping the extent of these indicator species and also delineating the various water dependencies of the species, the extent and characteristics of GDEs has been mapped to evaluate risk to wetland values and functions.

To determine the range of groundwater depths the indicator species are predicted to be accessing, the distribution of GDE indicator species was overlaid on the depth to groundwater obtained from data recorded from bores (Appendix D). Soil samples were also collected along several of the GDE transects to measure soil moisture. Where possible, the soil samples were collected adjacent to indicator species to enable inferences to be made regarding the soil moisture requirements of these species.

5.8.5.1. Indicator Species

Based on the literature, a total of 29 flora species from the project area are known to indicate GDEs (presented in Table 5.8-9). Mapping the locations and densities of the indicator species has resulted in an extent of GDEs and within the GDEs, a finer scale classification of GDE sub-community type.

Table 5.8-9: Depth to Groundwater and Root Architecture for GDE Indicator Species

GDE Indicator Species	Indicator of GDE/Wetland Classification	Depth to Groundwater March 2010**	Published Literature	Root Architecture^	Landscape Position
Allocasuarina humilis	GDE	11–15m	>2m	Type 4	Upland
Astartea scoparia	GDE (subsurface water – perched)	Unknown*	<1m	Type 1	Wetland
Banksia attenuata	GDE	11–18m	2–30m	Type 4	Upland
Banksia ilicifolia	GDE	7–11m	1.5–3.2m	Type 4	Upland to Wetland
Banksia littoralis	GDE	5m	1.5–3.2m	Type 4	Wetland
Banksia menziesii	GDE	11m	2–30m	Type 4	Upland
Baumea articulata	Wetland (groundwater or seasonal surface water)	6m	<1m	Type 2	Wetland
Baumea juncea	Wetland (groundwater or seasonal surface water)	Unknown*	<1m	Type 2	Wetland
Baumea rubiginosa	Wetland (groundwater or seasonal surface water)	Unknown*	<1m	Type 2	Wetland
Centella asiatica	Wetland (groundwater or seasonal surface water)	11–15m	<1m	Type 2	Wetland
Conostephium minus	GDE (vadose zone (shallow rooted))	Unknown*	Unknown	Type 3	Upland to Wetland
Conostephium pendulum	GDE (vadose zone (shallow rooted))	11–15m	1–2m	Type 3	Upland to Wetland
Corymbia calophylla	GDE (deep aquifer)	11–15m	>30m	Type 4	Upland
Eucalyptus gomphocephala	GDE	Unknown*	>9m	Type 4	Upland
Eucalyptus rudis	GDE	3–9m		Type 4	Upland to Wetland
Eucalyptus todtiana	GDE	Unknown*	10m	Type 4	Upland
Hypocalymma angustifolium	GDE (vadose zone (shallow rooted))	Unknown*	<1m	Type 5	Upland to Wetland
Kunzea glabrescens	GDE	5–7m	1–2m	Type 1	Wetland
Lepidosperma longitudinale	Wetland (groundwater or seasonal surface water)	Unknown*	<1m	Type 2	Wetland
Leucopogon conostephioides	GDE	11m	1–2m	Type 3	Upland
Meeboldina scariosa	Wetland (groundwater or seasonal surface water)	Unknown*	<1m	Type 2	Wetland

GDE Indicator Species	Indicator of GDE/Wetland Classification	Depth to Groundwater March 2010**	Published Literature	Root Architecture^	Landscape Position
Melaleuca lateritia	GDE	Unknown*	1–2m	Type 4	Wetland
Melaleuca preissiana	GDE	5–6m	<5m	Type 4	Wetland
Melaleuca rhaphiophylla	GDE	6m	<5m	Type 4	Wetland
Melaleuca teretifolia	GDE	Unknown*	<5m	Type 4	Wetland
Schoenoplectus validus	Wetland (groundwater or seasonal surface water)	Unknown*	<1m	Type 2	Wetland
Scholtzia involucrata	GDE (vadose zone (shallow rooted))	7m	1–2m	Type 4	Upland to Wetland
Stirlingia latifolia	GDE (vadose zone (shallow rooted))	15m	>2m	Type 4	Upland to Wetland
Taxandria linearifolia	GDE	8m	1–2 m	Type 1	Upland to Wetland
Typha orientalis	Wetland (groundwater or seasonal surface water)	6m	<1m	Type 2	Wetland

*no bores were installed at the time of survey

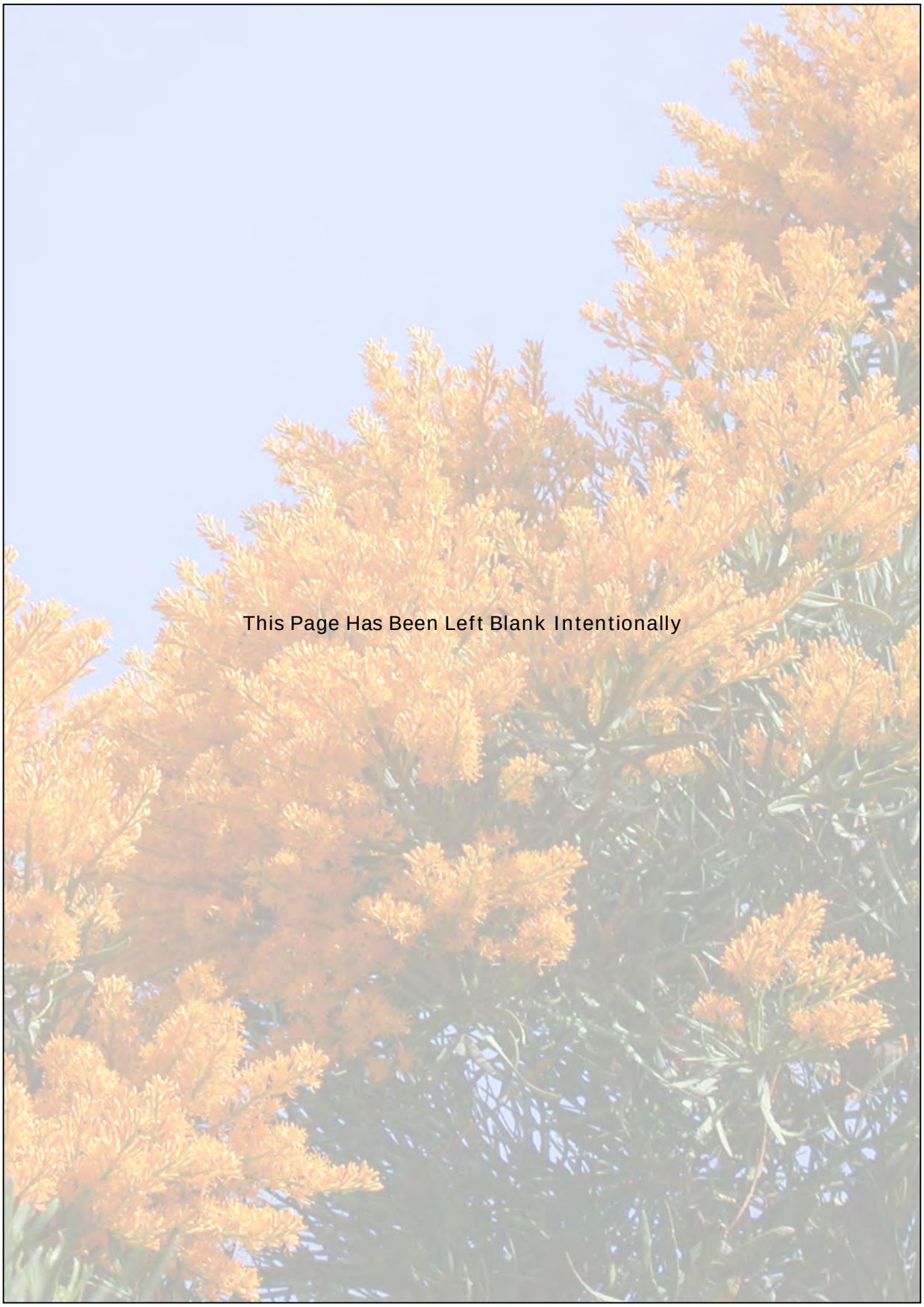
**Appendix D

^ Refer Figure 5.8-10

70 GDE sub-communities exist in the study area

5.8.5.2. Vegetation Distributions in Relation to Water Dependence

In relation to water dependence, vegetation is typically surface water dependent, groundwater dependent or dependent on moisture in the vadose (subsurface) zone. The water dependency of wetland vegetation is usually a combination of these and will be dictated by and, in turn, reveals the natural water characteristics that support it. A total of 23 broad GDE communities were assigned with 70 GDE sub-communities (presented in Figure 5.8-9). Examples of the relationship between GDEs (sub-communities) and the underlying stratigraphy and hydrology are demonstrated in Table 5.8-10 (detailed in Appendix D).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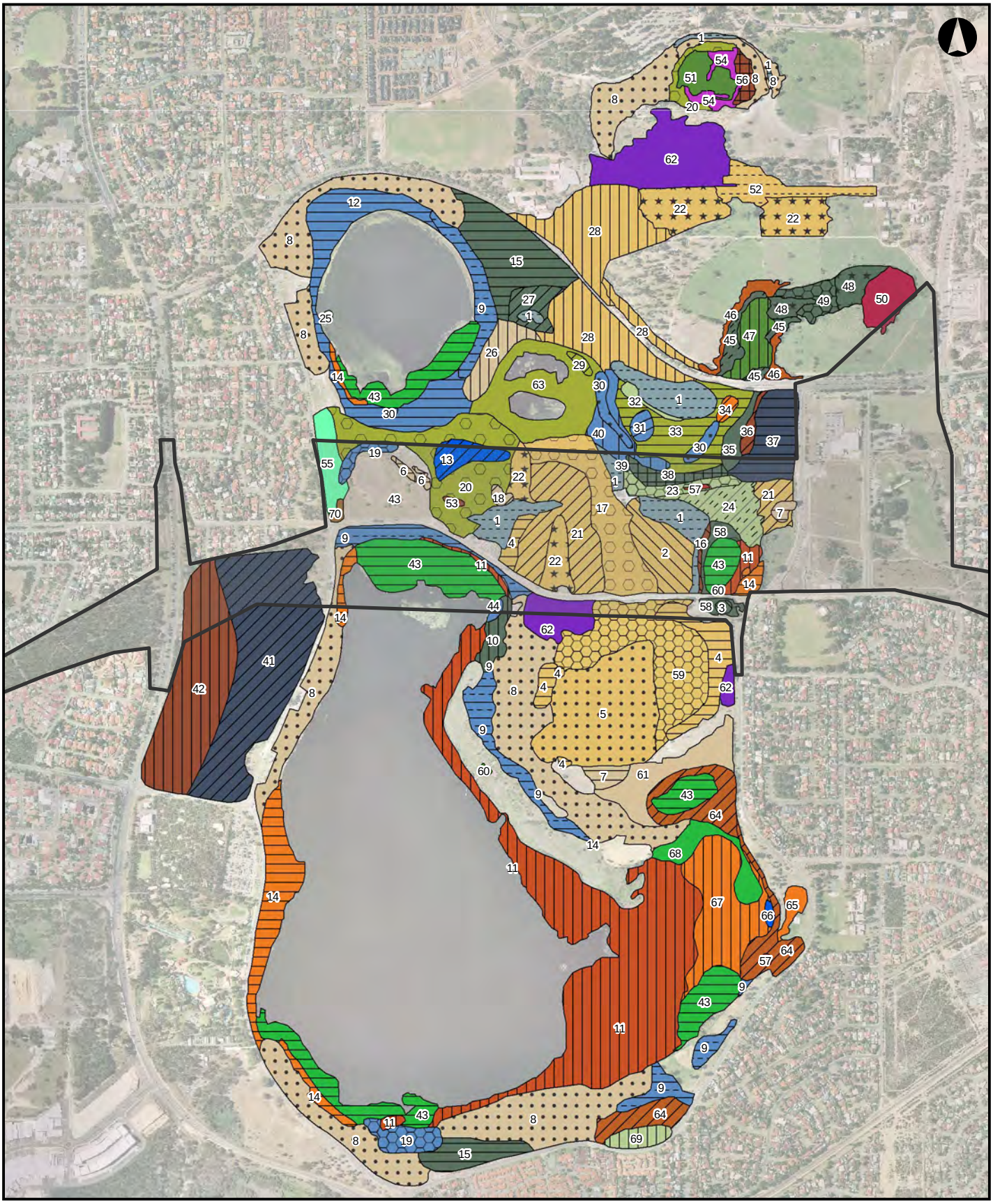

Source : Syrinx Environmental PL, 2010

Groundwater Dependent Ecosystem Sub-Communities

South Metro Connect

Figure 5.8-9a

0 100 200 300 400 500

Metres
1:16,000 (A4)
Datum: GDA94 Projection: MGA z50

Project Area

Please Refer to Figure 5.8-9b for Community Descriptions

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SouthmetroConnect

Eucalyptus rudis tall woodland over mixed woodlands

3. *Eucalyptus rudis* closed forest over *Melaleuca preissiana/ Banksia littoralis* low open woodland SubComm 5

10. *Eucalyptus rudis* tall woodland over *Melaleuca rhaphiophylla / Melaleuca preissiana / Banksia littoralis* closed woodland SubComm 4

15. *Eucalyptus rudis* tall open woodland over mixed *Banksia* woodland SubComm 9

27. *Eucalyptus rudis* tall woodland over *Banksia menziesii and Banksia attenuata* woodland SubComm 3

35. *Eucalyptus rudis* tall woodland over *Banksia ilicifolia* and *Melaleuca preissiana* open woodland SubComm 1

38. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 6

45. *Eucalyptus rudis* tall open forest over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* closed forest SubComm 8

48. *Eucalyptus rudis* / *Melaleuca preissiana* / *Banksia littoralis* open forest Sub Comm 2

49. *Eucalyptus rudis* / *Melaleuca preissiana* / *Banksia littoralis* open forest Sub Comm 1

58. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 7

Banksia Woodland

2. Mixed Banksia woodland SubComm 1

4. *Banksia ilicifolia* open woodland SubComm 4

5. *Banksia attenuata/ Banksia menziesii* woodland SubComm 7

17. *Banksia attenuata* / *Banksia menziesii* open forest SubComm 8

21. *Banksia attenuata* / *Banksia menziesii* woodland SubComm 9

22. Mixed Banksia woodland SubComm 2

28. Mixed Banksia woodland SubComm 3

52. Mixed Banksia woodland SubComm 5

59. *Banksia attenuata* and *Banksia menziesii* open woodland SubComm 6

Eucalyptus rudis tall closed forest and _Melaleuca rhaphiophylla_ closed forest

9. *Eucalyptus rudis* tall open woodland over *Melaleuca rhaphiophylla* open woodland SubComm 1

12. *Eucalyptus rudis* and *Melaleuca rhaphiophylla* open forest SubComm 5

19. *Melaleuca rhaphiophylla* and *Eucalyptus rudis* woodland SubComm 6

30. *Eucalyptus rudis* tall closed forest over *Melaleuca rhaphiophylla* closed forest SubComm 2

31. *Eucalyptus rudis* tall open forest over *Melaleuca rhaphiophylla* closed forest SubComm 3

40. *Eucalyptus rudis* tall closed forest over *Melaleuca rhaphiophylla* closed forest SubComm 4

44. *Eucalyptus rudis* tall closed forest over *Melaleuca rhaphiophylla* closed forest SubComm 7

Scattered

6. Scattered *Banksia littoralis*

7. Scattered *Corymbia calophylla* and *Eucalyptus todtiana*

8. Scattered *Eucalyptus rudis*

18. Scattered *Eucalyptus todtiana*

26. Scattered *Banksia menziesii*

61. Scattered *Corymbia calophylla*

Corymbia calophylla tall woodland

16. *Corymbia calophylla* tall open woodland SubComm 1

36. *Corymbia calophylla* tall woodland over *Banksia littoralis* open woodland SubComm 2

42. *Corymbia calophylla* tall open woodland over *Banksia attenuata* woodland SubComm 3

53. *Corymbia calophylla* open woodland SubComm 4

56. *Corymbia calophylla* tall woodland SubComm 5

Groundwater Dependent Ecosystems Sub-Communities Legend

Figure 5.8-9b

Eucalyptus rudis tall closed forest and _Melaleuca preissiana_ closed forest

23. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* open woodland SubComm 2

24. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* woodland SubComm 3

32. *Eucalyptus rudis* tall open forest over *Melaleuca preissiana* closed forest SubComm 4

69. *Eucalyptus rudis* and *Melaleuca preissiana* open woodland SubComm 1

Eucalyptus rudis tall closed forest over _Melaleuca preissiana_ and _Melaleuca rhaphiophylla_ closed forest

20. *Eucalyptus rudis /Melaleuca preissiana* / *Melaluca rhaphiophylla* open woodland SubComm 4

29. *Eucalyptus rudis* tall closed forest over *Melaleuca rhaphiophylla* and *Melaleuca preissiana* open forest SubComm 1

33. *Eucalyptus rudis* tall closed forest over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* closed forest SubComm 2

63. *Eucalyptus rudis* / *Melaleuca preissiana* / *Melaleuca rhaphiophylla* closed forest SubComm 3

Melalecua rhaphiophylla closed forest

14. *Melaleuca rhaphiophylla* closed forest SubComm 2

34. *Melaleuca rhaphiophylla* closed forest SubComm 1

65. *Melaleuca rhaphiophylla* closed forest SubComm 3

67. *Melaleuca rhaphiophylla* closed forest SubComm 4

Eucalyptus rudis tall forest

46. *Eucalyptus rudis* tall open forest SubComm 1

64. *Eucalyptus rudis* closed forest SubComm 2

Corymbia calophylla tall open woodland over _Banksia menziesii_ and _Banksia attentuata_ woodland

37. *Corymbia calophylla* tall woodland over *Banksia menziesii* and *Banksia attenuata* woodland SubComm 1

41. *Corymbia calophylla* tall open woodland over *Banksia menziesii* and *Banksia attenuata* woodland SubComm 2

Melaleuca preissiana and _Melaleuca rhaphiophylla_ woodland

47. *Melaleuca preissiana* and *Melaleuca rhaphiophylla* woodland SubComm 1

51. *Melaleuca preissiana* and *Melaleuca rhaphiophylla* woodland SubComm 2

Kunzea glabrescens closed tall scrub

1. *Kunzea glabrescens* closed tall scrub SubComm 1

39. *Kunzea glabrescens* closed tall scrub SubComm 2

Melaleuca preissiana closed forest

13. *Melaleuca preissiana* closed forest SubComm 1

66. *Melaleuca preissiana* closed forest SubComm 2

Typha orientalis closed sedgeland

43. *Typha orientalis* closed sedgeland SubComm 2

68. *Typha orientalis* closed sedgeland SubComm 1

Melaleuca preissiana and _Banksia littoralis_ closed forest

50. *Melaleuca preissiana* and *Banksia littoralis* closed forest

Eucalyptus gomphocephala closed forest

70. *Eucalyptus gomphocephala* closed forest

Corymbia calophylla and _Eucalyptus rudis_ closed forest

55. *Corymbia calophylla* and *Eucalyptus rudis* closed forest

Astartea scoparia closed tall scrub

54. *Astartea scoparia* closed tall scrub

Baumea rubiginosa sedgeland

57. *Baumea rubiginosa* sedgeland

Baumea juncea closed sedgeland

25. *Baumea juncea* closed sedgeland

Baumea articulata closed sedgeland

60. *Baumea articulata* closed sedgeland

Melaleuca teretifolia closed tall scrub

11. *Melaleuca teretifolia* closed tall scrub

Revegetation

62, Revegetation

SouthmetroConnect

Table 5.8-10: Examples of Key Relationships between the GDE Vegetation Communities and Site Specific Stratigraphy and Hydrology

Community Code	Description	Situation, Soil Type and Groundwater Condition
T3B	37: *Corymbia calophylla* tall woodland over *Banksia menziesii* and *Banksia attenuata* woodland sub-community indicator species consisting of *Kunzea glabrescens*, *Stirlingia latifolia*	Located on slope down to site T3-C. Mostly coarse and medium sand interspersed with layers of slightly muddy sand and iron coated grains. Water table is relatively shallow; and sand recharges quickly after rainfall and drains quickly
T3C	38: *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland; sub-community indicator species consisting of sedge 1, sedge 2, *Taxandria linearifolia*	Coarse and very coarse sand with iron cemented layer at 3m which perches groundwater. Water table close to surface
T3D	On boundary of: 1: *Kunzea glabrescens* closed tall scrub 23: *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* open woodland; sub-community indicator species consisting of *Astartea scoparia*, *Baumea rubiginosa*, *Hypocalymma angustifolium*, *Melaleuca rhaphiophylla*, sedge 1, sedge 2, *Taxandria linearifolia*	Located on slope down to site T3-C. Coarse sand sediments. Seepage zone at base of dune
T3E	20: *Eucalyptus rudis* open woodland over *Melaleuca preissiana* open woodland	Iron coated sand 3–4m below surface which does not retard vertical groundwater discharge sufficiently to saturate the sediments, but does allow access to the water table for plants. Water table moderately shallow <4m
T4B	3: *Eucalyptus rudis* open woodland over *Melaleuca preissiana/Banksia littoralis* low open woodland; sub-community indicator species consisting of *Melaleuca teretifolia*	Wetland muddy sand sediments at 1–2m and 2.5–3m indicating it is the margin of Roe Swamp. Water table very shallow <1m
T4C	5: *Banksia attentuata/Banksia menziesii* woodland	Dune underlain by very coarse and coarse yellow sand
T4D	2: Mixed *Banksia* woodland, subcommunity indicator species consisting of *Banksia attenuata*, *Banksia menziesii*, *Banksia illicifolia*, *Leucopogon constephoides*	High dune underlain by medium yellow sand
T5B	8: Scattered *Eucalyptus rudis*	Sediments with several layers of iron coated sands interlayered with diagenetically altered sand, indicating fluctuating water tables consistent with wetland margins and zone of water flow into wetland. Shallow water table located above iron coated sands

5.8.5.3. Root Structure of Individual GDE Species

Groundwater dependent species have variable characteristics that influence their zonation and habitat boundaries, with rooting depth a key defining trait (Zencich *et al*. 2002). The root depths of individual species can be compared with the recorded depth to water table, to define their local groundwater dependency requirements.

Several GDE areas containing species with typical root depths of 1 to 2m were located where the depth to groundwater was in excess of 11m. The species were flowering at the time of survey, suggesting either that these species used the water within the vadose zone for survival or were accessing a perched water table.

Generic root architecture types have been previously described by Dodd *et al*. (1984) for the Swan Coastal Plain (Figure 5.8-10). These morphotypes were used to categorise the various indicator species. There is a lack of specific literature on rooting depth and architecture of many GDE indicator species. However, for those that are known (Table 5.8-9), the rooting depth and architecture varied between species–most in the area belonged to Type 4 (Figure 5.8-10).

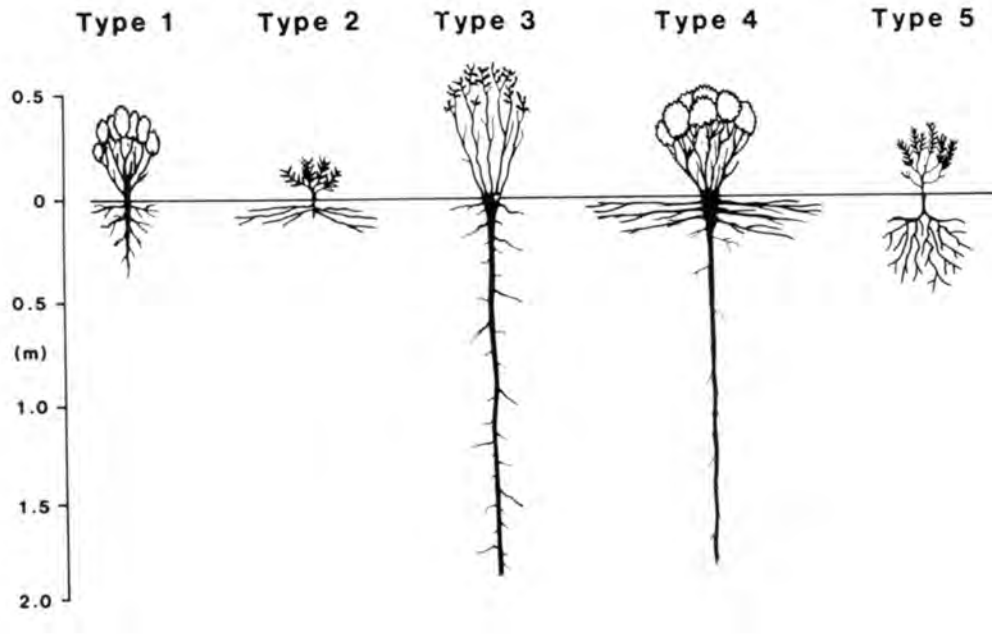
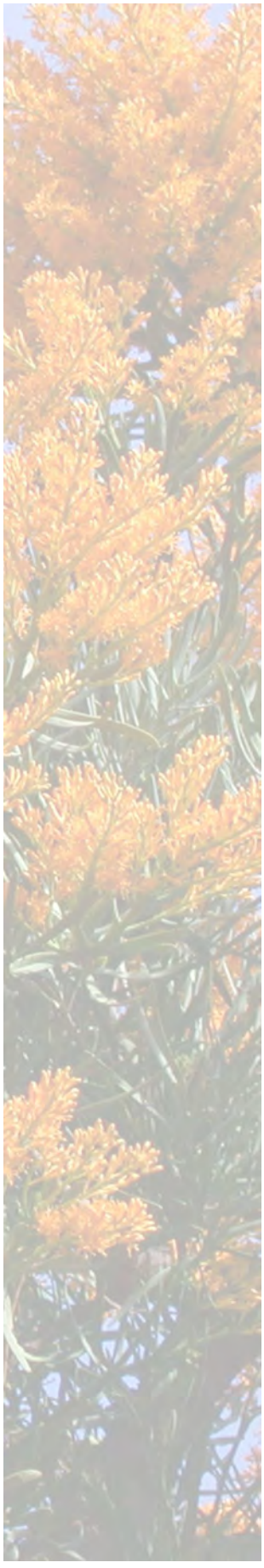


Figure 5.8-10: Rooting Architecture of Swan Coastal Plain Flora

5.8.5.4. Summary of Groundwater Dependent Ecosystems

The 70 sub-communities identified within the study area represent a construct of the various distributions of groundwater dependent species. Structurally, the sub-communities include closed sedgelands, closed tall scrub, woodlands, closed forest and open woodlands. Each sub-community and associated GDE indicator species has a 'living' requirement, based on both hydrology and the stratigraphy that underlies the community it occupies.



Indicator species are not limited or restricted to a particular position in the landscape (i.e. wetland or uplands), but are present due to a range of soil properties, wetting-drying cycles and depths to groundwater. This is not uncommon on the Swan Coastal Plain, particularly where deep-rooted genera such as *Banksia* are present. *Eucalyptus rudis*, for example, was found both within upland and wetland areas and *Kunzea glabrescens* was recorded in wetland areas and *Banksia* woodlands. This demonstrates that, for certain species, there is no single groundwater condition (depth or season) that is a prerequisite for growth and survival success. Responses to changes in groundwater availability are not consistent for all individuals of a species and can be site-specific (Zencich *et al*. 2002).

Groundwater use by vegetation has long been established (e.g. Dodd *et al*. 1984; Dodd and Bell 1993); however, establishing the degree of dependency is difficult (Groom 2004). The degree of dependency depends on the proximity of groundwater, availability of moisture in shallow horizons of the soil profile, root system distribution and maximum root depth (Zencich *et al*. 2002).

In summary, plants are dependent on local multiple water levels and a range of hydroperiods:

- The flushing of evaporative salts from the system;
- The present geographic locations and levels of conduits in the stratigraphic profiles, e.g. very coarse grading to fine sand layers in the nearby stratigraphy;
- The present distribution of iron enriched sediments; and
- Other geochemical properties of the subsurface materials.

5.8.6. Conclusion

The flora and vegetation survey highlights the following key findings for the project area:

- There are no *EPBC Act* listed flora, State listed DRF, TECs or PECs;
- 55 percent of vegetation surveyed was classified as being between 'Completely Degraded' and 'Degraded' (inclusive);
- 45 percent of vegetation surveyed is classified as intact native vegetation ('Degraded to Good' condition or better);
- 10 percent of vegetation surveyed is classified as 'Very Good' or 'Good to Very Good' condition;
- There was no evidence of *P. cinnamomi*;
- Six species of State Priority Flora were recorded;
- Weed invasion is identified to be relatively high, with 129 introduced or non-endemic and three Declared Plant species recorded;
- Two of the four vegetation complexes are currently below the 30% pre-European extent;
- Ten vegetation communities may be considered significant due to limited representation in a local context;
- The majority of vegetation that occurs within Bush Forever Site 244 is comprised of GDE communities that are well represented elsewhere in the region.

5.9. Fauna

Extensive fauna investigations have been undertaken in the project area in accordance with Guidance Statement 56, *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004c), Guidance Statement 20, *Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia* (EPA 2009c) and Position Statement 3, *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002). The fauna investigations were completed to:

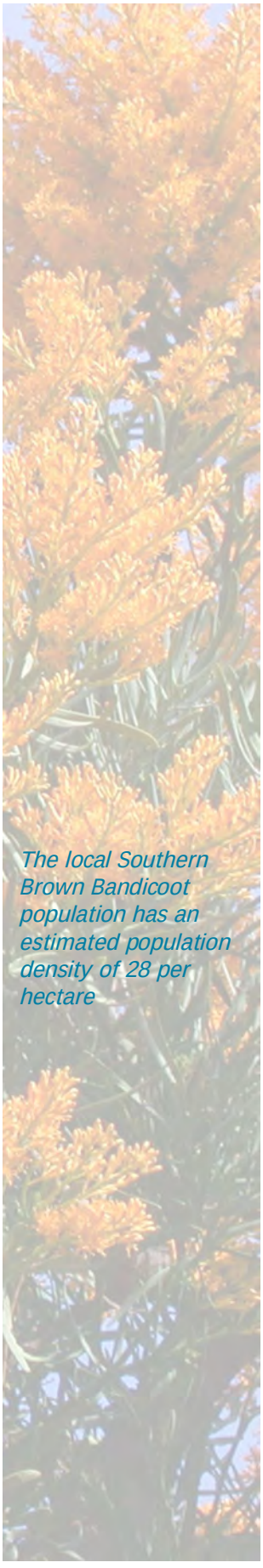
- Define the fauna species, assemblages and habitats of the project area;
- Identify conservation significant fauna and fauna habitats of the project area;
- Determine the potential impacts of the proposed project on relevant fauna species, assemblages and associated habitats; and
- Develop management and mitigation strategies to minimise, rectify and/or reduce fauna impacts.

A desktop study identified several fauna species of conservation significance as potentially occurring within the project area. The study comprised searches of the following databases:

- *EPBC Act* Protected Matters Database;
- DEC Priority and Threatened Fauna Database;
- DEC NatureMap; and
- Birds Australia Birdata Database.

Results from database searches and previous reports indicated that a total of 22 mammal (14 native and eight introduced), 177 native and five naturalised bird, 41 reptile and 14 amphibian species may utilise the project area. However, native fauna of the Swan Coastal Plain have been subject to significant pressures from urbanisation and habitat fragmentation, which have led to significant population declines. Database search results are likely to overestimate the number of vertebrate species that utilise the project area, due to the reliance on historical records. Subsequent to the desktop studies, extensive literature reviews were also undertaken for particular fauna investigations (summarised in Appendices M through T).

This chapter describes the fauna and associated habitats recorded within the project area. The chapter commences with a description of vertebrate fauna (Section 5.9.1) and wetland birds and shorebirds (Section 5.9.2). Invertebrate fauna are addressed in Section 5.9.3. The chapter concludes with a review of the fauna of conservation significance and their habitats (Section 5.9.4) and a summary of key findings of the studies (Section 5.9.5).



The local Southern Brown Bandicoot population has an estimated population density of 28 per hectare

5.9.1. Vertebrate Fauna

5.9.1.1. Systematic Vertebrate Fauna Surveys

A Level 2 vertebrate fauna survey was conducted in December 2009 and March 2010 (Appendix M). Six systematic bushland trapping sites were established: three sites within and three sites adjacent to the project area (Appendix M). The terrestrial fauna habitat was identified as being fairly similar across the project area, containing various forms of Jarrah-Marri-*Banksia* associations. Survey sites were selected on the basis of habitat condition, potential to support native fauna and representation of more distinct variations within the broad Jarrah-Marri-*Banksia* associations. The fauna habitats are well represented locally and regionally.

A Level 1 survey comprising a habitat assessment and reconnaissance was undertaken in May 2010 over the extended project area. Surveys were undertaken for 'significant' trees (potential breeding trees) as defined by the DSEWPaC for black cockatoos during both Level 2 and Level 1 surveys (December 2009 and May 2010). The location of every tree observed to have a diameter at breast height (DBH) of over 500mm was recorded and assessed for its potential to contain or develop suitable hollows for black cockatoo nesting. Additional surveys were conducted from June to December 2010 to assess potential nest hollows for evidence of nesting black cockatoos, specifically Carnaby's and Forest Red-tailed Black Cockatoos.

Black cockatoo foraging habitat was mapped, based on surveys conducted for evidence of feeding activity (March 2010 and May 2010). Targeted searches were also undertaken for potential roost sites within the project area in March 2010.

A Southern Brown Bandicoot monitoring programme was undertaken from May to December 2010 and is detailed in Appendix N. The main purpose of the study was to characterise the movement patterns of the Southern Brown Bandicoot population using the project area. The monitoring programme consisted of collecting information on population structure and morphology, breeding, reproductive status and movement patterns. The local Southern Brown Bandicoot population residing within and adjacent to the project area is at least 107 individuals, with an estimated population density of 28 per hectare.

Although Long-necked or Oblong Turtles (*Chelodina oblonga*) are not listed as species of conservation significance, they are considered to have local significance and are important to the local community and visitors to North and Bibra lakes. Accordingly, in response to community concerns, targeted Oblong Turtle surveys were undertaken in January 2011 (Appendix R).

5.9.1.2. Vertebrate Fauna Habitats of the Project Area

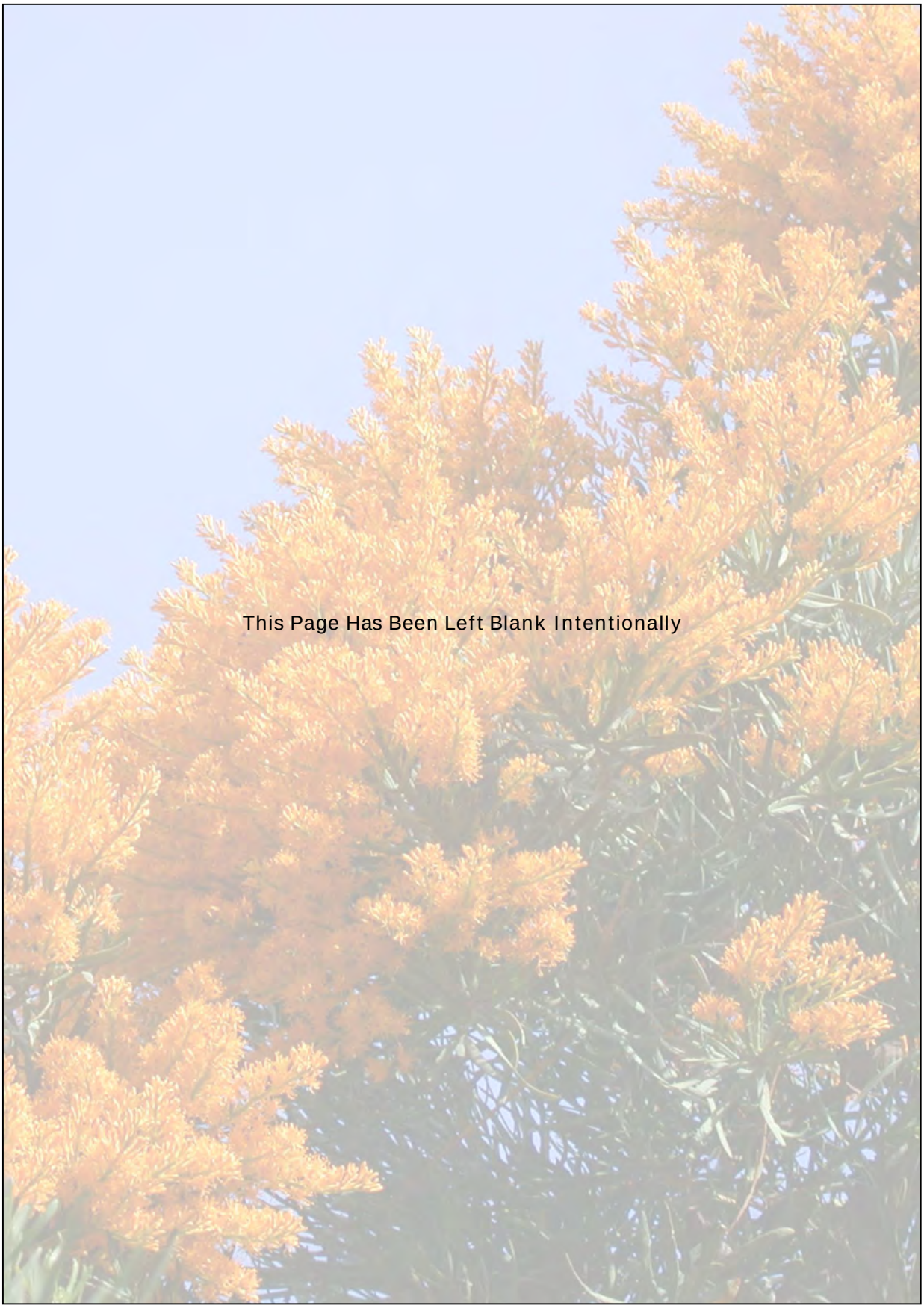
Most of the upland areas within the project area support fairly similar terrestrial fauna habitat, consisting of Jarrah-Marri-*Banksia* woodlands (Table 5.9-1, Figure 5.9-1). There are pockets of *Kunzea* shrublands, as well as small areas comprising man-made habitats (roadside batters, parkland and rehabilitated areas). The project area intersects riparian vegetation (mainly consisting of *Typha orientalis* with scattered *Juncus pallidus*) on the northern edge of Bibra Lake and the southern edge of Horse Paddock Swamp.

Table 5.9-1: Fauna Habitats

Habitat Type	Habitat Description	Corresponding Fauna Survey Sites[b]
Eucalyptus/ *Banksia* woodland	Generally an open woodland with *Eucalyptus marginata* over a low open woodland of *Banksia attenuata* and *Banksia menziesii* with variable overstorey and understorey assemblages including: open heath of *Hibbertia hypericoides* and *Xanthorrhoea preissii* over an open sedgeland of *Mesomelaena pseudostygia*	Sites 1
	Corymbia calophylla and *Allocasuarina* over low shrubland to low open shrubland, with grass trees common. Densities of various tree species varied across the site; some groves of *Allocasuarina*. Substrate of sandy soil	Site 4
	Open heath of *Allocasuarina humilis, Conostephium minus* and *Eremaea pauciflora* over an open grassland/sedgeland of *Amphipogon turbinatus* and *Mesomelaena pseudostygia* on grey sand	Site 6
Eucalyptus/ *Xanthorrhoea* woodland	Woodland of *Corymbia calophylla* and *Eucalyptus marginata* over *Xanthorrhoea preisii* and *Macrozamia riedlei* over a mixed grassland/herbland	Sites 2 and 3
Eucalyptus/ *Melaleuca* woodland	Woodland of *Eucalyptus rudis* and *Melaleuca preissiana* with occasional *Banksia attenuata*/ *Banksia littoralis*/ *Melaleluca rhaphiophylla* over a herbland/sedgeland or shrubland	Site 5[a]
Banksia woodland	Low open woodland of *Banksia attenuata* and *B. menziesii* over a tall shrubland of *Regilia ciliata* over a low shrubland of *Allocasuarina humilis* over an open sedgeland of *Mesomelaena pseudostygia* or grassland of introduced species on grey sand	Level 1 and 2 surveys
Kunzea shrublands	Open woodland of *Eucalyptus* spp. and/or *Melaleuca preissiana* and/or *Banksia illicifolia* over a tall shrubland to closed scrub of *Kunzea glabrescens* over an open herbland	Very small areas only, Site 1 adjacent to this habitat
Sedgeland	Closed sedgeland of *Typha domingensis, *Typha orientalis*, *Baumea vaginalis* and *Baumea articulata* on brown sandy loam	Level 1 survey only
Parkland	Cleared parkland consisting mainly of **Araucaria heterophylla, Eucalyptus gomphocephala, Melaleuca viminea, Xanthorrhoea preissii, Melaleuca nesophila, Callistemon phoeniceus* over grasses dominated mainly by **Cynodon dactylon* and **Pennisetum clandestinum*	Small areas only, Level 1 survey conducted
Riparian vegetation	Herbland of **Typha orientalis* with scattered *Juncus pallidus* surrounded by fringing wetland vegetation comprising of but not limited to *Melaleuca teretifolia*, *Eucalyptus camaldulensis*, *Melaleuca rhaphiophylla* and *Corymbia calophylla* on grey sand	Very small area, Level 2 surveys
Roadside batters (planted with non-local species)	Roadside batters, planted with non-local species such as *Eucalyptus erythrocorys*, *Leptospermum laevigatum*, *Acacia iteaphylla*, *Calothamnus* spp. over introduced grasses such as *Ehrharta calycina*	Small areas only, Level 1 survey conducted

[a]Site 5 intercepted both these habitat types

[b]See Appendix M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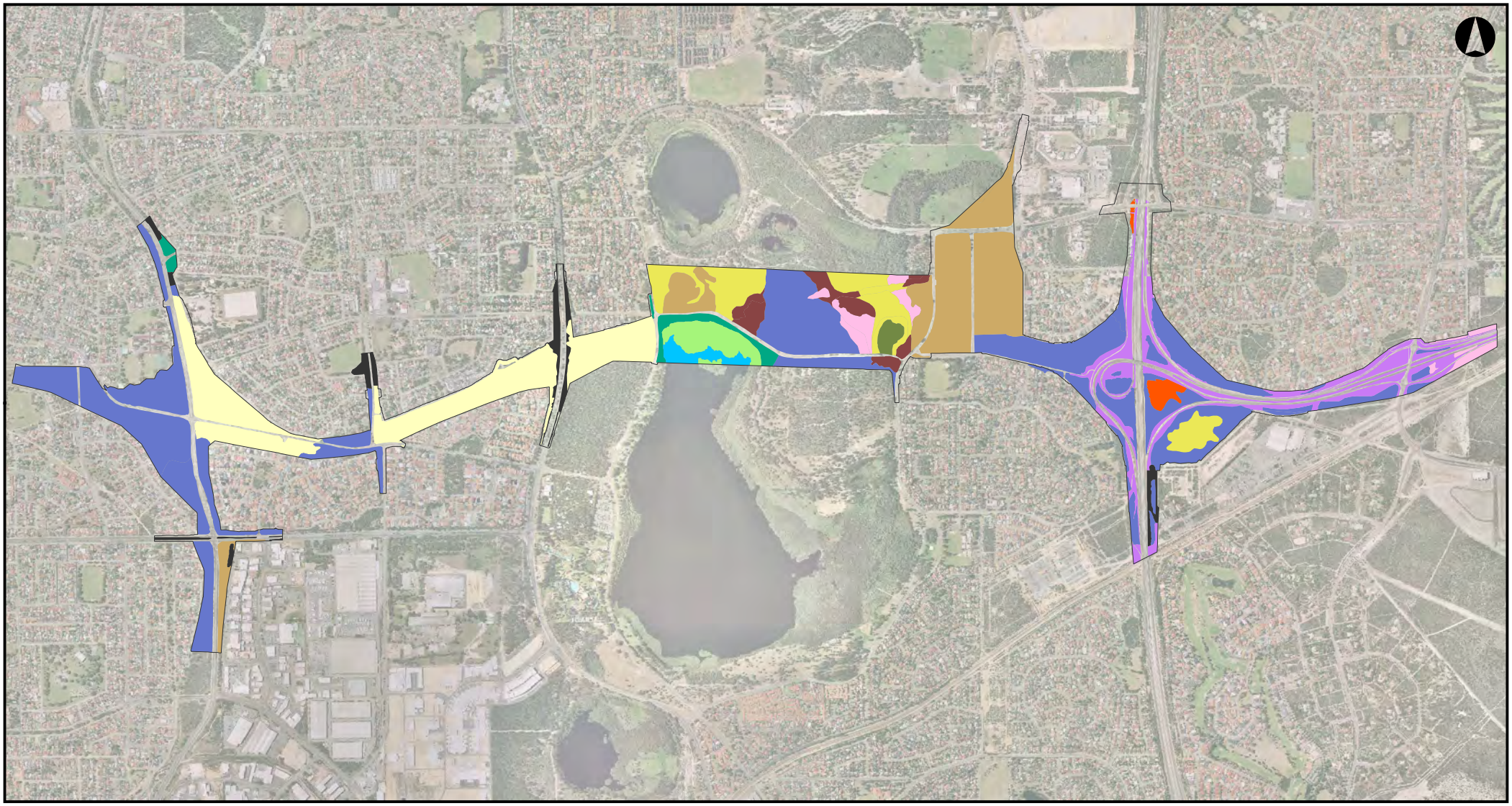

Major Vertebrate Fauna Terrestrial Habitats

South Metro Connect

Figure 5.9-1

0 250 500 750 1,000

Metres

1:28,000 (A4)

- *Banksia* woodland
- *Banksia* woodland in low lying areas
- Rehabilitated *Banksia* Woodlands
- Degraded low value habitat
- *Eucalyptus/Banksia* woodland
- *Eucalyptus/Melaleuca* woodland
- *Eucalyptus/Xanthorrhoea* woodland
- *Kunzea* shrublands
- Open Water/Lakebed
- Parkland
- Riparian Vegetation
- Roadside Batters (planted with non-local species)
- Sedgeland
- Project Area

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The vertebrate surveys recorded 120 native vertebrate species comprising up to eight amphibians, 83 birds, eight mammals and 21 reptiles

Survey results conducted in the past 15 years show considerably fewer recorded species in the area than indicated by older data sets

5.9.1.3. Survey Results

The vertebrate surveys (including native birds but excluding the results of the wetland bird investigation) recorded 120 native vertebrate species comprising up to eight amphibians, 83 birds, eight mammals and 21 reptiles (Table 5.9-2). Five introduced mammal species and five naturalised exotic bird species were also recorded. Although fish traps were set, no fish were recorded in the surveys. Approximately half of the species expected to occur within the study area (based on the desktop review) were positively recorded in the field surveys.

The results of surveys conducted in the past 15 years, within approximately 20km of the proposed project, show considerably fewer recorded species (particularly birds) in the area than indicated by older data sets. These local and recent surveys have recorded 21 mammal species (14 native and seven introduced), 131 bird species (including five naturalised exotics), 39 reptile species and eight amphibian species, with many of these records being infrequent. Furthermore, Birds Australia lists 116 species as occurring at Bibra Lake, fewer than documented in earlier records.

Table 5.9-2: Vertebrate Fauna Assemblage

Group	No. of Species Recorded in Vertebrate Fauna Surveys	No. of Species Recorded in Previous Studies[1]	No. of Species Expected to Occur in the Study Area[2]
Native Amphibians	8	7	11
Native Birds	83	126	177
Native Fish	0	0	1
Native Mammals	8	14	14
Introduced Mammals	5	7	7
Native Reptiles	21	39	41
Naturalised Exotic Birds	5	5	5
Total Native Fauna Species	120	186	244
Total Fauna Species	130	198	256

Source: Appendix M

[1] According to previous surveys within a 20km radius of study area

[2] Based on database searches and previous literature

Eight species of amphibians were recorded from three families: Myobatrachidae (four species), Limnodynastidae (two species) and Hylidae (two species) (Table 5.9-3). An individual from the *Crinia* genus was recorded that could not be identified to species level, but is most likely one of the three recorded *Crinea* species. The recorded amphibian assemblage accounts for approximately two-thirds of the amphibian species expected to occur over the study area. None of the recorded amphibian species are conservation significant.

Eighty three native avifauna species from 35 families were recorded (Table 5.9-3). Thirty-one of these species are wetland birds. The most speciose families were Anatidae (ducks) and Meliphagidae (honeyeaters), with ten and seven species recorded, respectively. Based on Birds Australia records, just over half of the total complement of avifauna species likely to occur was recorded. Two conservation significant species were recorded: Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*) and Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*). Four species listed as Migratory under the *EPBC Act* were also recorded: Eastern Osprey, Eastern Great Egret, Glossy Ibis and Rainbow-Bee-eater.

Carnaby's and Forest Red-tailed Black Cockatoos were recorded within the project area

A number of 'significant' species have been listed under the habitat conservation programme Bush Forever as 'of concern' or locally extinct on the Swan Coastal Plain, within the Perth Metropolitan Region (WAPC 2000b). These include birds that are habitat specialists and declining in distribution; as well as wide-ranging birds with reduced populations on the Swan Coastal Plain. Twenty two bird species of regional significance were recorded during surveys.

Eight native mammal species were recorded, including five bats representing two families: Molossidae and Vespertilionidae (Table 5.9-3). The remaining three recorded native mammals were from three different families: Southern Brown Bandicoot (*Isoodon obesulus fusciventer*) from the family Peramelidae, Common Brushtail Possum (*Trichosurus vulpecula*) from the family Phalangeridae and Western Grey Kangaroo (*Macropus fuliginosus*) from the family Macropodidae. The Southern Brown Bandicoot is rated by the State as a Priority 5 listed species. The recorded native mammal assemblage represents just over half the native mammal species expected to occur.

Five recorded introduced mammals include the Black Rat (*Rattus rattus*), an unidentified rat species, the European Rabbit (*Oryctolagus cuniculus*), European Red Fox (*Vulpes vulpes*) and House Mouse (*Mus musculus*). The five naturalised exotic birds recorded were the Rock Dove (*Columba livia*), Laughing Dove (*Streptopelia senegalensis*), Spotted Dove (*Streptopelia chinensis*), Laughing Kookaburra (*Dacelo novaeguineae*) and Rainbow Lorikeet (*Trichoglossus haematodus*).

Five introduced mammals and five exotic birds were recorded during project surveys

Twenty-one reptile species were recorded from six families (Table 5.9-3). The most speciose family was Scincidae, with 12 skink species recorded. The remainder of the assemblage consisted of four legless lizards, two snakes, one gecko and one dragon. Secondary evidence (carapaces) of the Oblong Turtle was recorded. One conservation significant species recorded during the surveys was identified to be the Perth Lined Lerista (*Lerista lineata*). A detailed list of species and numbers of individuals recorded in each habitat type is provided in Appendix M.

Out of the 21 reptiles recorded during project surveys, one is designated as conservation significant – Perth Lined Lerista

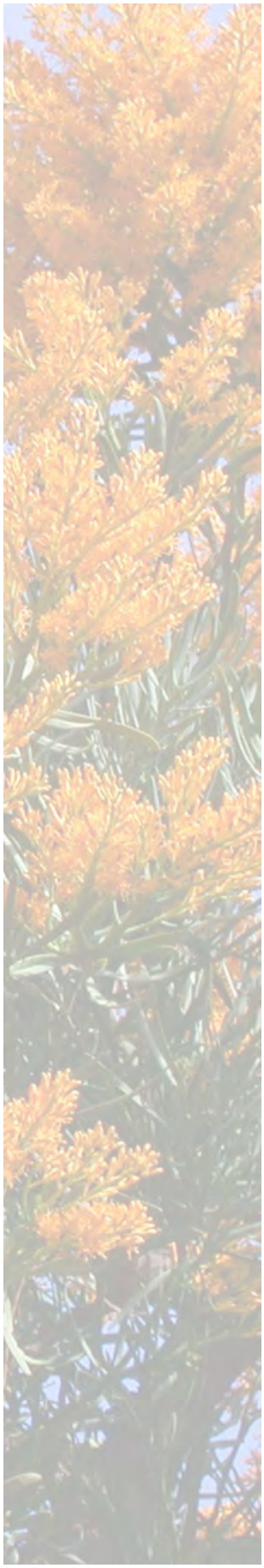
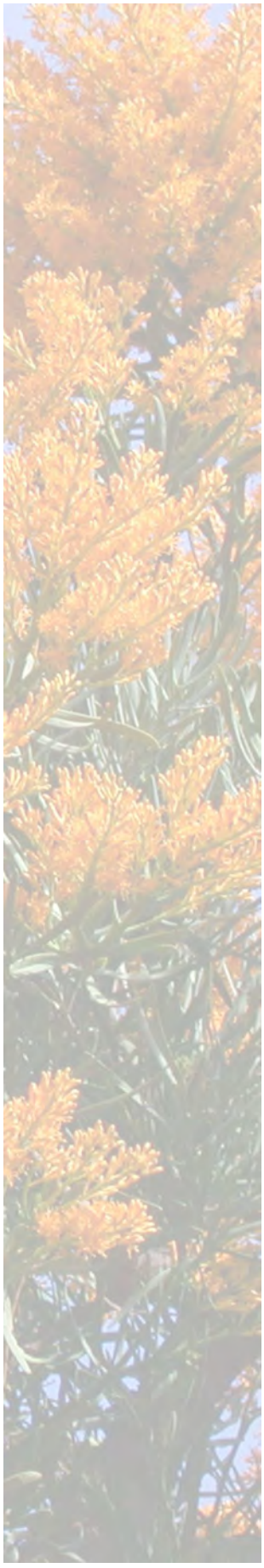


Table 5.9-3: Vertebrate Fauna Species Recorded

Family	No. of Species	Species
Amphibians (8 Species)		
Myobatrachidae	4	Quacking Frog (*Crinia georgiana*), Clicking Froglet (*Crinia glauerti*), Squelching Froglet (*Crinia insignifera*) and Turtle Frog (*Myobatrachus gouldii*)
Limnodynastidae	2	Moaning Frog (*Heleioporus eyrie*) and Western Banjo Frog (*Limnodynastes dorsalis*)
Hylidae	2	Motorbike Frog (*Litoria moorei*) and Slender Tree Frog (*Litoria adelaidensis*)
Birds (83 Species)		
Acanthizidae	6	Inland Thornbill (*Acanthiza apicalis*), Yellow-rumped Thornbill (*Acanthiza chrysorrhoa*), Western Thornbill (*Acanthiza inornata*), Western Gerygone (*Gerygone fusca*), White-browed Scrubwren (*Sericornis frontalis*), Weebill (*Smicrornis brevirostris*)
Accipitridae	6	Brown Goshawk (*Accipiter fasciatus*), Wedge-tailed Eagle (*Aquila audax*), Swamp Harrier (*Circus approximans*), Black-shouldered Kite (*Elanus notatus*), Whistling Kite (*Haliastur sphenurus*), Eastern Osprey (*Pandion haliaetus*)
Acrocephalidae	1	Australian Reed-Warbler (*Acrocephalus australis*)
Aegothelidae	1	Australian Owlet-nightjar (*Aegotheles cristatus*)
Anatidae	10	Chestnut Teal (*Anas castanea*), Grey Teal (*Anas gracilis*), Australasian Shoveler (*Anas rhynchotis*), Pacific Black Duck (*Anas superciliosa*), Musk Duck (*Biziura lobata*), Black Swan (*Cygnus atratus*), Pink-eared Duck (*Malacorhynchus membranaceus*), Blue-billed Duck (*Oxyura australis*), Radjah Shelduck (*Tadorna radjah*), Australian Shelduck (*Tadorna tadornoides*)
Anhingidae	1	Australasian Darter (*Anhinga novaehollandiae*)
Ardeidae	3	Eastern Great Egret *(Ardea modesta*), White-faced Heron (*Egretta novaehollandiae*), Nankeen Night-Heron (*Nycticorax caledonicus*)
Artamidae	3	Dusky Woodswallow (*Artamus cyanopterus*), Grey Butcherbird (*Cracticus torquatus*), Australian Magpie (*Gymnorhina tibicen dorsalis*)
Cacatuidae	5	Galah (*Cacatua roseicapillus*), Little Corella (*Cacatua sanguinea*), Corella sp. (*Cacatua* sp.), Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*), Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*)
Camphephagidae	1	Black-faced Cuckoo-Shrike (*Coracina novaehollandiae*)
Charadridae	1	Black-fronted Dotterel (*Charadrius melanops*)
Columbidae	1	Crested Pigeon (*Ocyphaps lophotes*)
Corvidae	1	Australian Raven (*Corvus coronoides*)
Cuculidae	1	Shining Bronze-Cuckoo (*Chalcites lucid*us)
Falconidae	2	Nankeen Kestrel (*Falco cenchroides*), Australian Hobby (*Falco longipennis*)
Halcyonidae	1	Sacred Kingfisher (*Todirhamphus sanctus*)
Hirundinidae	2	Welcome Swallow (*Hirundo neoxena*), Tree Martin (*Hirundo nigricans*)
Laridae	1	Silver Gull (*Larus novaehollandiae*)
Maluridae	1	Splendid Fairy-Wren (*Malurus splendens*)

Family	No. of Species	Species
Meliphagidae	7	Western Spinebill (*Acanthorhynchus superciliosus*), Red Wattlebird (*Anthochaera carunculata*), Western Wattlebird (*Anthochaera lunulata*), Singing Honeyeater (*Lichenostomus virescens*), Brown Honeyeater (*Lichmera indistincta*), White-cheeked Honeyeater (*Phylidonyris nigra*), New Holland Honeyeater (*Phylidonyris novaehollandiae*)
Meropidae	1	Rainbow Bee-eater (*Merops ornatus*)
Monarchidae	1	Magpie-Lark (*Grallina cyanoleuca*)
Neosittidae	1	Varied Sittella (*Daphoenositta chrysoptera pileata*)
Pachycephalidae	2	Grey Shrike-Thrush (*Colluricincla harmonica*), Rufous Whistler (*Pachycephala rufiventris*)
Pardalotidae	2	Spotted Pardalote (*Pardalotus punctatus*), Striated Pardalote (*Pardalotus striatus*)
Pelecanidae	1	Australian Pelican (*Pelecanus conspicillatus*)
Phalacrocoracidae	2	Great Cormorant (*Phalacrocorax carbo*), Little Pied Cormorant (*Phalacrocorax melanoleucos*)
Podicipedidae	1	Hoary-headed Grebe (*Poliocephalus poliocephalus*)
Psittacidae	3	Australian Ringneck (*Barnardius zonarius*), Elegant Parrot (*Neophema elegans*), Red-capped Parrot (*Purpureicephalus spurius*)
Rallidae	4	Eurasian Coot (*Fulica atra*), Black-tailed Native-Hen (*Galinula ventralis*), Dusky Moorhen (*Gallinula tenebrosa*), Purple Swamphen (*Porphyrio porphyrio*)
Recurvirostridae	2	Black-winged Stilt (*Himantopus himantopus*), Red-necked Avocet (*Recurvirostra novaehollandiae*)
Rhipiduridae	2	Grey Fantail (*Rhipidura albiscapa*), Willie Wagtail (*Rhipidura leucophrys*)
Strigidae	1	Southern Boobook (*Ninox novaeseelandiae*)
Threskiornithidae	4	Yellow-billed Spoonbill (*Platalea flavipes*), Glossy Ibis (*Plegadis falcinellus*), Straw-necked Ibis (*Threskiornis spinicollis*), Australian White Ibis (*Threskiornis molucca*)
Timaliidae	1	Silvereye (*Zosterops lateralis*)
Naturalised Exotic Birds (5 Species)		
Columbidae	3	Rock Dove (*Columba livia*), Laughing Dove (*Streptopelia senegalensis*), Spotted Dove (*Streptopelia chinensis*)
Halcyonidae	1	Laughing Kookaburra (*Dacelo novaeguineae*)
Psittacidae	1	Rainbow Lorikeet (*Trichoglossus haematodus*)
Native Mammals (8 Species)		
Macropodidae	1	Western Grey Kangaroo (*Macropus fuliginosus*)
Molossidae	2	South-western Free-tailed Bat (*Mormopterus* sp. 4), White-striped Free-tailed Bat (*Tadarida australis*)
Peramelidae	1	Southern Brown Bandicoot (*Isoodon obesulus fusciventer*)
Phalangeridae	1	Common Brushtail Possum (*Trichosurus vulpecula*)
Vespertillionidae	3	Gould's Wattled Bat (*Chalinolobus gouldii*), Lesser Long-eared Bat (*Nyctophilus geoffroyi*), Southern Forest Bat (*Vespadelus regulus*)



Family	No. of Species	Species
Introduced Mammals (5 Species)		
Canidae	1	European Red Fox (*Vulpes vulpes*)
Leporidae	1	European Rabbit (*Oryctolagus cuniculus*)
Muridae	3	House mouse (*Mus musculus*), Black Rat (*Rattus rattus*), Rat sp. (*Rattus* sp.)
Reptiles (21 Species)		
Agamidae	1	Western Bearded Dragon (*Pogona minor*)
Cheluidae	1	Oblong Turtle (*Chelodina oblonga*)
Elapidae	2	Tiger Snake (*Notechis scutatus*), Dugite (*Pseudonaja affinis*)
Gekkonidae	1	Marbled Gecko (*Christinus marmoratus*)
Pygopodidae	4	Sand-plain Worm Lizard (*Aprasia repens*), Burton's Snake-Lizard (*Lialis burtonis*), West Coast Keeled Legless Lizard (*Pletholax gracilis gracilis*), Southern Scaly Foot (*Pygopus lepidopodus*)
Scincidae	12	South-western Cool Skink (*Acritoscincus trilineatum*), Buchanan's Snake-eyed Skink (*Cryptoblepharus buchananii*), West-coast Long-tailed Ctenotus (*Ctenotus australis*), West Coast Ctenotus (*Ctenotus fallens*), South-western Crevice Skink (*Egernia napoleonis*), Shrubland Pale-flecked Morethia (*Morethia obscura*), Perth Lined Lerista (*Lerista lineata*), West Coast Four-toed Lerista (*Lerista elegans*), Two-toed Mulch Skink (*Hemiergis quadrilineata*), Common Dwarf Skink (*Menetia greyii*), West Coast Pale-flecked Morethia (*Morethia lineoocellata*), Western Bobtail (*Tiliqua rugosa rugosa*)

Source: Appendix M

Twenty three adult Oblong Turtles were captured and an additional 37 were sited at Bibra Lake. Based on these results it is estimated that approximately 168 of these turtles occupy Bibra Lake. Although none were found in North Lake, anecdotal evidence and opportunistic findings (turtle remains) suggest that they have been present in the area.

5.9.2. Wetland Birds and Shorebirds

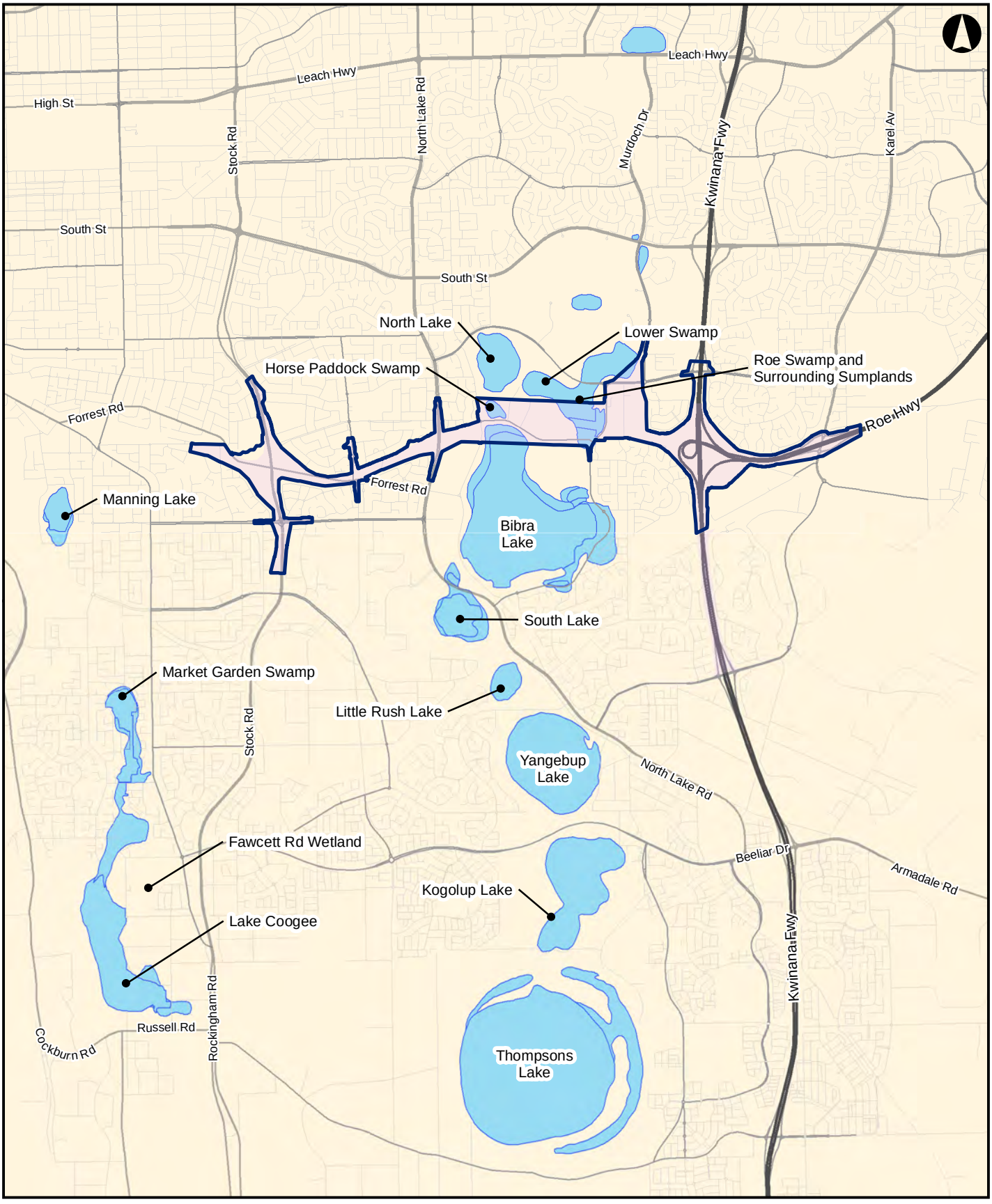
Wetland and shorebird surveys were conducted between August 2009 and July 2010 (Appendix O). Bird surveys were carried out at 13 of the Beeliar Wetlands for wetland and shorebird species (Figure 5.9-2), as they are widely recognised as providing important habitat for wetland and migratory birds on the Swan Coastal Plain. As over 70 percent of wetlands in the area have been lost or extensively modified over the past 150 years (Storey *et al*. 1993), the remaining wetlands have acquired an increased importance as habitat. In 1989, the EPA reported on discussions with the Royal Australasian Ornithological Union (RAOU, presently Birds Australia) about the significance of various Beeliar Wetlands to waterbirds (EPA 1989). Notes from these discussions pointed out the importance of Yangebup Lake (for supporting high numbers of Pink-eared and Blue-billed Ducks), Bibra Lake (for high waterbird diversity and high numbers of Hoary-headed Grebes) and North Lake (as an important breeding area for ducks).

Wetland birds have been determined to be those that rely on wetlands for most of their needs and are most likely to use the shallow wetlands of the Beeliar Wetland Chain. Shorebirds were generally considered to be the members of the families Charadridae and Scolopacidae, and include plovers, godwits, sandpipers, tattlers and stints. Shorebirds are typically found on beaches, estuaries, saltwater and freshwater wetlands, with some species mainly preferring coastal environments and others using a range of inland wetlands. Many shorebird species are international migrants, but some are sedentary or make movements within Australia. Migratory shorebirds have been defined as those species that are listed as Migratory under the *EPBC Act*.

Surveys were undertaken from August 2009 to July 2010 with the 13 wetlands surveyed on the same day, in order to reduce the error due to birds moving between wetlands between days. Of the 13 wetlands surveyed, four are located within and/or adjacent to the project area: North and Bibra lakes, Lower Swamp and Horse Paddock Swamp. Details of survey methodology are described in Appendix O.

Bibra Lake is recognised for its high water bird diversity

North Lake is an important breeding area for ducks



Wetland Bird and Shorebird Study Area

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Figure 5.9-2

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Kilometres

1:60,000 (A4)

Datum: GDA94 Projection: MGA z50

Project Area

Geomorphic Wetlands

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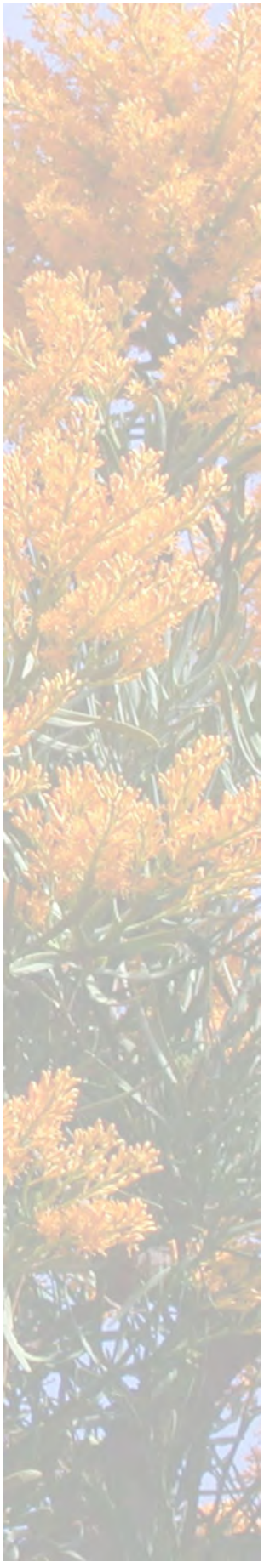
5.9.2.1. Wetland Bird and Shorebird Habitat

The 13 wetlands surveyed in the wetland bird and shorebird survey range from large permanently wet lakes to small seasonal sumplands (Table 5.9-4). Salinity in the wetlands varies from fresh to saline.

Table 5.9-4: Description of Wetlands Surveyed

Wetland	Type	Area (ha)	Description
Bibra Lake	Lake	188.7	Large, open freshwater wetland, usually with permanent open water. Fringing vegetation of rushes and woodlands. Open parkland on southern edge
Horse Paddock Swamp	Lake	3.2	Small, open freshwater wetland, usually with seasonal open water. Partly cleared
Kogolup Lake	Sumpland	72.4	Large, open freshwater wetland, usually with permanent open water. Fringing vegetation of rushes and woodlands
Lake Coogee	Lake	62.9	Large, open saltwater wetland, usually with permanent open water. Fringing vegetation of samphire, rushes and woodlands
Fawcett Road Wetland	Sumpland	4.4	Small, open freshwater wetland, usually with seasonal open water. Fringing vegetation of samphire, rushes and woodlands. Semi-rural properties border the south-western edge
Little Rush Lake	Sumpland	11.2	Medium, open freshwater wetland, usually with seasonal open water. Fringing vegetation of rushes and woodlands
Manning Lake	Lake	14.9	Medium, open freshwater wetland, usually with permanent open water. Fringing vegetation of rushes and woodlands
Market Garden Swamp	Sumpland	4.8	Small, densely vegetated freshwater wetland with some open water. Fringing vegetation of samphire, rushes and woodlands
North Lake	Lake	24.6	Medium, open freshwater wetland, usually with seasonal open water. Fringing vegetation of rushes and woodlands
Roe Swamp (including Lower Swamp)	Sumpland	12.0	Medium, densely vegetated freshwater wetland with little open water. Fringing vegetation of rushes and woodlands
South Lake	Sumpland	31.5	Medium, open freshwater wetland, usually with seasonal open water. Fringing vegetation of rushes and woodlands
Thomsons Lake	Lake	244.3	Large, open freshwater wetland, usually with seasonal open water. Fringing vegetation of rushes and woodlands
Yangebup Lake	Lake	89.9	Large, open freshwater wetland, usually with permanent open water. Fringing vegetation of rushes and woodlands

Source: Appendix O



Riparian and groundwater dependent vegetation form key habitat for wetland birds. The project area encompasses riparian vegetation on the northern edge of Bibra Lake and the southern edge of Horse Paddock Swamp. It also intersects part of Roe Swamp, although this is not near the open bed of Lower Swamp and follows an existing transmission line corridor. Riparian vegetation may support many wetland bird species that may forage, roost and breed in this habitat. Of particular importance are:

- *Melaleuca* woodlands, which may support roosting habitat for species, such as the Nankeen Night Heron;
- Emergent rushes, which provide shelter and breeding habitat for many species, particularly ducks, crakes, rails, reed-warblers and grassbirds. They may also support conservation significant species such as bitterns; and
- Eucalypt woodland up to 1km from wetlands for roosting sites for various duck species.

5.9.2.2. Bird Species Richness

The wetland and shorebird species of the Beeliar Wetland Chain are represented by the following 15 families:

- Anatidae (ducks and swans);
- Podicipedidae (grebes);
- Anhingidae (darters);
- Phalacrocoracidae (cormorants);
- Pelecanidae (pelicans);
- Ardeidae (bitterns, egrets and herons);
- Threskiornithidae (ibis and spoonbills);
- Rallidae (crakes, rails and allies);
- Recurvirostridae (stilts and avocets);
- Charadridae (plovers and dotterels);
- Rostratulidae (Painted snipe);
- Scolapacidae (godwits, sandpipers, stints and other shorebirds);
- Laridae (gulls and terns);
- Acrocephalidae (acrocephalid warblers); and
- Megaluridae (megalurid warblers).

The highest known species richness was recorded at Thomsons Lake, with 71 species identified, followed by Bibra Lake and Yangebup Lake, with 66 and 65 species counted, respectively (Table 5.9-5). In the 2009–2010 study, the highest species richness was also recorded at these three wetlands (Appendix O).

During a 1990–1992 study of 251 Swan Coastal Plain wetlands, Thomsons Lake, Kogolup Lake, Yangebup Lake and Bibra Lake ranked 2nd, 7th, 10th and 11th, respectively, for species richness (Storey *et al.* 1993). This indicates that these wetlands are regionally significant for the number of waterbird species present. In general, the larger the wetland, the more species they support. These species-rich wetlands are also the largest. In addition, these wetlands tend to support a high number of migratory shorebirds (Appendix O).

Of the wetlands within the project area, North and Bibra lakes consistently rank high in species richness in the surveys, while Horse Paddock and Lower Swamps rank relatively low.

North and Bibra lakes rank high for bird species richness and total bird count; while Horse Paddock Swamp ranks low

Table 5.9-5: Wetlands Ranked by Total Species Richness

Wetland	Total Bird Species Richness	Species Richness in Each Survey		
		2009–2010[a]	1990–1992[b]	1981–1988[c]
Thomsons Lake	71	43	47	66
Bibra Lake	66	45	35	48
Yangebup Lake	65	43	36	48
North Lake	57	26	29	30
Kogolup Lake	56	40	39	37
Lake Coogee	50	31	-	17
Little Rush Lake	43	30	-	19
South Lake	40	28	-	23
Market Garden Swamp	33	27	-	-
Manning Lake	32	20	-	23
Lower Swamp	23	11	-	22
Horse Paddock Swamp	23	0	17	22
Fawcett Rd Wetland	13	18	-	-

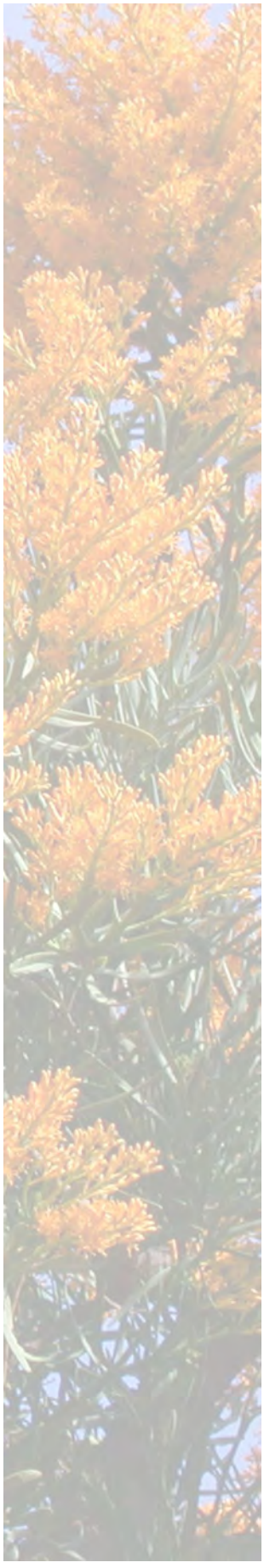
Source: Appendix O

[a] current study

[b] Storey *et al.* (1993)

[c] WetlandBase (2010)

- Not surveyed.



5.9.2.3. Highest Total Bird Count

The highest total count of waterbirds on a wetland indicates the maximum number that a wetland can support. In the present studies, summarised in Table 5.9-6, Bibra Lake and Thomsons Lake ranked in the top three wetlands for supporting high numbers of birds. In the 2009–2010 study, Bibra Lake ranked highest with a count of 9,947 birds (Appendix O). However, in the 1980s up to 22,196 birds were recorded at Thomsons Lake. In general, the smaller wetlands support lower total counts of birds. No birds were recorded in the Horse Paddock Swamp during 2009 and 2010 as it was dry, yet historical studies indicate that the swamp, in the past, has supported a moderate number of birds.

Of the wetlands within the project area, North and Bibra lakes consistently rank high over most surveys in highest total count, although the highest count at North Lake is lower than at Bibra Lake. Horse Paddock and Lower swamps generally rank the lowest of the surveyed wetlands.

Table 5.9-6: Wetlands Ranked by Highest Total Count in 2009-2010

Wetland	Rank	Highest Total Count (Rank)			
		2009–2010[a]	1999–2009[b]	1990–1992[c]	1981–1988[d]
Bibra Lake	1	9,947	3,378 (3)	7,598 (2)	8,848 (2)
Thomsons Lake	2	4,696	11,525 (1)	18,472 (1)	22,196 (1)
Yangebup Lake	3	1,758	3,897 (2)	1,404 (4)	4,976 (3)
North Lake	4	1,357	-	521 (5)	1,449 (4)
Lake Coogee	5	792	-	-	398 (6)
Kogolup Lake	6	670	1,281 (4)	1,732 (3)	273 (8)
South Lake	7	430	-	-	165 (9)
Manning Lake	8	379	-	-	397 (7)
Little Rush Lake	9	300	-	-	59 (11)
Market Garden Swamp	10	163	-	-	-
Fawcett Rd Wetland	11	99	-	-	-
Lower Swamp	12	28	-	147 (7)	156 (10)
Horse Paddock Swamp	13	0	-	178 (6)	604 (5)

Source: Appendix O

[a]current study

[b]Bamford (2009)

[c]Storey *et al.* (1993)

[d]WetlandBase (2010)

- Not surveyed.

5.9.2.4. Conservation Significant Bird Species

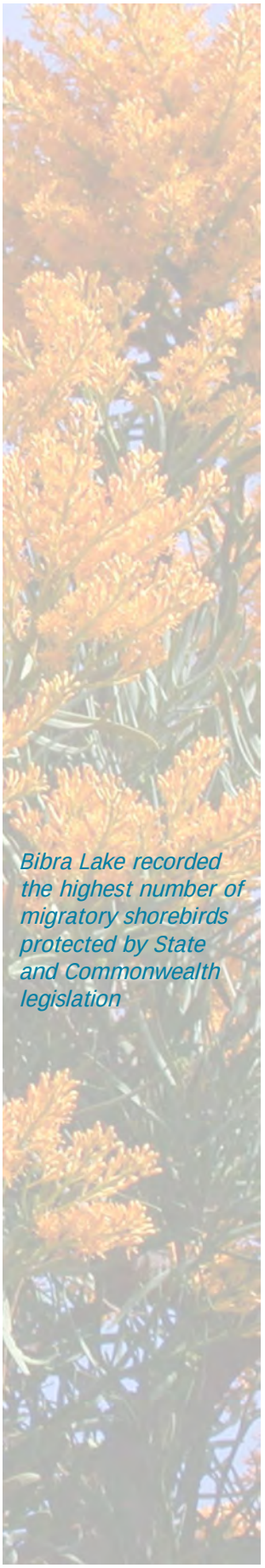
Conservation significant species recorded in the wetland and shorebird surveys are divided into three categories:

- CS1 species are protected under State or Commonwealth legislation (including migratory species under the *EPBC Act*);
- CS2 species are listed as Priority species by the DEC and considered regionally significant; and
- CS3 species are those that are considered to be of local significance.

Thomsons Lake supports the highest number of conservation significant species, with an overall total of 31 species (Table 5.9-7). Yangebup Lake, Bibra Lake and Kogolup Lake supported more than 20 conservation significant species. Small wetlands such as Fawcett Road Wetland and Lower Swamp were found to support few conservation significant species. This may be related to their small area, and to the lack of waterbird data in sources such as Storey *et al.* (1993) and Jaensch *et al.* (1988). Smaller wetlands also lack expanses of open lakebed suitable for foraging of conservation significant migratory shorebirds.

Although the number of conservation significant birds present is important, some wetlands have significance for supporting one species in particular. For example, Thomsons Lake is the only site in the study area (possibly on the Swan Coastal Plain) where the Australasian Bittern (CS1) has been recorded (CALM 2003; CALM 2005a; Jaensch *et al.* 1988), as well as one of the few wetlands where the Australian Little Bittern (CS2) has been recorded (Birds Australia Atlas Database 2010). Kogolup Lake supports the Australian Little Bittern and has the only breeding record for this species in the study area.

Of the wetlands within the project area, Bibra Lake ranks the highest (3rd), with North Lake ranking 5th. Horse Paddock and Lower Swamps were found to support relatively few conservation significant species during the 2009–2010 survey.



Bibra Lake recorded the highest number of migratory shorebirds protected by State and Commonwealth legislation

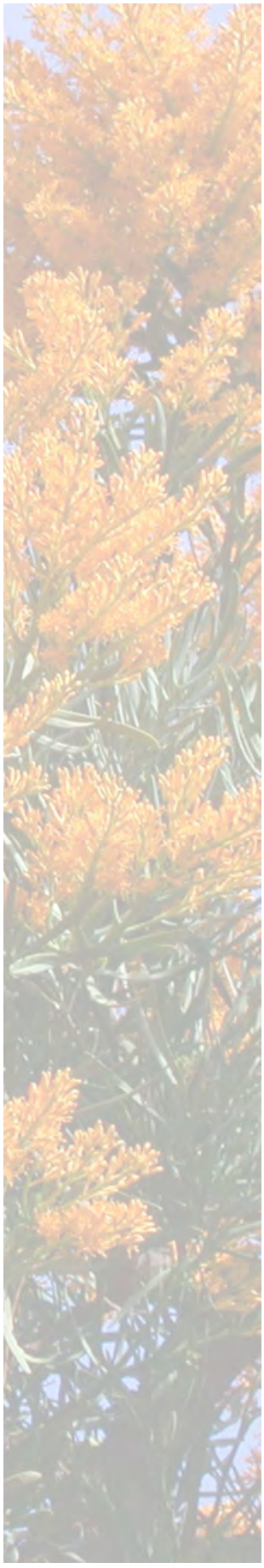


Table 5.9-7: Wetlands Ranked by Total Number of Conservation Significant Species

Wetland	Rank	Total CS Species	Number of Each CS Category		
			CS1	CS2	CS3
Thomsons Lake	1	31	20	2	9
Yangebup Lake	2	24	14	1	9
Bibra Lake	3	23	13	1	9
Kogolup Lake	4	22	12	1	9
North Lake	5	19	10	0	9
Lake Coogee	6	18	11	0	7
South Lake	7	15	5	0	10
Little Rush Lake	8	12	5	0	7
Manning Lake	9	10	2	0	8
Market Garden Swamp	10	9	2	0	7
Horse Paddock Swamp	11	7	2	0	5
Lower Swamp	12	6	1	0	5
Fawcett Rd Wetland	13	3	0	0	3

Source: Appendix O

CS - Conservation Significant

5.9.2.5. Migratory Shorebirds

Migratory shorebirds undertake annual migrations of thousands of kilometres (some in excess of 20,000km) between breeding areas in the Arctic to non-breeding areas of Australia, Asia, Africa and South America (Bamford *et al*. 2008). Shorebird migrants from the northern hemisphere typically arrive in Australia during September to November. They are known to use offshore islands as stopover or staging sites before dispersing to intertidal flats on the mainland, coastal areas or freshwater wetlands and grasslands (Table 5.9-8). Shorebirds typically spend the Australian summer in these habitats, building up stores of fat, and leave for the northward migration between February and April.

Some individuals remain in Australia during the breeding season (May to August). Typically, these individuals are too old, too young or did not accumulate enough fat reserves to make the return migration. Population numbers of some shorebirds are therefore more abundant during the non-breeding season (summer) rather than the breeding season (winter). Northward migration to the Arctic breeding grounds takes place between March and April, where waders capitalise on abundant food during the brief summer (Bamford *et al*. 2008).

Table 5.9-8: Migration Routes and Timing

Migration Direction and Breeding Period	Route/Location	Timing
Southward/ Non-breeding	Northern Hemisphere → Southern Hemisphere (Siberia → Australia)	September to November
Non-breeding	Southern Hemisphere (Australia)	December to January
Northward/ Non-breeding	Southern Hemisphere → Northern Hemisphere (Australia → Siberia)	February to April
Breeding	Northern Hemisphere (Siberia)	May to August

Source: Appendix O

The surveyed wetlands are ranked by the average number of migratory shorebirds recorded (Table 5.9-9). The numbers presented in Table 5.9-9 are based on a small number of studies.

Thomsons Lake in most years supports high numbers of migratory shorebirds, with the exception of 2009 and 2010. This may be due to below average rainfall in the 1990s, resulting in the lake drying too quickly in the summer months (Bancroft and Bamford 2009). However, Thomsons Lake is recognised as an important site for shorebirds (Bamford *et al.* 2008).

Yangebup Lake supported moderate numbers of migratory shorebirds in the 1980s, but recent records are limited. The remaining wetlands support low or negligible numbers of migratory shorebirds.

Of the wetlands within the project area, Bibra Lake recorded the highest number of CS1 migratory shorebirds in the current survey. North Lake, Horse Paddock Swamp and Lower Swamp provided only two records collectively.

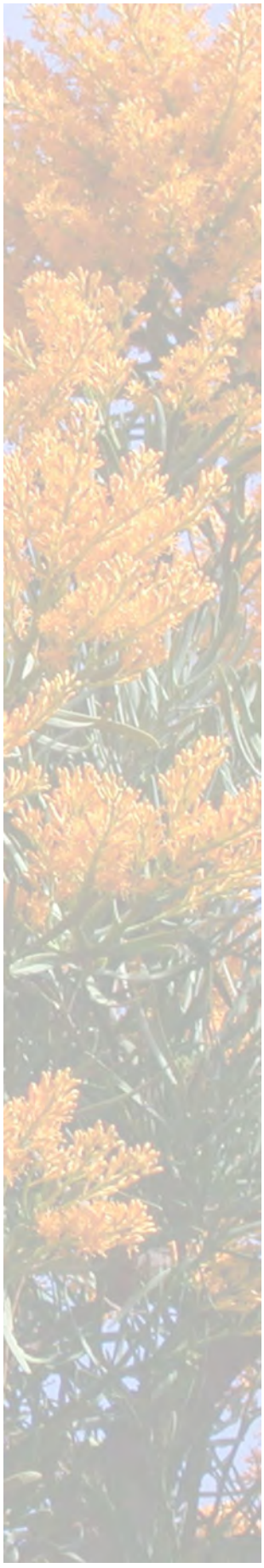


Table 5.9-9: Wetlands Ranked by Mean Total Abundance of CS1 Migratory Shorebirds

Wetland	Rank	Mean Abundance	Maximum Total Count in Each Study (Rank)			
			2009–2010[a]	1999–2009[b]	1990–1992[c]	1981–1988[d]
Thomsons Lake	1	1,542.5	25 (2)	15 (2)	681 (1)	5,449 (1)
Yangebup Lake	2	387.8	1	0	18 (2)	1,532 (2)
Bibra Lake	3	30.0	42 (1)	71 (1)	0	7
Kogolup Lake	4	12.0	9 (3)	2 (3)	14 (3)	23 (3)
Little Rush Lake	5	4.5	9 (3)	-	-	0
Lake Coogee	6	3.5	1	-	-	6
South Lake	7	2.0	2	-	-	2
Lower Swamp	8	1.0	0	-	0	3
North Lake	9	0.7	2	-	0	0
Manning Lake	10	0.5	0	-	-	1
Horse Paddock Swamp	11	0.3	0	-	0	1
Market Garden Swamp	12	0	0	-	-	-
Fawcett Rd Wetland	12	0	0	-	-	-

Source: Appendix O

[a]current study, [b]Bamford (2009)

[c]Storey *et al.* (1993), [d]WetlandBase (2010)

- Not surveyed.

5.9.3. Invertebrate Fauna

Invertebrate fauna surveys conducted for the proposed project comprised:

- A short-range endemic (SRE) invertebrate survey (Appendix P);
- Targeted invertebrate assessment for conservation significant species (as defined by those listed in Specially Protected Fauna Notice) (Appendix P); and
- An aquatic macroinvertebrate survey (Appendix Q).

5.9.3.1. Targeted and Short Range Endemic Terrestrial Invertebrates

SRE fauna are defined as animals that display restricted geographic distributions, nominally less than 10,000km^2, that may also be disjunct and highly localised (Harvey 2002). SRE taxa typically have low dispersal powers, are confined to discontiguous habitats, have a highly seasonal activity pattern (often active in cooler, wetter periods) and low levels of fecundity (Harvey 2002). Isolating mechanisms and features such as roads, urban infrastructure, large creek lines and ridges can act to prevent the dispersal and gene flow of the less mobile invertebrate species.

During SRE and targeted invertebrate surveys, approximately 125 invertebrate species were recorded in the study area, representing at least 73 genera from 58 families known to contain SRE taxa and the targeted invertebrate species. Scorpions were the most speciose group recorded, followed by butterflies/moths millipedes, centipedes, slaters, grasshoppers/crickets, land snails, scorpions and pseudoscorpions and harvestmen (Appendix P).

Seven SRE species (three species of spiders and four millipedes) with a distribution limited to the Perth metropolitan region were recorded within the study area. One of these, an unidentified sucking millipede *Siphonotidae sp*. was found in the project area (Table 5.9-10). Without previous confirmed records, this species warrants particular attention. The *siphonotid* millipede cannot be further evaluated taxonomically as the collection of the WA Museum (WAM) is currently on loan to a millipede specialist. *Siphonotidae* are rarely found in the Perth metropolitan area (the WAM only has records from Woodman Point and two unspecified historical localities in 'Perth'). In Western Australia, these millipedes are generally restricted to the wet western region of the south coast (Appendix P). Australian *Siphonotidae* species have highly restricted distributions.

Seven SRE species were recorded during project surveys

Table 5.9-10: Short-range Endemic Invertebrate Species Limited to the Perth Metropolitan Area

Common Name	Scientific Name	Known Distribution	Project Area	Study Area
Brushfooted Trapdoor Spider	*Synothele michaelseni*	Bindoon, Bold Park, Hamersley, Jarrahdale, John Forrest NP, Kings Park, Murdoch, Swanbourne, Tenilba, Wembley	SRE site 3	SRE site 4
Trapdoor Spider	*Kwonkan* `MYG225`	Bold Park, Tuart Hill, Jandakot Airport, Woodman Point, Landsdale Farm School	SRE site 6	SRE site 9
Flattened Ground Spider	*Tinytrema yarra*	Single female: Great Southern Highway and Yarra Road Junction (31°51°S, 116°28°E)		SRE site 10
Polydesmid Millipede	*Antichiropus* `UBS2`	Cardup, Brookdale, Bushmead, Coolbellup, East Rockingham, Forestfield, Hepburn Heights, Mt Henry, Parmelia, Perth Airport, Martin, Warwick, Wexcombe	SRE sites 2, 3, 5	TIA site 5
Polydesmid Millipede	*Antichiropus `UBS3`*	Bold Park, Mt Claremont, Brookdale	SRE sites 1-3, 6	SRE sites,4, 8
Sucking Millipede	Siphonotidae sp.	Unknown	SRE site 3	
Spirostreptid Millipede	*Podykipus collinus*	Unknown	SRE site 1-3,5	Sites 4, 8

Source: Appendix P

A population of Graceful Sun-moths was recorded adjacent to Stock Road

Targeted invertebrate assessments involved surveys for conservation significant species including the Graceful Sun-moth (*Synemon gratiosa*), the Scorpion Fly (*Austromerope poultoni*), four native bee species, the Yellow Admiral Butterfly (*Vanessa itea*) and two cricket species. Table 5.9-11 presents these species and their conservation status and habitat. Sampling was conducted at seven sites within the project area (Appendix P).

Surveys for the Graceful Sun-moth were conducted in March-April 2010 and March 2011. Sweep netting was conducted within survey transects within the project area (Appendix P). Since the species is known to be active around access tracks and elevated areas, the transects were placed near known populations of *Lomandra* plants, near paths and sunlit areas, and in proximity to hills and rises. The sampling methodology used was consistent with Bishop *et al.* (2009). Additional Graceful Sun-moth surveys were conducted in the project area and regional locations in March 2011, following further habitat mapping (Appendix S). Figure 5.9-3 indicates the location of regional surveys undertaken in 2011.

Of the conservation significant invertebrate species targeted during the invertebrate survey, one species, the Graceful Sun-moth (*Synemon gratiosa*), was recorded. Six specimens were recorded from the north-western quadrant of the Stock Road and Forrest Road intersection in the project area in March 2010. Two additional specimens were recorded from the same location in March 2011 and three specimens representing new records were collected from an adjacent population in the north-eastern quadrant of the Stock Road and Forrest Road intersection.

Table 5.9-11: Targeted Conservation Significant Invertebrate Species

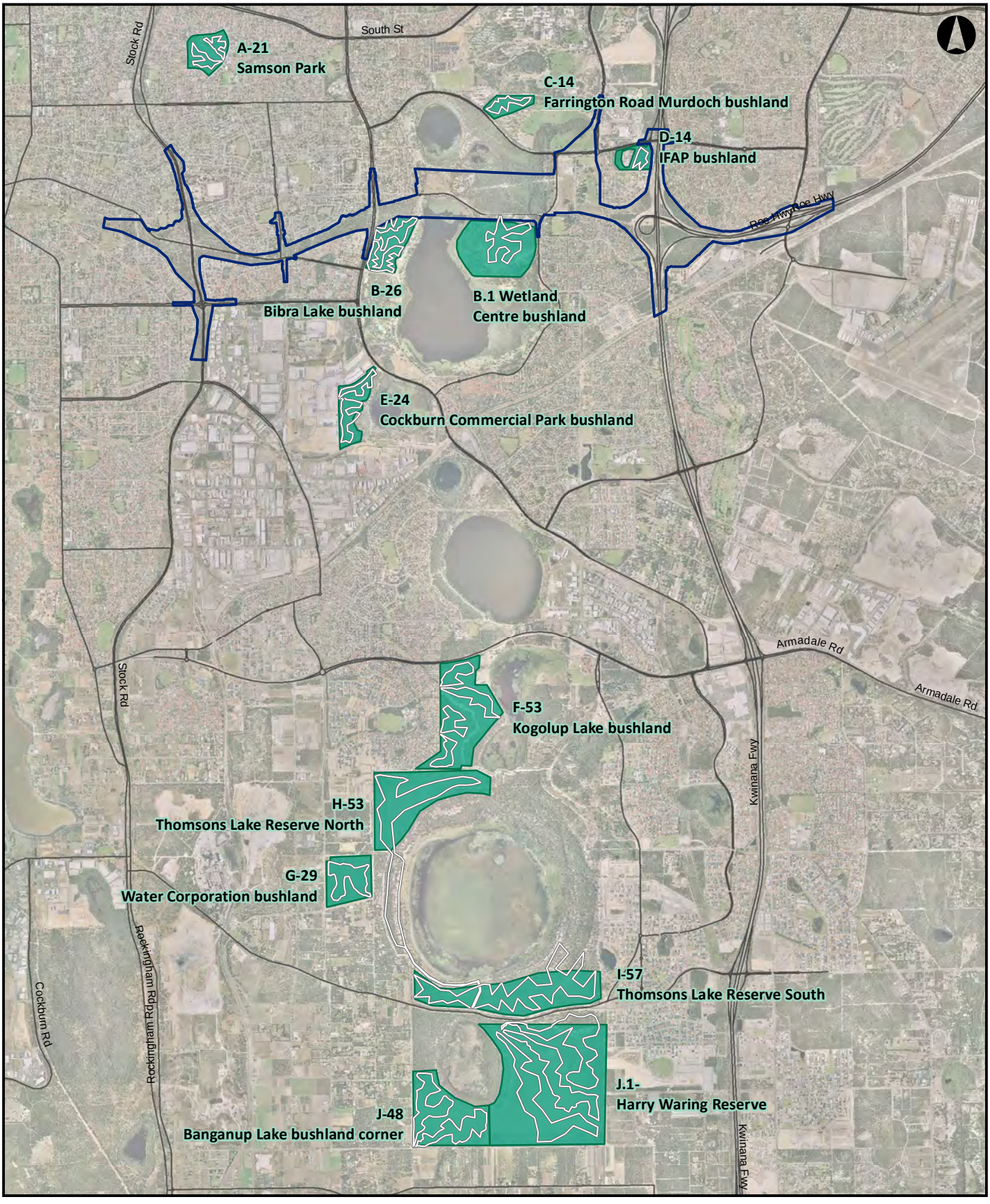
Common Name (considerations)	Scientific Name	Conservation Status	Habitat
Graceful Sun-moth	*Synemon gratiosa*	Endangered (*EPBC Act*) Schedule 1 (*WC Act*) CS Level 1	*Lomandra hermaphrodita* and *L. maritima*
Scorpion Fly (Ground dwelling)	*Austromerope poultoni*	DEC P2 CS Level 2	*Banksia* woodland
Native bee (Nectar feeding/ low flying)	*Leioproctus contrarius*	DEC P3 CS Level 2	*Goodenia* sp. *Lechenaultia* sp.
	Neopasiphae simplicior	Schedule 1 (*WC Act*) CS Level 1	Banksia woodland *Goodenia* sp. *Lobelia* sp.
Yellow Admiral Butterfly (Nectar feeding, low flying)	*Vanessa itea*	CS Level 3	Urban areas, forest woodland; and heath, shrubs and open track areas
Native cricket species (fly near the ground amongst shrubs and grasses)	*Austrosaga spinifer*	DEC P3, IUCN Vulnerable CS Level 2	*Banksia* heaths Low woodlands
	Throscodectes xiphos	DEC P1 CS Level 2	Banksia woodland Near Grand Spider Orchid, *Caladenia huegelii*

Source: Appendix P

CS Level 1: Species listed under State or Commonwealth Acts
CS Level 2: Species not listed under State or Commonwealth Acts, but listed in publications on threatened fauna or as Priority species by DEC
CS Level 3: Species not listed under Acts or in publications, but considered locally significant because of their pattern of distribution

WC Act: *Wildlife Conservation Act 1950*

IUCN: International Union for Conservation of Nature



Regional GSM Survey Sites

South Metro Connect

Figure 5.9-3

0 0.5 1 1.5 2

Kilometres
1:55,000 (A4)

Regional
Graceful Sun-moth Transect

Regional Sites

Project Area

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

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SouthmetroConnect

5.9.3.2. Subterranean Fauna

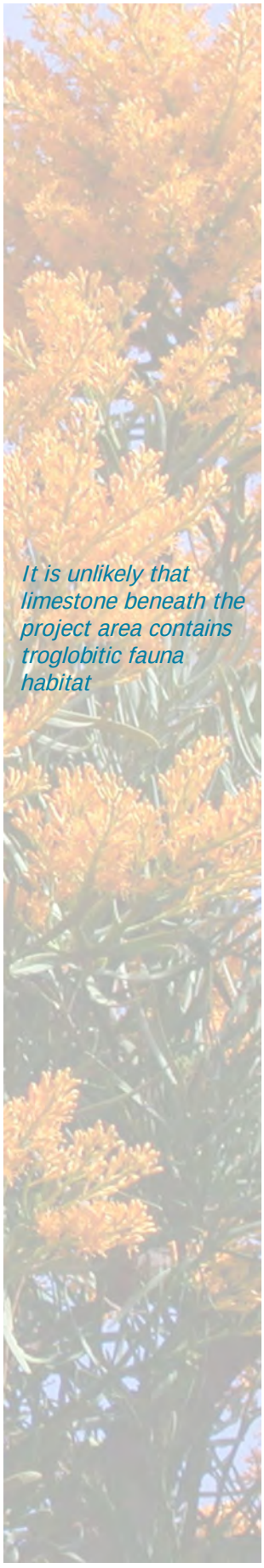
Troglofauna are obligate cave or karst-dwelling, air-breathing subterranean invertebrate fauna. In Western Australia to date, relatively diverse troglobitic fauna has been recorded at various locations, including in caves of karstified carbonate rocks located in the Kimberley, Cape Range and Barrow Island in the north of the state. In the south-east of the state they have been recorded from the Perth Basin, the Leeuwin-Naturaliste Ridge and the Nullarbor Plain. More recently troglofauna have been recorded in voids of pisolite and other geologies in the Pilbara region (Eberhard 2007).

Troglofauna are typically divided into three categories (Gilbert *et al.* 1994; Howarth 1983):

- Troglobitic fauna – adapted to subterranean life and are unable to survive outside of this environment;
- Troglophiles – complete their life cycles in the subterranean environment, but can survive in terrestrial (above ground) habitats; and
- Trogloxenes – use caves and karstic environments for refuge, but are unable to complete their life cycle within the subterranean environment.

Trogolofauna display morphological and physiological adaptations suited to their level of dependence on subterranean environments, such as a general lack of pigmentation and eyes, slender filiform body shape with elongated appendages and highly developed chemical and mechanical receptors. Troglobitic fauna generally display the most extreme morphological adaptations. They often display poor dispersal abilities, with highly localised distributions reflecting disjunct habitats. As a result, even modest habitat alterations can result in drastic changes in the richness, abundance and distribution of these fauna. Troglobitic fauna are therefore particularly vulnerable to disturbance.

The EPA has assessed the probability that subterranean fauna will be present in different regions and geologies in Western Australia and found there to be a low likelihood of occurrence of troglofauna in most geologies of the South-West. The exception to this is karstic geologies, including those of the Swan Coastal Plain (EPA 2005), where a high likelihood of occurrence is expected (Table 5.9-12). Troglobitic taxa have been recorded from caves in karstified carbonate rocks in the Perth Basin at Eneabba, Jurien and Yanchep (Tomlinson and Boulton 2008; EPA 2005).



It is unlikely that limestone beneath the project area contains troglobitic fauna habitat

Table 5.9-12: Likelihood of Presence of Subterranean Fauna in Western Australia

Region	Geology	Likelihood of Stygofauna	Likelihood of Troglofauna
Kimberley	Karst, limestone sandstone, alluvium islands	High	High
Pilbara	Most geologies	Very High	High
Various	Barrow Island	Very High	Very High
Inland deserts	Calcrete, alluvium	High	Low
Gascoyne/Murchison	Calcrete, alluvium, banded ironstone	High	High
Various	Cape Range	Very High	Very High
Yilgarn/Goldfields	Calcrete, alluvium, banded ironstone	Very High	High
South-West	Most geologies	Low	Low
Various	Karst	High	High

Source: EPA 2007

It is considered unlikely that the limestone strata within the project area contains habitat suitable for troglobitic fauna. There is no direct evidence of karst formation in the project area and the lithology logs provide no evidence of sample loss due to cavities or voids being present. Therefore, the likelihood of troglofauna occurrence in the project area is considered to be low and a targeted troglobitic survey has not been undertaken.

5.9.3.3. Aquatic Macro-Invertebrate Fauna

Bibra Lake, Melaleuca Swamp, North Lake, South Lake and Lower Swamp were sampled in the macroinvertebrate survey. Sweep net sampling (250µm pore size) was undertaken whereby the water column and sediment-water column interface fauna were targeted. No direct sampling of sediment or interstitial fauna was conducted.

Aquatic macroinvertebrate assemblages of the wetlands are integral to supporting many of the known wetland values. In particular, aquatic macroinvertebrates play a role in ecological processes. They are an essential food resource for higher-order fauna, particularly wetland birds, frogs and the Long-necked Turtle (*Chelodina oblonga*). They also play an important role for sediment and water nutrient decomposition and cycling, and water quality.

Generally, the results confirm findings of earlier surveys and reviews (Horwitz *et al*. 2009; Giles and Davis 2005), in terms of species richness and overall macroinvertebrate diversity. There are, however, differences in results pertaining to the pattern of species diversity between wetlands recorded here and by the reviews mentioned above.

The assemblages across the five wetlands were dominated by insects (59 species), crustaceans (23 species), arachnids (nine species) and worms and leeches (eight species) (Table 5.9-13). A decline in species, genus and family richness from the spring to summer sampling rounds was recorded at each wetland. Such seasonal declines are typical of wetlands on the Swan Coastal Plain and most wetlands governed by a Mediterranean climate (Appendix Q).

A range of structurally separated fauna were recorded, including epifauna (sediment surface dwelling), mud dwelling infauna (predominantly midges) and free swimming planktonic or nektonic species.

Bibra Lake displayed the most diverse macroinvertebrate assemblage, with a total of 64 species recorded (Table 5.9-13). The spring and summer surveys recorded 50 and 32 species, respectively. South Lake contained the second most species rich assemblage with a total of 51 species recorded. North Lake contained 46 species (Table 5.9-13). Melaleuca Swamp displayed the least species rich assemblage (25 species), possibly due to its closed paperbark overstorey and thick sedge understory with dense submerged macrophytes.

None of the wetlands are considered particularly significant in terms of diversity of taxa or iconic species within the macroinvertebrate assemblages. The most noteworthy species was the freshwater Gilgie (crayfish), *Cherax quinquecarinatus*, recorded in Lower Swamp. Small crayfish were once common inhabitants of most Swan Coastal Plain aquatic environments, but have disappeared from many lakes, sumplands and rivers. The presence of freshwater crayfish indicates that Lower Swamp remains in reasonably good condition, even with the establishment of introduced terrestrial grasses on the margins.

None of the project wetlands are considered particularly significant in terms of macroinvertebrate species

In contrast to Horwitz *et al*. (2009), who found macroinvertebrate assemblages to be largely homogenous across 66 Swan Coastal Plain wetlands, this survey found invertebrate assemblages in the five wetlands to be markedly different at the species level. Lower Swamp and Melaleuca Swamp were found to support the most distinct species assemblages, followed by North Lake. Bibra Lake and South Lake recorded the most similar species assemblages. SIMPER Analysis examined the contribution of each variable (species, in this case) to the average resemblances between sample groups (seasons, habitats and wetlands) (Appendix Q). Differences in assemblage composition within each wetland were identified.

The relative similarity of the assemblages is largely dictated by a few species. For example, the similarity of Bibra Lake and South Lake is due to the presence of three species: the gastropod (*Physa acuta*), the amphipod (*Austrochiltonia subtenius*) and the ostracod (*Sarscypridopsis aculeata*). These species also make a significant contribution to the dissimilarity of Bibra and South lakes and to the other three wetlands investigated. The second two species are free swimming species that are representative of the 'lake' environment of Bibra Lake and South Lake and thus the result is expected.

Table 5.9-13: Seasonal Aquatic Macroinvertebrate Assemblages

Taxa	Bibra Lake			Melaleuca Swamp			North Lake			South Lake			Lower Swamp	Total
	Spring	Summer	Total	Spring	Summer	Total	Spring	Summer	Total	Spring	Summer	Total	Spring	
Arachnida (mites)	4	2	6	1	0	1	4	2	4	5	2	6	3	9
Clitellata (worms)	6	2	7	2	1	3	3	2	3	2	1	3	3	8
Crustacea	8	8	14	4	1	4	6	8	10	8	3	7	3	28
Branchiopoda (Cladocera: water fleas)	2	2	2	0	0	0	1	1	1	0	0	0	0	2
Copepoda	6	2	6	1	1	1	1	1	1	2	0	2	0	7
Malacostraca (Isopods and amphipods)	2	1	2	4	0	4	1	1	1	2	2	2	2	5
Decapoda (freshwater crayfish)	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Ostracoda	6	4	6	3	0	3	4	6	8	6	3	6	3	13
Gastropoda (snails and limpets)	2	2	2	2	0	2	2	2	2	1	1	1	3	5
Hydrozoa	0	0	0	0	0	0	0	1	1	0	0	0	0	1
Insecta	20	16	31	8	4	12	18	13	25	18	19	30	16	59
Coleoptera (beetles)	4	3	7	4	2	6	5	3	6	3	0	3	5	16
Diptera (flies)	4	4	6	0	1	1	2	0	2	4	6	9	1	11
Hemiptera (true bugs)	6	7	11	2	1	3	8	7	11	5	10	12	6	20
Odonata (dragonflies)	2	2	4	2	0	2	3	2	5	3	2	4	2	6
Tricoptera (caddis flies)	2	2	2	0	0	0	0	1	1	1	2	2	2	4
Rotifera[1]	2	2	2	0	0	0	0	0	0	0	0	0	0	2
TOTAL RICHNESS	50	32	64	20	6	25	34	29	46	36	29	51	31	113

Source: Appendix Q

[1]Rotifers are microinvertebrates (<1mm) and were not specifically sampled for but included in results for completeness. As pore size of the sweep nets used was 250µm, the recorded rotifers would have been attached to organic debris collected during sampling

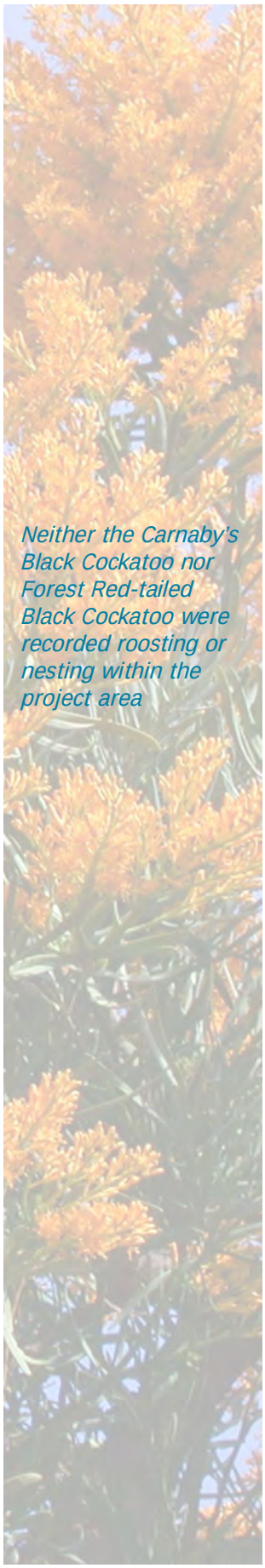
Terrestrial and aquatic invertebrates are frequently used as bio-indicators in ecosystem monitoring. A list of species known to respond positively or negatively to elevated nutrient levels in Swan Coastal Plain wetlands is provided in Davis *et al*. (1993). Positive-response indicator species were recorded in each of the five surveyed wetlands suggesting that they are eutrophic, which is further characterised by water quality data in Section 5.7. Only one positive-response indicator species was recorded at Melaleuca Swamp.

5.9.4. Fauna of Conservation Significance

Four fauna species listed as endangered or vulnerable under the *EPBC Act*, or threatened under the *Wildlife Conservation Act 1950 (WC Act*), were identified as potentially occurring within the project area (Table 5.9-14). Another seven species, listed as Priority by the DEC, were identified as potentially occurring in the project area. Four of these listed priority species were recorded in the surveys.

Table 5.9-14: Conservation Significant Species

Scientific Name	Common Name	Conservation Status[1]			Recorded in the Project Area
		EPBC Act	*WC Act* - (Specially Protected Fauna) Notice	Priority List Maintained by DEC	
Avifauna					
Calyptorhynchus latirostris	Carnaby's Black-Cockatoo	EN	S1	-	✓
Calyptorhynchus banksii naso	Forest Red-tailed Black-Cockatoo	VU	S1	-	✓
Botaurus poiciloptilus	Australasian Bittern	EN	S1	-	-
Falco peregrinus	Peregrine Falcon	-	S4	-	-
Ixobrychus dubius	Australian Little Bittern	-	-	P3	-
Thinornis rubricollis	Hooded Plover	-	-	P4	-
Mammals					
Hydromys chrysogaster	Water Rat	-	-	P4	-
Macropus irma	Western Brush Wallaby	-	-	P4	-
Isoodon obesulus fusciventer	Southern Brown Bandicoot	-	-	P5	✓
Reptiles					
Lerista lineata	Perth Lined Lerista	-	-	P3	✓
Ctenotus gemmula	Jewelled Sandplain Ctenotus	-	-	P3	-
Neelaps calonotus	Black-striped Snake	-	-	P3	
Invertebrates					
Synemon gratiosa	Graceful Sun-moth	EN	S1		✓
Leioproctus douglasiellus	Native bee	-	S1	-	-
Neopasiphae simplicitor	Native bee	-	S1	-	-
Throscodectes xiphos	Native cricket	-	-	P1	-



Neither the Carnaby's Black Cockatoo nor Forest Red-tailed Black Cockatoo were recorded roosting or nesting within the project area

Scientific Name	Common Name	Conservation Status[1]			Recorded in the Project Area
		EPBC Act	*WC Act* - (Specially Protected Fauna) Notice	Priority List Maintained by DEC	
Austromerope poultoni	Scorpion Fly	-	-	P2	-
Leioproctus bilobatus	Native bee	-	-	P2	-
Austrosaga spinifer	Native cricket	-	-	P3	-
Leioproctus contrarius	Native bee	-	-	P3	-

Source: Appendices J and N

EN – Endangered

VU – Vulnerable

S1 – Schedule 1

S4 – Schedule 4

P1-P5 – Priority 1-5

5.9.4.1. Black Cockatoos

Carnaby's Black-Cockatoo and the Forest Red-tailed Black-Cockatoo are protected species under the *EPBC Act* and the *WC Act.*

5.9.4.1.1. Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*)

Carnaby's Black-Cockatoo is listed as Endangered under the *EPBC Act* and Schedule 1 under the *WC Act*. The species is endemic to the south-west of Western Australia. Its range and abundance has significantly reduced due to land clearing for agriculture, forestry and urban development. It faces continuing threats on the Swan Coastal Plain as important feeding habitat is cleared (DEWHA 2010a).

Carnaby's Black-Cockatoos breed in eucalypt woodlands between the Stirling Range and Three Springs. Numerous records also exist for the Swan Coastal Plain and the northern Darling Scarp (Higgins 1999; Johnstone and Kirkby 2009). The closest breeding record is at Baldivis, 27km south of the project area (Kirkby 2010). Individuals nest mainly in hollows of smooth-barked eucalypts, especially Salmon Gum (*Eucalyptus salmonophloia*) and Wandoo (*Eucalyptus wandoo*). On the Swan Coastal Plain, nests are mostly recorded in Tuart (*Eucalyptus gomphocephala*). There has been a shift in the breeding range of this species further west and south since the middle of last century. A more rapid transgression in the past 10 to 30 years has shown their range to be moving into the Jarrah (*Eucalyptus marginata*)/Marri (*Corymbia calophylla*) forests of the Darling Scarp and the Tuart forests of the Swan Coastal Plain (Johnstone and Kirkby 2009).

Breeding success for Carnaby's Black-Cockatoo is largely dependent on suitable feeding habitat adjacent to the nest site, to provide the necessary food for the survival of the chick. Breeding individuals forage no more than approximately 20km from their nesting hollows (ENV 2009), so having sufficient foraging resources close to breeding areas (particularly within a 12km radius) is critical to its breeding success (ENV 2009). Non-breeding birds visit the Swan Coastal Plain (including the Perth metropolitan region) from December to July. On the Swan Coastal Plain, important foraging species consist of *Banksia attenuata*, *B. menziesii*, *B. grandis*, *B. ilicifolia*, *B. sessilis*, *B. prionotes*, *Corymbia callophyla*, *Eucalyptus marginata* and non-native *Pinus* species (Valentine and Stock 2008; Higgins 1999).

As shown in Figure 5.9-4, Carnaby's Black-Cockatoo was recorded at several locations in the study area, including flocks of up to 70 individuals. Several records exist from previous surveys in the vicinity of the project area (DEC 2010b). Extensive foraging records were documented throughout the study area during the latest surveys.

A flock of up to 70 Carnaby's Black Cockatoos were recorded during a project survey

Targeted surveys to date have not recorded evidence of breeding or the use of potential nesting hollows by Carnaby's Black-Cockatoo within the project area. However, the Great Cocky Count (Birds Australia 2010) recorded twelve roost sites within 6km of the centre point of the project area during April and July 2010 (Figure 5.9-4).

5.9.4.1.2. Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*)

The Forest Red-tailed Black-Cockatoo is listed as Vulnerable under the *EPBC Act* and Schedule 1 under the *WC Act*. This subspecies is endemic to the south-west of Western Australia. It displays erratic breeding activity in the summer and winter seasons (Kirkby 2010). These birds primarily nest in large hollows of Marri, Jarrah, Wandoo, Bullich (*Eucalyptus megacarpa*), Tuart and Karri (*Eucalyptus diversicolor*) (Johnstone and Kirkby 2009). Their closest breeding record is at Stake Hill, which is located 47km south of the project area (Kirkby 2010). The diet of the Forest Red-tailed Black-Cockatoo primarily consists of seeds of Marri, Jarrah, Blackbutt, Karri, Sheoak (*Allocasuarina fraseriana*), Snottygobble (*Persoonia longifolia*) and, in recent times, the seeds of Cape Lilac (Johnstone and Kirkby 2009). This species was recorded during spring 2009 and autumn 2010 surveys in several locations in the study area (Figure 5.9-4).

To date, targeted surveys have not recorded evidence of breeding or use of potential nesting hollows by Forest Red-tailed Black-Cockatoo nor are there known roost locations within the vicinity of the project area.

5.9.4.1.3. Black Cockatoo Habitat

In assessing significant impacts on black cockatoo habitat, DSEWPaC identifies a number of important elements, specifically: known and potential breeding trees ('significant' trees), foraging habitat and known roost sites. Potential breeding trees are classified as hollow-forming trees (termed 'significant'), predominantly eucalypts, with a DBH greater than 500mm.

Significant Trees

The project area contains 605 significant trees, of which 71 are known to have existing potential nesting hollows (Figure 5.9-4). The majority of these trees are within vegetation communities that occur west of Progress Drive. Surveys to date have not recorded evidence of breeding or use of potential nesting hollows within the project area by black cockatoos.

Breeding records of Carnaby's Black-Cockatoo are from the Darling Scarp and foothills (e.g. Bindoon, Bullsbrook, Mundaring), and further south on the Swan Coastal Plain (Lake Clifton and Bunbury). The closest confirmed nesting sites for Carnaby's and Forest Red-tailed black-cockatoos within the Swan Coastal Plain are located approximately 27km south of the project area at Baldivis and 47km south of project area at Stake Hill, respectively (Kirkby 2010; Johnstone and Kirkby 2009).

Detailed information on the critical habitat utilised by the Forest Red-tailed Black-Cockatoo (breeding, foraging and roosting areas) is largely unknown, as the forested habitat in which this species occurs is difficult to monitor (DEC 2007a).

Foraging Habitat

The results of the targeted surveys indicate that black cockatoos (specifically Carnaby's Black-Cockatoo) mainly forage in *Banksia menziesi* and *Banksia attenuata* trees within the project area. Chewings of Marri, Jarrah, *Allocasuarina frasierana* and non-native pines were also evident to a lesser extent, in isolated patches.

Potential foraging habitat has been mapped based on foraging records and vegetation units (Figure 5.9-5). Vegetation units containing one or more of the principal foraging plant species have been included as potential foraging habitat. Approximately 177ha (44 percent) and 166ha (45 percent) of the project area contains potential foraging habitat for Carnaby's Black-Cockatoo and Forest Red-tailed Black-Cockatoo, respectively.

Roost Sites

There are no known black cockatoo roost sites within the project area. However, the Great Cocky Count (Birds Australia 2010) recorded twelve known roost sites within 6km of the centre point of the project area during April and July 2010 (Figure 5.9-5). Anecdotal evidence suggests that Carnaby's Black-Cockatoo return to the same roost sites from year to year with roost sites primarily being tall pine trees and eucalypt trees with dense canopies (Shah 2006). However, cockatoo numbers in roost locations may vary for a number of reasons. For example, a cockatoo may not distinguish roost sites within relatively close proximity (0.5–1km apart); little is known about how these birds use and perceive the landscape (Shah 2006).

Carnaby's Black-Cockatoo movements are dictated by food availability, with studies suggesting that birds disperse throughout the landscape in search of food sources each day and return to the same roost area each night (Shah 2006; Johnstone and Kirkby 2009). It has also been suggested that a roost site needs to be within 10 to 12km of a foraging area. However, this estimation applies for foraging in Kwongan heath, where birds would have to travel further from surrounding areas to reach these particular foraging habitats (Barrett G 2010; Kirkby 2010).

It is likely that the flocks of black cockatoos recorded as roosting within 6km of the centre point of the project area (Birds Australia 2010) are foraging in the project area (Barrett G 2010; Kirkby 2010). Further, the close proximity of roost sites to foraging habitats within the study area suggests that Carnaby's Black-Cockatoos are travelling a shorter distance to forage and may indeed have a smaller foraging range on the Swan Coastal Plain than in the Kwongan heath habitat (Kirkby 2010).

As the same roost sites are utilised over a period of time, it is suggested that roost sites for Carnaby's Black-Cockatoo along the Swan Coastal Plain are a significant habitat for the seasonal movements of these birds. This would include known roost sites within 6km of the centre of the study area. Birds Australia is currently mapping foraging habitat for black cockatoos on the Swan Coastal Plain; however, this information is not currently available.

Four known Forest Red-tailed Black Cockatoo roost sites located between 150m and 1.5km of the project area were recorded in November 2010. One roost was observed to be in use in November 2010 and another was observed being used intermittently from March to November 2010. Little is known about the Forest Red-tailed Black-Cockatoo in regard to roosting and foraging patterns.

Potential Nesting Habitat for Black Cockatoos

South Metro Connect

Figure 5.9-4a

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos (DBH > 500mm)
- Project Area

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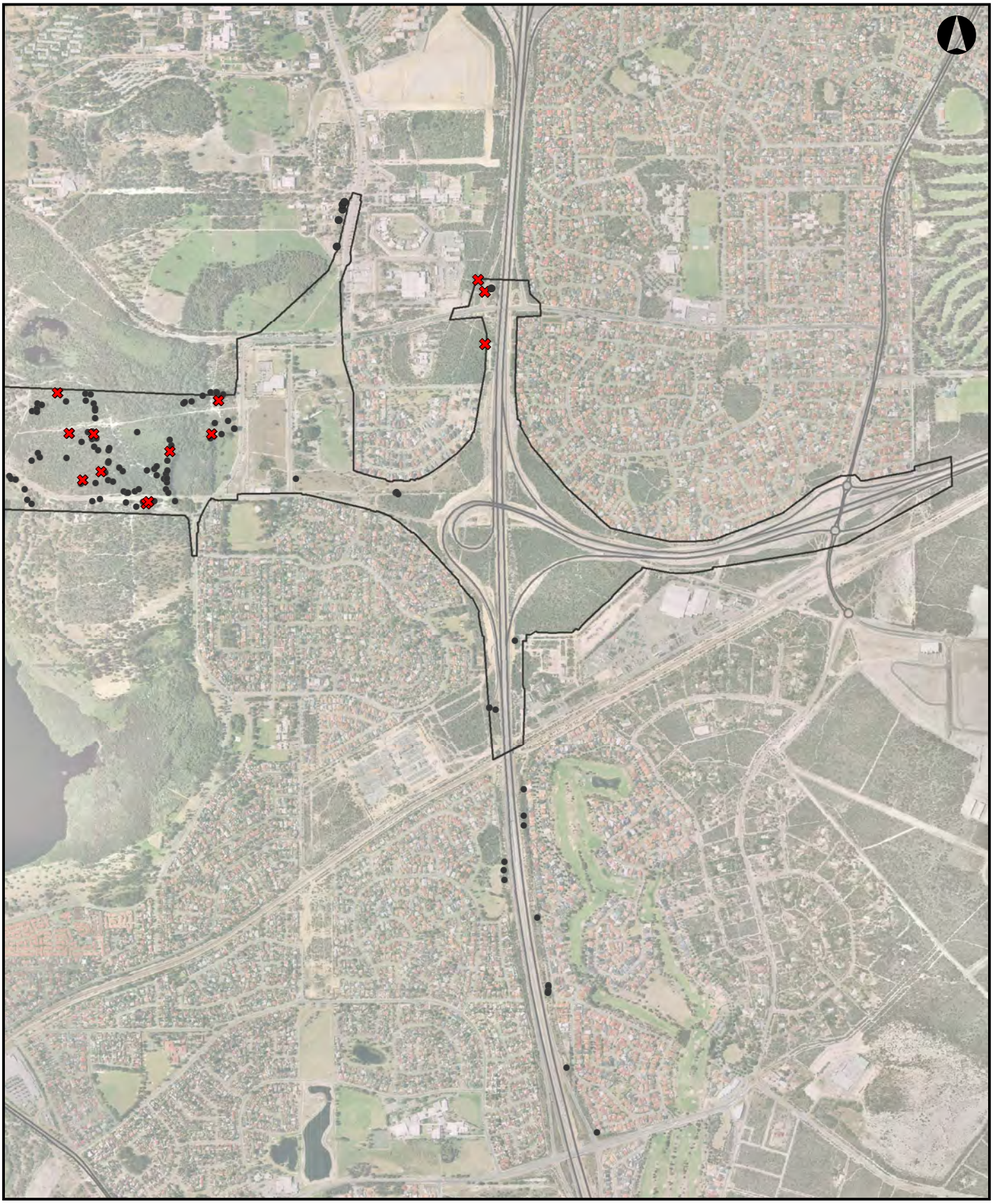

Potential Nesting Habitat for Black Cockatoos

South Metro Connect

Figure 5.9-4b

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos (DBH > 500mm)
- Project Area

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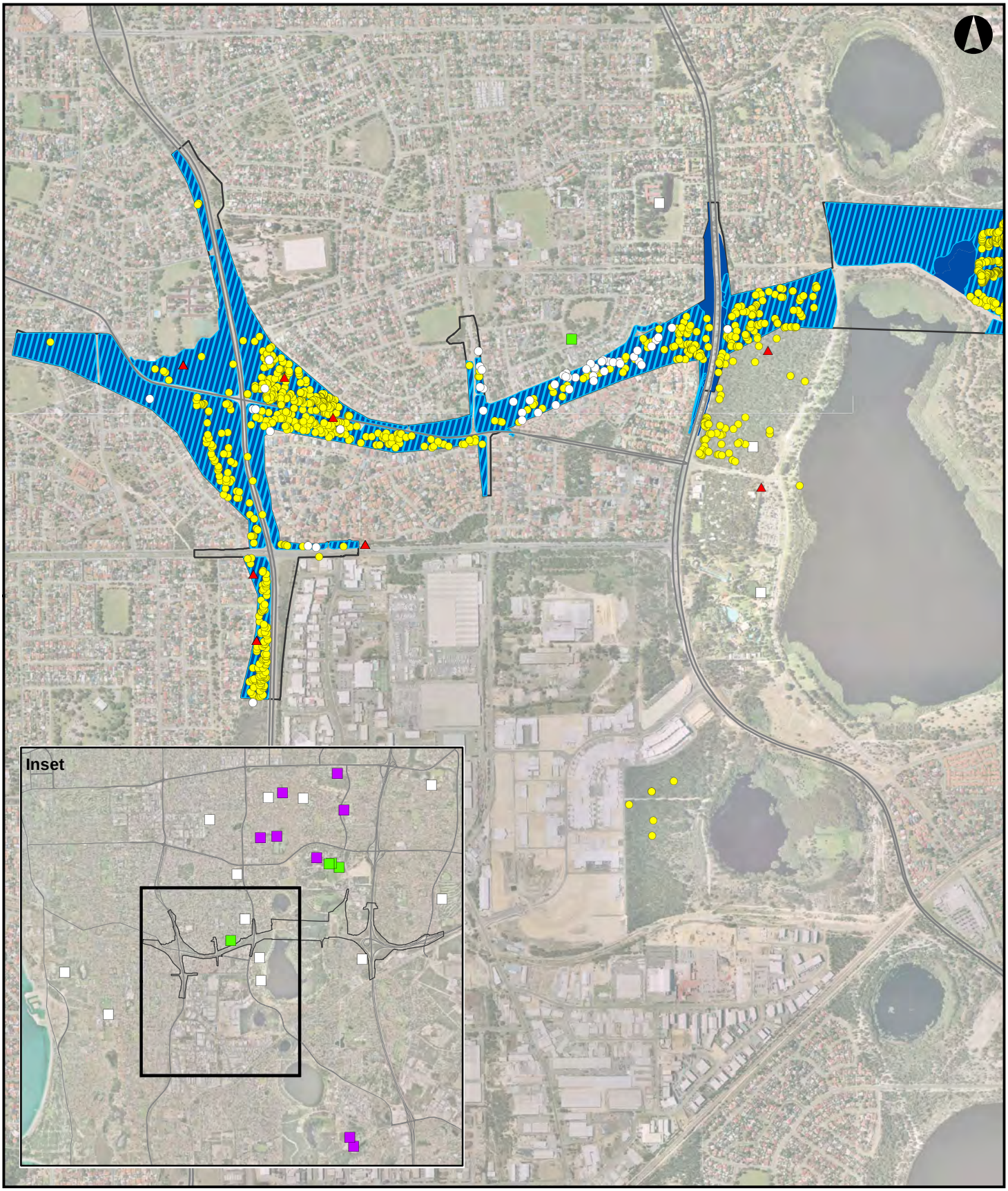

Black Cockatoo Foraging Habitat and Records

South Metro Connect

Figure 5.9-5a

0 100 200 300 400 500

Metres
1:21,000 (A4)
Datum: GDA94 Projection: MGA z50

- Carnaby's Chewings (*Banksia*)
- Carnaby's or Forest Red-tailed Chewings (*Marri* and *Jarrah*)
- Carnaby's Sightings
- Forest Red-tailed Chewings (*Allocasuarina*)
- Forest Red-Tailed Black Cockatoo Foraging Habitat
- Carnaby's Black Cockatoo Foraging Habitat

Roost Sites (see Inset)

- Known Carnaby's Black-Cockatoo Roost Sites
- Potential Carnaby's Black-Cockatoo Roost Sites
- Known Forest Red-tailed Black-Cockatoo Roost Sites

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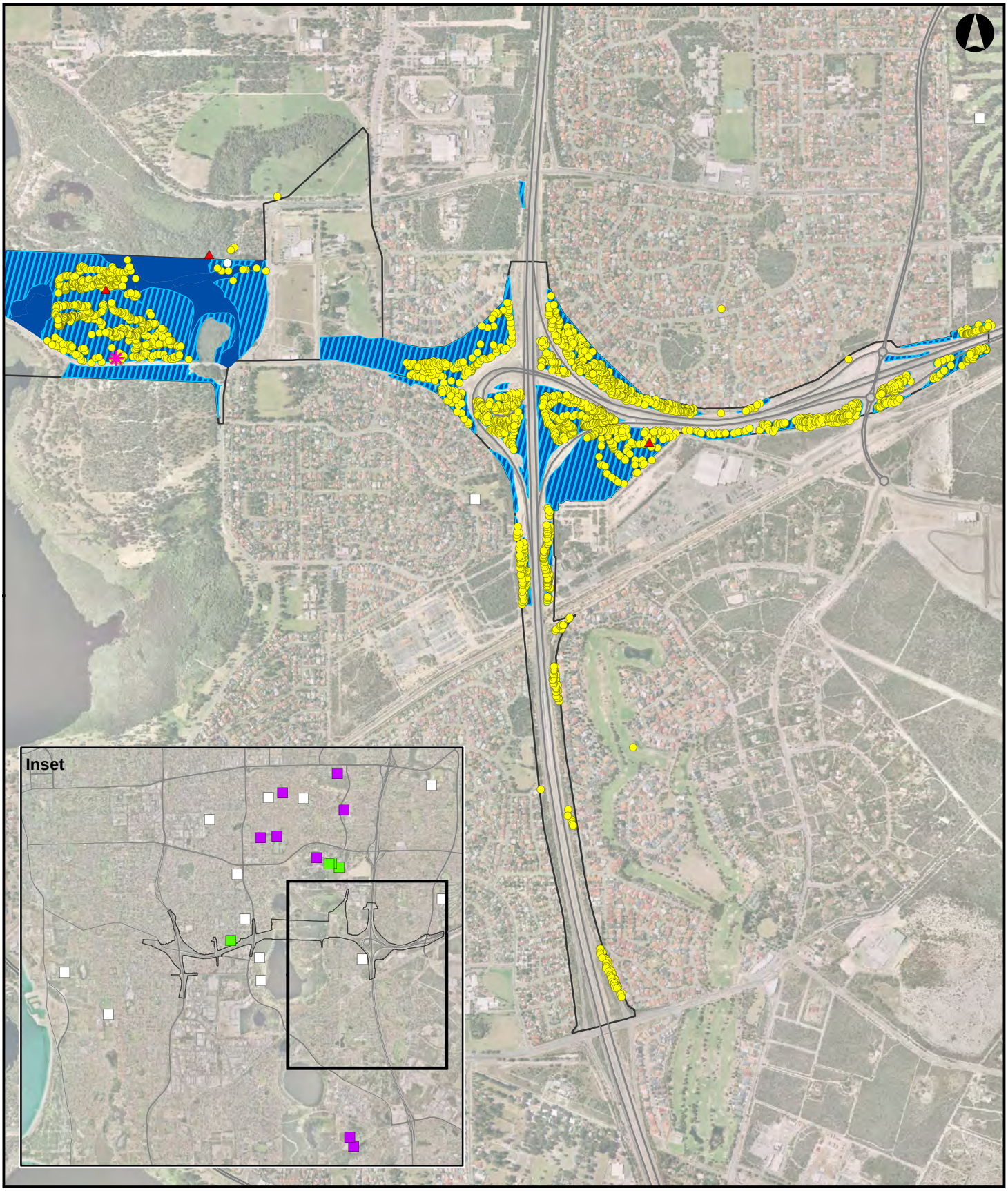

Black Cockatoo Foraging Habitat and Records

South Metro Connect

Figure 5.9-5b

0 100 200 300 400 500

Metres
1:21,000 (A4)
Datum: GDA94 Projection: MGA z50

- Carnaby's Chewings *(Banksia)*
- Carnaby's or Forest Red-tailed Chewings (*Marri* and *Jarrah*)
- Carnaby's Sightings
- Forest Red-tailed Chewings *(Allocasuarina)*
- Forest Red-Tailed Black Cockatoo Foraging Habitat
- Carnaby's Black Cockatoo Foraging Habitat

Roost Sites (see Inset)

- Known Carnaby's Black-Cockatoo Roost Sites
- Potential Carnaby's Black-Cockatoo Roost Sites
- Known Forest Red-tailed Black-Cockatoo Roost Sites

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5.9.4.2. Australasian Bittern (*Botaurus poiciloptilus*)

The Australasian Bittern is listed as Endangered under the *EPBC Act* and listed as Schedule 1 under the *WC Act*. This species inhabits shallow, densely vegetated wetlands that generally have a mixture of tall and short rushes (Johnstone and Storr 1998; Marchant and Higgins 1990).

This species was not recorded during project surveys (Appendix O). Of the 13 wetlands surveyed as part of the wetland and shorebird survey, the species is known to inhabit Thomsons Lake. Although this species was not recorded during the surveys, it may opportunistically inhabit and breed in wetlands within the study area that have dense beds of rushes such as *Typha* or *Baumea* species. Given the small area of suitable habitat intersecting the proposed project, the likelihood of the species occurring within the study area is probably quite low.

5.9.4.3. Peregrine Falcon (*Falco peregrinus*)

The Peregrine Falcon is listed as Schedule 4 under the *WC Act*. It is a nomadic species that is widely distributed throughout Australia, inhabiting a wide range of habitats including coastal cliffs, water courses, lakes, open woodland and arid shrubland (Johnstone and Storr 1998; Pizzey and Knight 2007). It has been known to nest amongst cliffs, granite outcrops and quarries; however, hollow trees located in wetlands have also been utilised for breeding (Johnstone and Storr 1998).

The Peregrine Falcon was not recorded during the surveys; however, it may opportunistically utilise habitats within the project area from time to time. It was previously recorded at Bibra Lake in 2002 (DEC 2010c).

5.9.4.4. Australian Little Bittern (*Ixobrychus dubius*)

The Australian Little Bittern is listed as Priority 3. This species may be resident on the Swan Coastal Plain or as a spring/summer visitor (Johnstone and Storr 1998). In 2006, there were two records of the Australian Little Bittern at Thomsons Lake (Birds Australia 2010). In 1987, there were two records of this species breeding at Lake Kogolup (WetlandBase 2010).

This species was not recorded during the surveys; however, it may inhabit and breed on wetlands in the study area that have dense beds of rushes such as *Typha* or *Baumea* species. The likelihood of the species occurring within the study area is probably quite low.

5.9.4.5. Hooded Plover (*Thinornis rubricollis*)

The Hooded Plover is listed as Priority 4. This species typically inhabits beaches, salt lakes and estuaries (Johnstone and Storr 1998). There is one previous record from 2007 for this species at Thomsons Lake on the Birds Australia Atlas Database, but it was not recorded in the surveys. This species is unlikely to utilise the project area.

5.9.4.6. Water Rat (*Hydromys chrysogaster*)

The Water Rat is listed as Priority 4. This species lives near permanent fresh, brackish or marine water. It can be found in wetlands, rivers, estuaries, along beaches and on islands (Atkinson *et al*. 2008). On the Swan Coastal Plain, the Water Rat is predominantly found along water courses and wetlands (Kitchener *et al*. 1978).

This species was not recorded during the vertebrate fauna surveys or in previous surveys within the study area. It was last recorded approximately 1km south of Thompsons Lake, near Bangabup Lake, in 1973 and also in the Kwinana area in the same year (DEC 2010d). Murdoch Drain within the *Melaleuca* woodland (north– west of Roe Swamp) provides the only suitable habitat within the project area for the Water Rat. This area contains sections of dense native vegetation (i.e. sedges and rushes), logs and approximately 1 – 1.5m of water (in winter). However, based on the species' requirements for relatively good water quality and permanent water, it is considered unlikely that it occurs within the project area.

5.9.4.7. Western Brush Wallaby (*Macropus irma*)

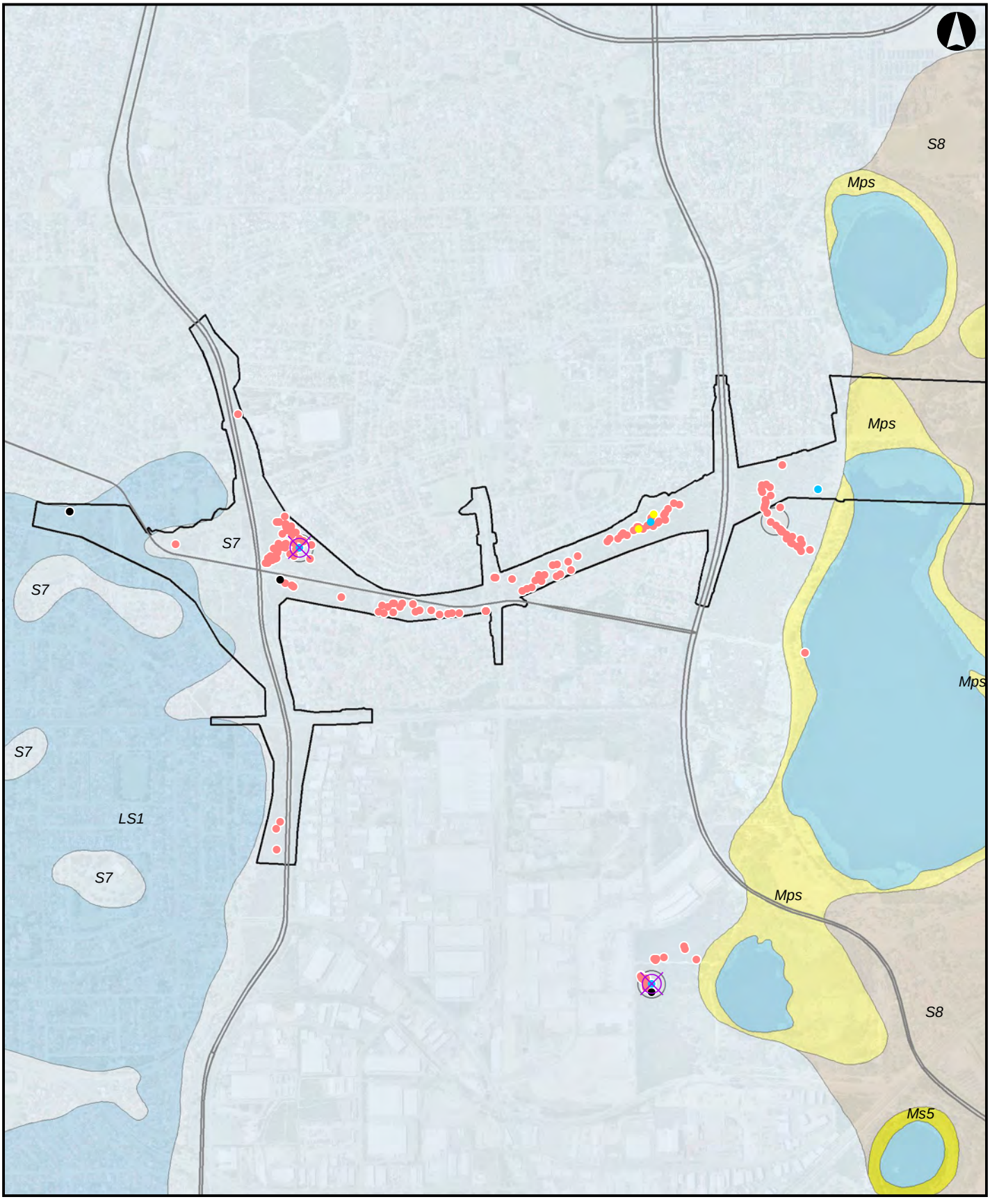
The Western Brush Wallaby is listed as Priority 4. This species is confined to the south– west of Western Australia favouring open forest or woodland, but can also be found in mallee and heathland and occasionally in wet sclerophyll forest. It prefers open forest or woodland, particularly seasonally wet areas with low grasses and open thickets (Van Dyck and Strahan 2008). The species is seemingly more diurnal than other macropods within the south– west region, often seen feeding in early morning and late afternoon (Van Dyck and Strahan 2008).

The Western Brush Wallaby was not recorded in the vertebrate fauna surveys, but has previously been recorded within the study area and in other regional surveys (Dell and Cooper 1992; Bamford and Bamford 2000; Bamford *et al*. 2002; ENV 2009). The Western Brush Wallaby may potentially use woodland habitats within the project area, particularly *Eucalyptus*/*Banksia* woodland. Two known food sources exist within the project area: *Cynodon dactylon* and *Nuytsia floribunda*.

5.9.4.8. Southern Brown Bandicoot (*Isoodon obesulus fusciventer*)

The Southern Brown Bandicoot is listed as Priority 5. This species is widely distributed near the south– west coast, with a patchy distribution on the Swan Coastal Plain. It is a common resident of actively managed remnant bushland across the Perth metropolitan region and is often associated with wetlands (DEC 2006a; Nastov 2009). The species inhabits dense, scrubby, often swampy vegetation with dense cover (up to one metre high). It will also occupy disturbed areas (such as those recently burnt), open paddocks and cleared areas that provide an increased food supply in the form of insects (Nastov 2009).

Numerous records were made of the Southern Brown Bandicoot in both the spring 2009 and autumn 2010 vertebrate fauna surveys throughout the study area (Figure 5.9-6). Numerous diggings were also recorded. Previous records indicate that the species is a common resident within the project area and the adjacent Fiona Stanley Health Precinct (GHD 2006).



Quenda and Perth Lined Lerista Records

South Metro Connect

Figure 5.9-6a

0 200 400 600 800

Metres
1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

Quenda Record
- Tracks
- Remains
- Sightings
- Diggings

Perth Lined Lerista Record

Vertebrate Fauna Trap Site

- Cps - Peaty clay
- Mps - Peaty silt
- Ms5 - Sandy silt
- S7 - Pale yellow-brown sand
- LS1 - Limestone
- S8 - Light grey sand (LGS)
- S10 - LGS over brown silt/clay
- Water

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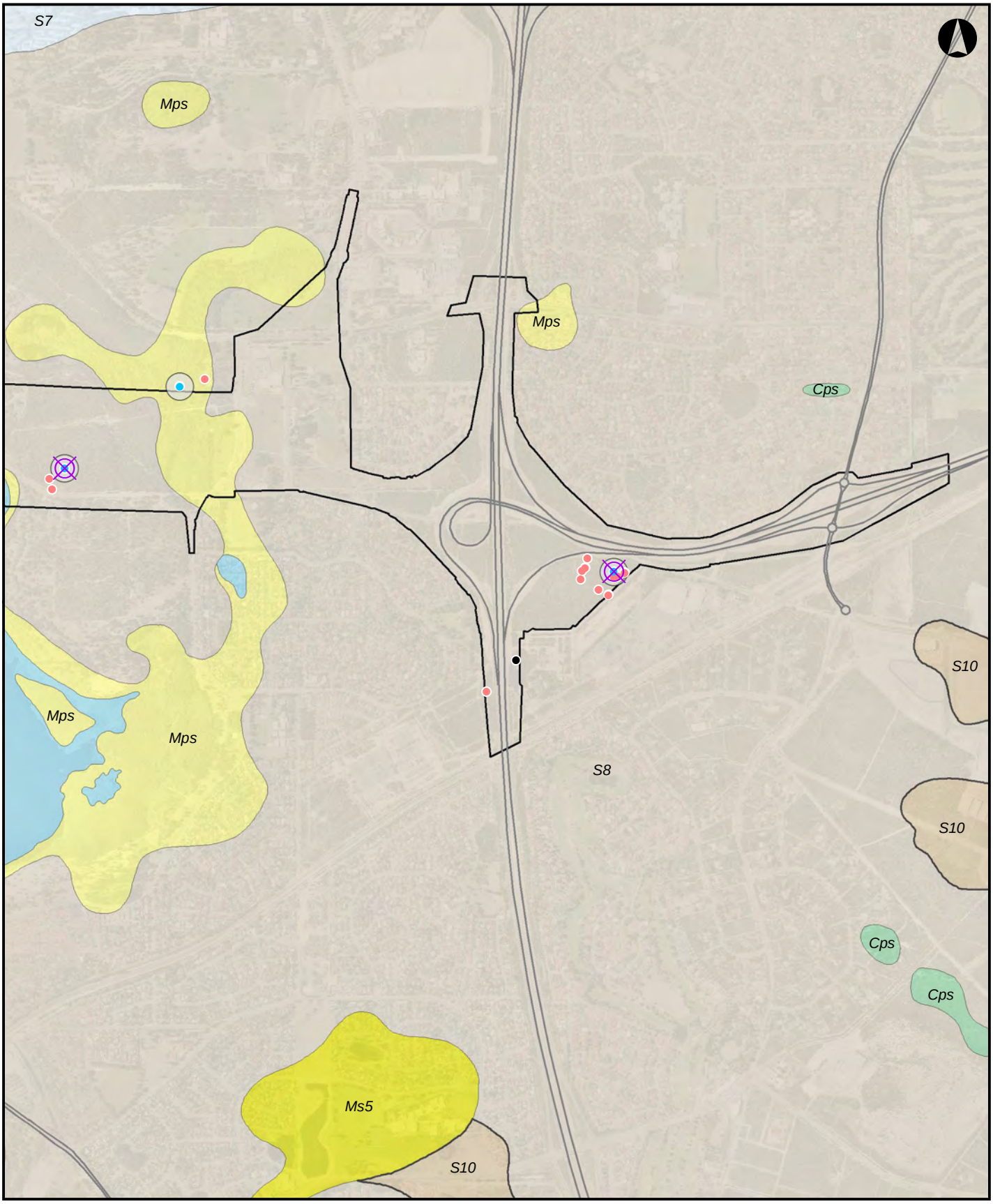

Southern Brown Bandicoot and Perth Lined Lerista Records

South Metro Connect

Figure 5.9-6b

0 200 400 600 800

Metres
1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

Quenda Record
- Tracks
- Remains
- Sightings
- Diggings

Perth Lined Lerista Record

Vertebrate Fauna Trap Site

- Cps - Peaty clay
- Mps - Peaty silt
- Ms5 - Sandy silt
- S7 - Pale yellow-brown sand
- LS1 - Limestone
- S8 - Light grey sand (LGS)
- S10 - LGS over brown silt/clay
- Water

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5.9.4.9. Perth Lined Lerista (*Lerista lineata*)

The Perth Lined Lerista is listed as Priority 3. It is a small slender skink that primarily feeds on small invertebrates, their eggs and larvae. This fossorial (living underground) species shelters in leaf litter and the upper layers of loose sand at bases of shrubs, spoil heaps and stick ant nests. It inhabits *Banksia* woodland, sandy coastal heath and low shrubland in soils containing a low percentage of clay (Bush *et al*. 2007; Wilson and Swan 2008). On the Swan Coastal Plain, the Perth Lined Lerista is restricted to white or pale sands (specifically the Bassendean and Spearwood dune complexes), which support *Banksia* woodlands, heathlands and shrublands. There are no records of this species north of the Swan River on the Swan Coastal Plain (Maryan 2010).

This species was recorded during the vertebrate fauna surveys at several locations within and adjacent to the project area (Figure 5.9-6). Several previous records exist within the study area and in surrounding areas (e.g. How *et al*. 1996; Bamford *et al*. 2002; Dell and Cooper 1992; GHD 2006). Suitable habitat exists for this species throughout most of the project area.

5.9.4.10. Black– striped Snake (*Neelaps calonotus*)

The Black– striped Snake is listed as Priority 3. This species is predominantly restricted to the sandy coastal strip of the Swan Coastal Plain between Mandurah and Lancelin. It primarily inhabits dunes and sand– plains vegetated with heaths and *Banksia* woodlands. There is limited information on its biology; however, it is known to spend much of its time concealed by upper layers of loose sand below shrubs and litter.

This species was not recorded during the survey periods. However, the availability of suitable *Banksia* woodland habitat suggests that this species may occur within the project area. It was previously recorded at Jandakot Airport in 2002 (Bamford *et al*. 2002).

5.9.4.11. Jewelled Sandplain Ctenotus (*Ctenotus gemmula*)

The Jewelled Sandplain Ctenotus is listed as Priority 3. This species occurs on the lower Swan Coastal Plain and South Coast Region in pale sand plains supporting heaths, particularly Banksia or mallee woodlands. It is scarce to rare on the Swan Coastal Plain with patchily distributed records.

This species was not recorded during the vertebrate fauna surveys. It may occur with *Eucalyptus/Banksia* woodlands within the project area. It was previously recorded at Jandakot by the Western Australian Museum approximately 5km south– east of the project area (AECOM 2010b; DEC 2010c).

5.9.4.12. Graceful Sun–moth (*Synemon gratiosa*)

The Graceful Sun– moth is listed as Endangered under the *EPBC Act* and as Schedule 1 under the *WC Act.* The species is considered threatened due to its restricted known distributions, small area of occupancy, severe fragmentation on the Swan Coastal Plain and the continuing decline of many remaining populations. The known range of the species was recently extended during surveys conducted in 2010, beyond *Banksia* woodland of the Swan region, into coastal parts of the northern South–West and southern Mid–West regions (Bishop *et al.* 2009). However, much of the potential habitat for the Graceful Sun–moth occurs in areas subject to development pressures, particularly the coastal and sub–coastal parts of the Perth metropolitan region.

The Graceful Sun–moth is dependent on two known host plant species, *L. hermaphrodita* and *L. maritima*. These host plants are critical to the reproductive success of the species forming the sole food source during the larval stage. The species has a short adult life span and variable flight periods for the mature adult moths during the target months. Graceful Sun–moth habitat has been mapped within and near the project area (Figure 5.9-7):

- Confirmed habitat – the north–western and north–eastern quadrants of the Stock Road/Forest Road intersection, where adults have been recorded;
- Suitable habitat – actual locations of *L. hermaphrodita* plants; and
- Potential habitat – vegetation communities in which *L. hermaphrodita* was recorded.

The total extent of confirmed habitat within the project area is 8.5ha. Detailed gridding has been undertaken in approximately 12 percent of the project area, resulting in the identification of extensive suitable habitat. A further 127.5ha of the project area comprises vegetation communities that contain *L. hermaphrodita*. Additional surveys have been undertaken to define the regional extent of *L. hermaphrodita* occurrence near the project area.

Six individuals were recorded at the north–western quadrant of the Stock Road and Forrest Road intersection in March 2010(Figure 5.9-7). Additional records were made in the north–eastern quadrant in March 2011. These records are significant because they represent the first population recorded south of the Swan River near the study area since 1969. Another population (represented by collection of three individuals) was recorded during surveys of the Wandi Nature Reserve and Jandakot Regional Park bushland in March/April 2010 (Wandi Progress Association 2010). The 2011 survey undertaken by Phoenix Environmental Sciences did not collect individuals at any of the regional survey locations (Appendix S), although a possible sighting was made at one of these sites (Frederick Samson Park).

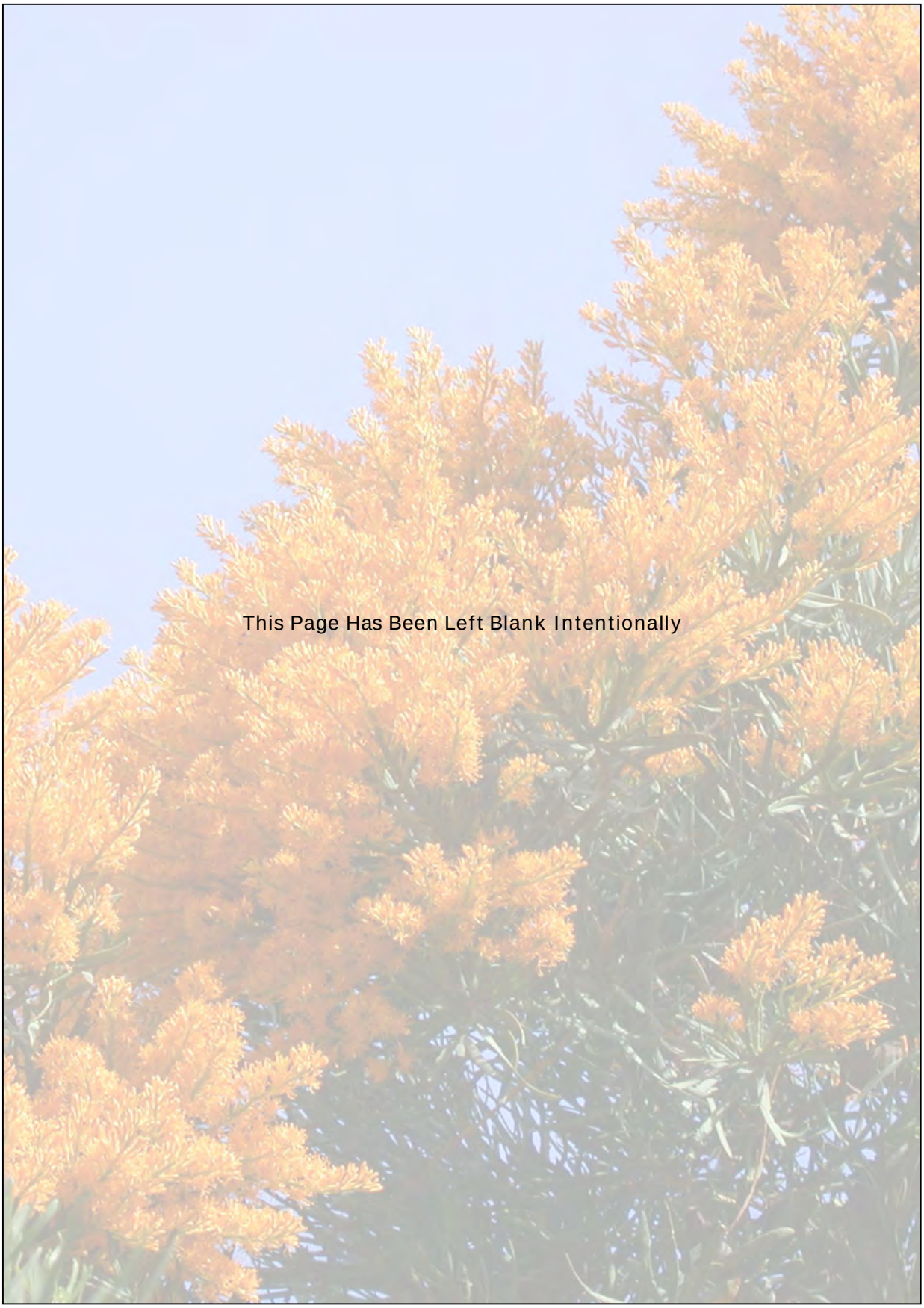
The population recorded in the project area is already unlikely to be viable, due to the combined pressures of habitat loss and habitat fragmentation. It is possible that, given the current small extent of habitat for this population, and its already fragmented state, it may not persist in the long term even in the absence of further disturbance. The minimum patch size required to sustain a population of moths in the long–term is not known. Populations in small coastal heathland sites (less than 2ha) have been known to persist for many years. However, minimum patch size requirements for *Banksia* woodland populations are likely to be larger, because of the lower population densities currently found in this habitat type (Bishop *et al.* 2009).

The recorded Graceful Sun-moth population is unlikely to be viable and may not persist in the long term even without further disturbance

Recorded new populations in conservation estates have resulted in a range extension for the Graceful Sun-moth

The lack of records for Graceful Sun–moth adults outside of the north–western and north–eastern quadrants of the Stock Road/Forrest Road intersection suggest that the species may be susceptible to habitat fragmentation, which has limited its ability to re–colonise beyond this area. The probable short–range (less than 100m) of adults further limits their ability to move beyond their existing habitat, where it is separated by gaps greater than this range and it's unlikely that interbreeding is occurring between the two sub–populations either side of Stock Road. Additionally, they have particular habitat requirements that have yet to be understood.

During recent studies, DEC found that Graceful Sun–moths were recorded at higher rates on *L. maritima* (coastal habitats) than on *L. hermaphrodita* (*Banksia* woodland habitats). Graceful Sun–Moths are generally confined to the Swan Coastal Plain region, but also extend into the Geraldton Sandplains region (Bishop *et al*. 2010). Surveys conducted by DEC have resulted in a range extension for this species with large populations found outside the previously known extent for the species. New populations were also recorded in various conservation estates. Regional data suggests that of the 49 sites (existing populations) recorded within the last 10 years, 17 sites are proposed for development and 16 of these are within the Perth metropolitan and Peel regions (DEC 2011).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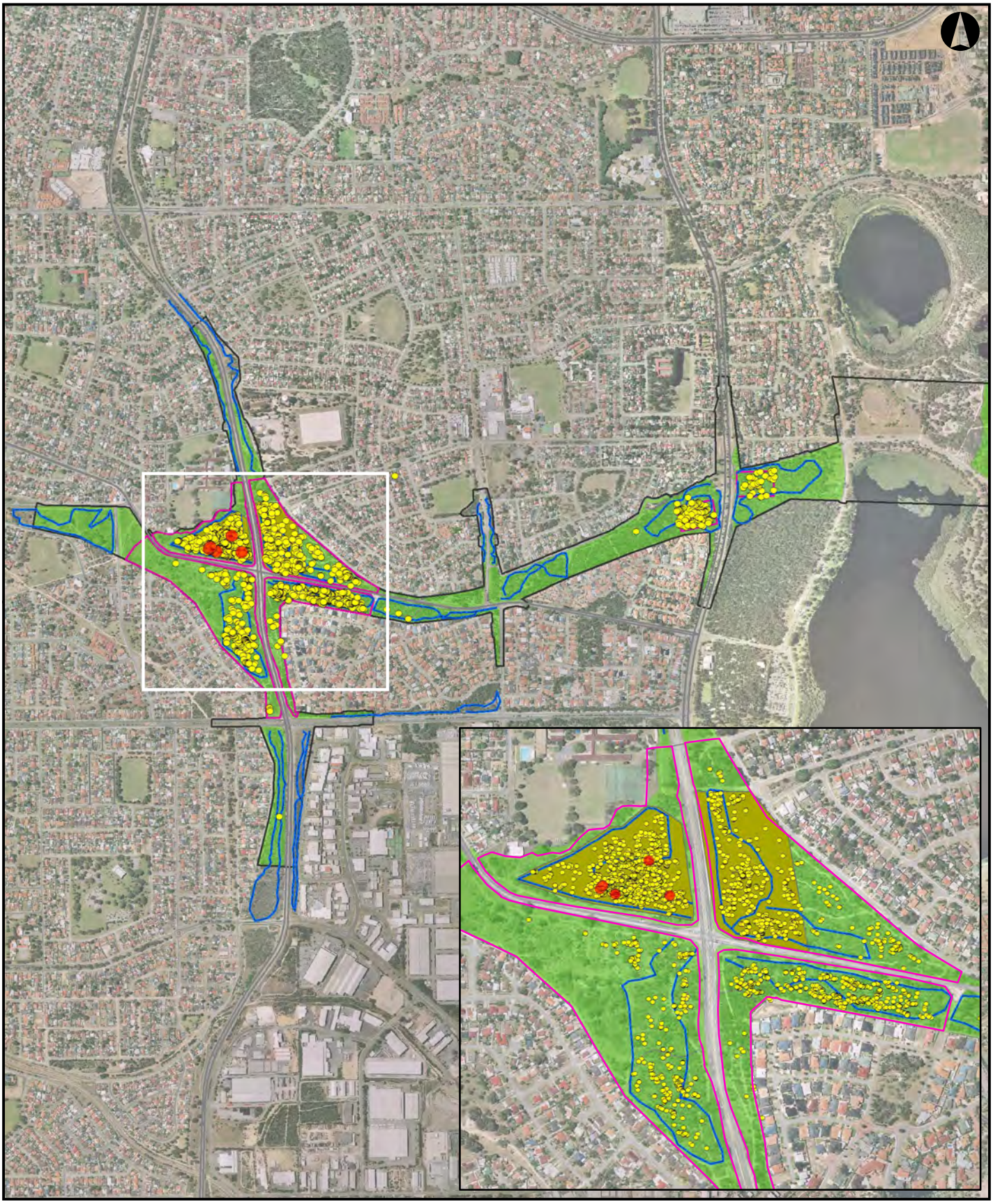

Graceful Sun-moth Records and Habitat

South Metro Connect

Figure 5.9-7a

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Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Graceful Sun-moth Record
- Suitable Graceful Sun-moth habitat (*Lomandra hermaphrodita* records)
- Graceful Sun-moth Transect
- Detailed Gridding Boundaries
- Confirmed Graceful Sun-moth Habitat
- Potential Graceful Sun-moth Habitat

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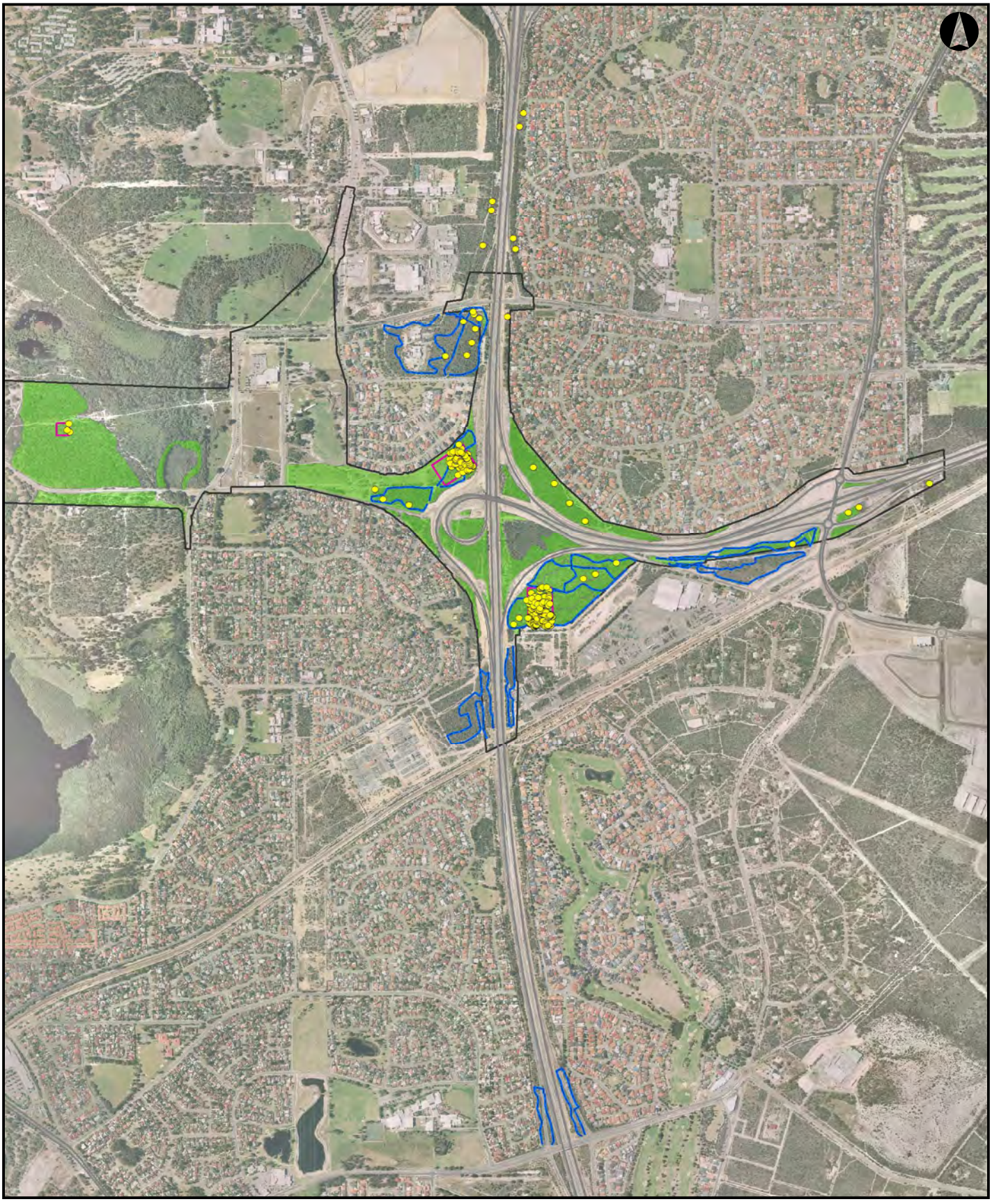

Graceful Sun-moth Records and Habitat

South Metro Connect

Figure 5.9-7b

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Graceful Sun-moth Record
- Suitable Graceful Sun-moth habitat (*Lomandra hermaphrodita* records)
- Graceful Sun-moth Transect
- Detailed Gridding Boundaries
- Confirmed Graceful Sun-moth Habitat
- Potential Graceful Sun-moth Habitat

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5.9.4.13. Other Conservation Significant Invertebrates

A number of conservation significant invertebrate species were identified as potentially occurring in the project area, including four native bee species (*Leioproctus douglasiellus*, *L. bilobatus*, *L. contrarius* and *Neopasiphae simplicior*), two native cricket species (*Austrosaga spinifer* and *Throscodectes xiphos*) and the Scorpion Fly (*Austromerope poultoni*). The locally significant Yellow Admiral Butterfly (*Vanessa itea*) was also identified as potentially occurring. None of these species were recorded in the invertebrate surveys completed to date. However, some of these species may occur in the project area as potential habitat exists for these species (Table 5.9-15).

Table 5.9-15: Potential Conservation Significant Invertebrate Species

Species	Conservation Status[1]	Likelihood of Occurrence	Potential Habitat in Project Area (ha)	Comments
Leioproctus douglasiellus (native bee)	Schedule 1 (*WC Act*)	Unlikely	none	Known host plants (*Goodenia filiformis* and *Anthotium junctiforme*) not recorded in project area
Neopasiphae simplicior (native bee)	CE (*EPBC Act*) Schedule 1 (*WC Act*)	Possible	7.5	*Lobelia tenuior* (from which species has previously been collected) present in some *Eucalyptus–Melaleuca* woodland
Throscodectes xiphos (native cricket)	Priority 1	Possible	133.1	Potential habitat exists in project area
Austromerope poultoni (Scorpion Fly)	Priority 2	Possible	13.9	Limited potential habitat present. Habitat inferred from *Merope tuber*, as limited information available on species habitat preferences
Leioproctus bilobatus (native bee)	Priority 2	Unlikely	none	Only collected from *Gompholobium aristatum*, which was not recorded in project area
Leioproctus contrarius (native bee)	Priority 3	Possible	122.3	Associated with *Lechenaultia stenosepala*, which was not present in project area; however, apparently dependent on upon flowers of *Goodenia* species and some *Goodenia* spp. were recorded in project area
Austrosaga spinifer (native cricket)	Priority 3	Unlikely	127.3	Potential habitat exists, but known records confined to Neerabup National Park (45km north of project area)

Species	Conservation Status[1]	Likelihood of Occurrence	Potential Habitat in Project Area (ha)	Comments
Vanessa itea (Yellow Admiral Butterfly)	Locally significant	Possible	166.5	Potential habitat exists in project area

[1]*WC Act – Wildlife Conservation Act 1950*

EPBC Act – Environment Protection and Biodiversity Conservation Act 1999

CE – Critically Endangered

Priority 1–3 is as per the DEC Priority list.

5.9.4.14. Migratory Birds

Twentyone bird species listed as migratory under the *EPBC Act* may occur, or are known to occur, within one or more of the 13 wetlands surveyed in the wetland bird and shorebird surveys (Table 5.9-16). There are records of most of these species from wetlands immediately adjacent to the project area, particularly North and Bibra lakes.

The Rainbow Bee–eater utilises most habitats for foraging throughout the project area including: *Banksia*, *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia*, *Eucalyptus–Melaleuca*, *Kunzea* shrublands, parklands and roadside batters. It was recorded nesting in open sandy areas/tracks within the project area and is widely recorded in surrounding areas (e.g. Thomsons Lake, Kogolup Lake, Market Garden Swamp and Lake Coogee). This species is a common spring/summer migrant to southern Australia and is considered common in most areas it inhabits (Johnstone and Storr 1998; Johnstone and Storr 2004).

The Rainbow Bee–eater is thought to be widespread, occurring within open woodlands, shrublands, grasslands and coastal dunes areas. Records of this species post–1970s suggest that the Rainbow Bee–eater has expanded in the south–west of Western Australia (DEWHA 2010b). Nesting is also known to occur over wide–ranging habitats of river banks, creeks, dams, cliff faces and in disturbed and exposed areas, such as roadside cuttings, the walls of gravel pits or quarries and gravel mounds or on the ground (DEWHA 2010b).

Refer to Section 5.9.2 for information on habitat, community composition and species richness comparisons across the Beeliar Wetlands.

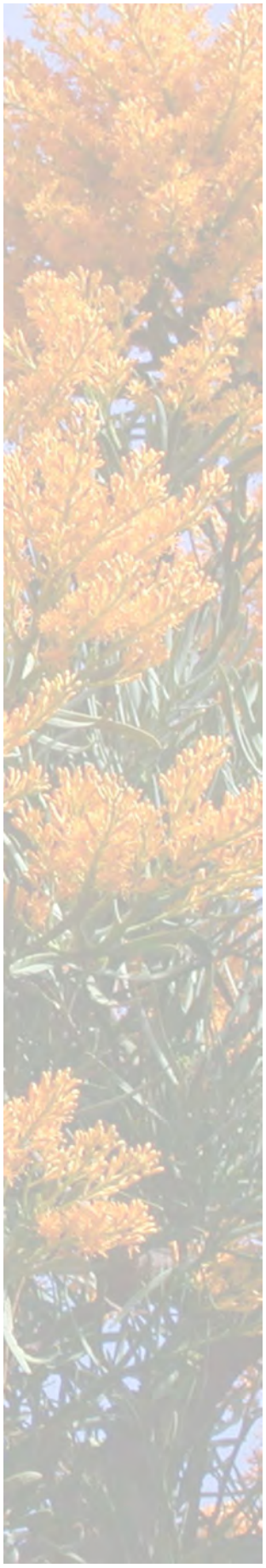
Table 5.9-16: *EPBC Act* Listed Migratory Birds

Species	Records in study area[a], 1981–2010	Recorded 2009–2010	Breeds in study area	Explanation
(*Apus pacificus*) Fork–tailed Swift	None	No	No	May overfly the study area on occasion. Wetlands adjacent to the project area are not likely to be of particular importance
(*Ardea modesta*) Eastern Great Egret	Most wetlands	Yes	Unknown, but may on occasion	Most South West wetlands support low numbers of this species. Wetlands adjacent to the project area are not likely to be of particular importance
(*Ardea ibis*) Cattle Egret	North and South lakes	Yes	Unknown, but unlikely	Only known from occasional records in the study area. Wetlands adjacent to the project area are not likely to be of particular importance
(*Plegadis falcinellus*) Glossy Ibis	Bibra, Kogolup, Little Rush, North and Thomsons lakes	Yes	Unknown, but unlikely	Occurs as a non–breeding summer visitor to some of the wetlands. Wetlands adjacent to the project area are not likely to be of particular importance
(*Pandion cristatus*) Eastern Osprey	Lake Coogee, Bibra, North and Thomsons lakes	Yes	Unknown, but unlikely	Generally a coastal species that has been recorded at some wetlands on occasion. Wetlands adjacent to the project area are not likely to be of particular importance
(*Haliaeetus leucogaster*) White–bellied Sea–Eagle	Lake Coogee, Bibra, North, Thomsons and Yangebup lakes	Yes	Unknown, but unlikely	Generally a coastal species that has been recorded at some wetlands on occasion. Wetlands adjacent to the project area are not likely to be of particular importance
(*Pluvialis squatarola*) Grey Plover	North and Yangebup lakes	–	No	Although this species occurs on drying freshwater wetlands, it also uses coastal and estuarine habitats and has only been recorded from the study area on occasion. Wetlands adjacent to the project area are not likely to be of particular importance
(*Charadrius dubius*) Little Ringed Plover	Bibra and Yangebup lakes	–	No	A vagrant species, as most birds migrate to Asia and Africa, only a few flying on to Australia. Wetlands adjacent to the project area are not likely to be of particular importance
(*Limosa limosa*) Black–tailed Godwit	Bibra, North, South and Thomsons lakes	Yes	No	Favours coastal habitats but also uses near–coastal wetlands and has been recorded in very low numbers at some of the wetlands. Wetlands adjacent to the project area are not likely to be of particular importance
(*Actitis hypoleucos*) Common Sandpiper	Lake Coogee, Bibra, Kogolup, North, Thomsons and Yangebup lakes	Yes	No	Occurs in low abundances at many wetlands. Wetlands immediately adjacent to the project area are not of particular significance
(*Tringa nebularia*) Common Greenshank	Most wetlands	Yes	No	Occurs in low abundances at many wetlands. Wetlands immediately adjacent to the project area are not of particular significance
(*Tringa stagnatilis*) Marsh Sandpiper	Lake Coogee, Bibra, Kogolup, Little Rush and Thomsons lakes	Yes	No	Occurs in low abundances at many wetlands. Wetlands immediately adjacent to the project area are not of particular significance

Species	Records in study area[a], 1981–2010	Recorded 2009–2010	Breeds in study area	Explanation
(*Tringa glareola*) Wood Sandpiper	Horse Paddock Swamp, Bibra, Kogolup, Little Rush, Thomsons and Yangebup lakes	Yes	No	Occurs in low abundances at many wetlands. Wetlands immediately adjacent to the project area are not of particular significance
(*Calidris ruficollis*) Red–necked Stint	Lake Coogee, Bibra, Kogolup, North, Thomsons and Yangebup lakes	Yes	No	Occurs in low abundances at many wetlands. More abundant on other wetlands in the study area, than those adjacent to the project area (Thomsons Lake, Yangebup Lake)
(*Calidris subminuta*) Long–toed Stint	Kogolup, Thomsons and Yangebup lakes	Yes	No	Occurs in low abundances at a few wetlands. Wetlands immediately adjacent to the project area are not of particular significance
(*Calidris melanotos*) Pectoral Sandpiper	Kogolup, Thomsons and Yangebup lakes	–	No	May be an occasional summer visitor. Wetlands immediately adjacent to the project area are not likely to be of particular importance
(*Calidris acuminata*) Sharp–tailed Sandpiper	Bibra, Kogolup, North, Thomsons and Yangebup lakes	Yes	No	Occurs in low abundances at many wetlands. Wetlands immediately adjacent to the project area are not of particular significance
(*Calidris ferruginea*) Curlew Sandpiper	Lake Coogee, Bibra, Kogolup, South, Thomsons and Yangebup lakes	–	No	Occurs in low abundances at many wetlands. Very abundant at Thomsons Lake compared to wetlands immediately adjacent to the project area
(*Philomanchus pugnax*) Ruff (Reeve)	Thomsons and Yangebup Lakes	–	No	A vagrant species, as most birds migrate to Africa, south Asia and southern Europe, only a few flying on to Australia. Wetlands immediately adjacent to the project area are not likely to be of particular importance
(*Chlidonias leucopterus*) White–winged Black Tern	Thomsons Lake and Lake Yangebup	–	No	An irruptive species. Other wetlands in the study area may have some importance to this species but has not been recorded at wetlands adjacent to the project area
(*Merops ornatus*) Rainbow Bee–eater	Bibra, Kogolup Lake, Little Rush Lake, North, South, Thomsons Lake and Yangebup Lake	Yes	Yes	Recorded at most wetlands. Can be sedentary or migratory. Pair recorded breeding in an open sandy area near fauna Site 5. Project area contains suitable habitat but this is not likely to be of particular importance

Source: Appendix M and Appendix O

[a]Study area for the wetland bird and shorebird surveys



5.9.5. Summary of Key Findings

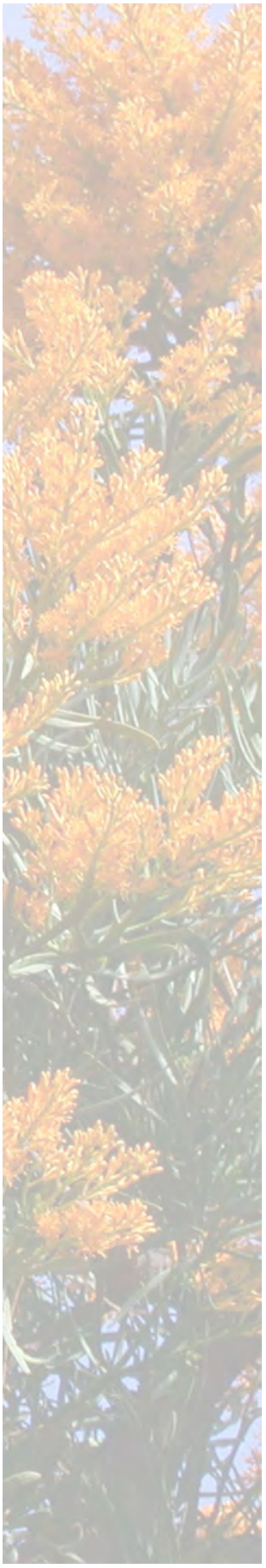
The project area supports a range of fauna habitats, but is dominated by various forms of Jarrah–Marri–*Banksia* associations. Fauna habitats of the project area are well represented both locally and regionally.

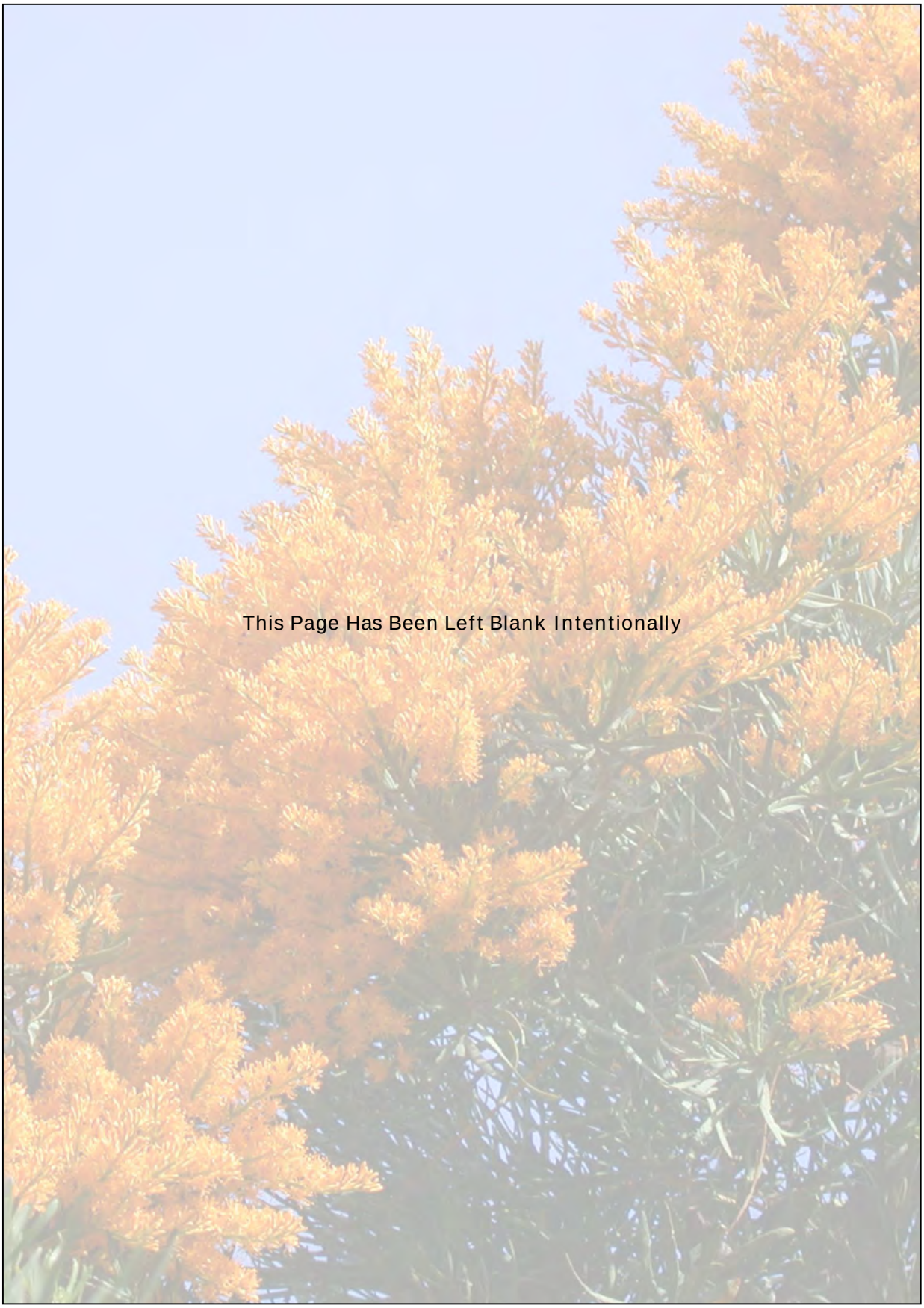
The various fauna surveys indicate that:

- Five conservation significant species (excluding wetland birds and shorebirds) were found to occur within the project area:
  - Carnaby's Black Cockatoo;
  - Forest Red–tailed Black Cockatoo;
  - Southern Brown Bandicoot;
  - Perth Lined Lerista; and
  - Graceful Sun–moth
- Carnaby's Black Cockatoo and Forest Red–tailed Black Cockatoo were both recorded in the project area. No evidence of breeding or use of potential nesting hollows has been recorded for either species within the vicinity of the project area. However, foraging habitat for both species exists within the project area and roosting sites are known to exist within close proximity;
- A total of 107 individual Southern Brown Bandicoot were made, with a mean estimated population density of 28 per hectare:
- The Perth Lined Lerista was recorded at several locations within and adjacent to the project area;
- The Graceful Sun–moth was recorded in the north–western and north–eastern quadrants of the Stock Road and Forrest Road intersection. These records are significant because they represent the first population recorded south of the Swan River near the study area since 1969. The population recorded in the project area is, however, already unlikely to be viable due to the existing combined pressures of habitat loss and fragmentation;
- Five introduced mammal species and five naturalised exotic birds were recorded in the project area;
- Of the wetlands within the project area:
  - North and Bibra lakes consistently rank high in species richness and highest total count of wetlands and shorebirds, while Horse Paddock and Lower swamps rank relatively low;
  - Bibra Lake is recognised for its high waterbird diversity and high numbers of Hoary–headed Grebes, and North Lake is an important breeding area for ducks; and
  - Bibra Lake recorded the highest number of CS1 migratory shorebirds during the 2009–2010 survey, while North Lake, Horse Paddock Swamp and Lower Swamp provided only two records collectively;
- Seven SRE species (three species of spiders and four millipedes) with a distribution limited to the Perth metropolitan region were recorded in the study area;
- One of the SRE species, an unidentified sucking millipede (*Siphonotidae sp.*), warrants particular attention. It is rarely found in the Perth metropolitan area. Although it may be conservation significant, it cannot be further taxonomically evaluated at this time.

- It is unlikely that the limestone strata within the project area contains habitat suitable for troglobitic fauna; and
- None of the wetlands of the project area are considered particularly significant in terms of diversity of taxa or iconic species within the macroinvertebrate assemblages.

Predicted impacts on fauna and proposed mitigations are discussed in Section 6.7.

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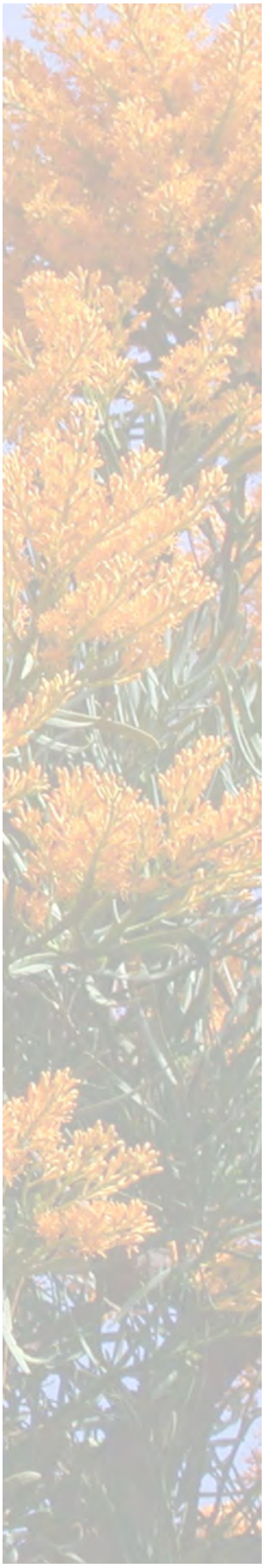
5.10. Ecological Linkages

The importance of retaining ecological linkages is recognised in environmental and planning policy (EPA 2006b; EPA 2008b; WAPC 2010). The EPA acknowledges the importance of ecological linkages to the Beeliar Regional Park in Bulletin 1088 (EPA 2003), in which it seeks to maintain ecological linkages and corridors between, within and across the Beeliar Regional Park in order to maintain the diversity and vigour of the Park's ecological systems.

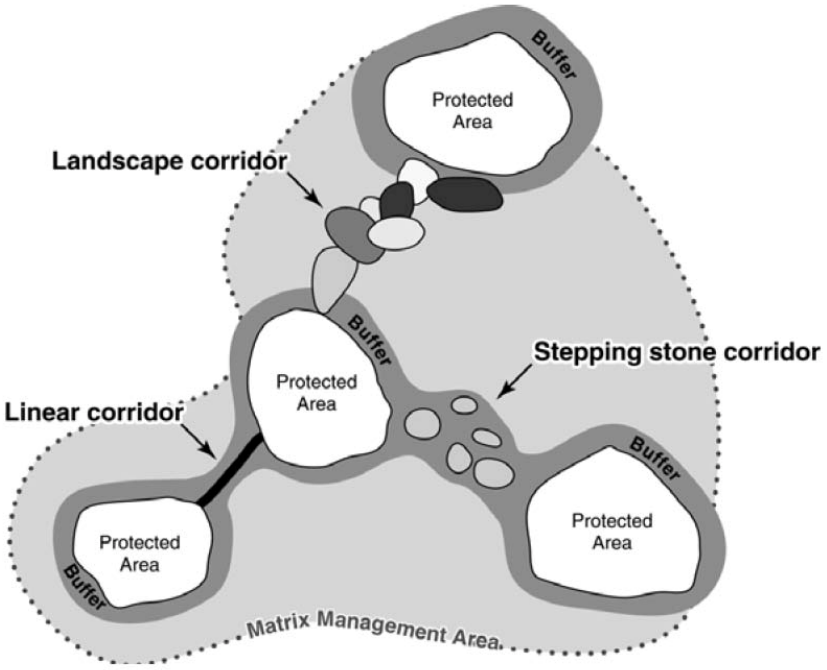
The term ecological linkage refers to a sequence or network of natural areas within developed areas (i.e. urban and agricultural) that connect remnant natural habitats. The form of an ecological linkage can vary from a landscape corridor (i.e. as an array of terrestrial and/or water patches), a linear corridor (i.e. roadside vegetation or buffer strips), stepping stone corridors or a combination of these (Figure 5.10-1). Ecological linkages can be connected or non–contiguous (fragmented). Protection and management of the 'islands' that are part of fragmented linkages is necessary in order to maintain functional value.

Generic terms, such as greenways and greenway corridors, are often used to describe a broader range of landscape planning strategies, concepts and plans that generally serve to maintain linkages in urban areas (Alan Tingay and Associates 1998). Greenway corridors are defined as 'networks' of land containing linear elements that are planned, designed and managed for ecological, recreational, cultural, aesthetic and/or other purposes compatible with the concept of sustainable land use (Ahern 1995).

The most recent methodology used in defining regional ecological linkages (Molloy *et al*. 2009), highlights the ecological importance of maintaining close proximity between a network of remnant vegetation patches to allow species movement, rather than focusing on a linear linkage concept. Ecological linkages in urban areas usually require ongoing management in order to maintain long–term function and viability.



Cumulative habitat isolation and loss has been occurring intensively since the 1970s



Source: NBSRTG 2009

Figure 5.10-1: Conceptual Spatial Planning for Terrestrial Connectivity

In practice, it is difficult to maintain ecological linkages in urban areas, because pressures, such as clearing for urban development, residential infilling, roads, railways and other built infrastructure, limit the connections between remnant ecosystems. The fragmentation of ecological linkages refers to the dissection of the passages between habitat areas into a series of spatially separated parts. Fragmentation of ecological linkages leads to spatial discontinuity and diminished viability of remnant populations and is a key threatening process to fauna biodiversity conservation in the project area, as well as within the Perth metropolitan region and Swan Coastal Plain.

Cumulative habitat isolation and loss due to urban development and encroachment has been occurring intensively within the project area since the 1970s. Figure 5.10-2 illustrates the historical urban encroachment (shaded range) around the project area (outlined in red) based on historic aerial photographs from the years 1970, 1989 and 2009.

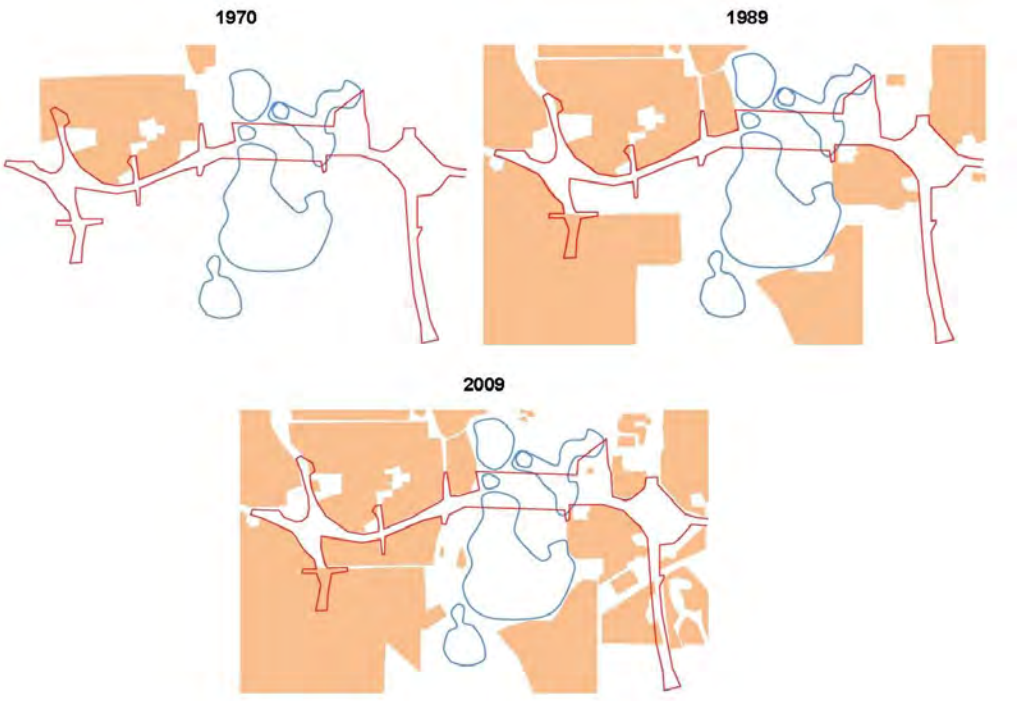


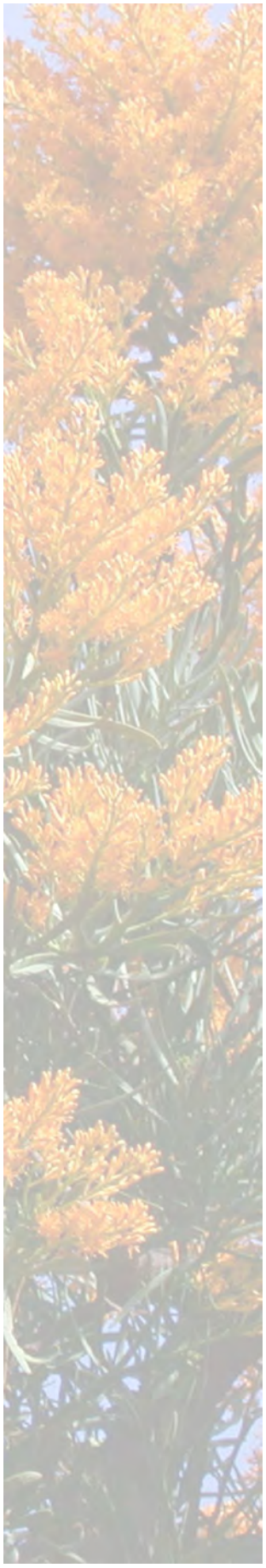
Figure 5.10-2: Interpretation of Urban Encroachment from 1970 to 2009

Ecological linkages are important for maintaining faunal biodiversity

Ecological linkages are important for maintaining faunal biodiversity by:

- Extending the foraging and nesting range of isolated fauna species, populations and assemblages;
- Facilitating gene flow between isolated populations, which reduces problems arising from in–breeding; and
- Providing opportunities to colonise new areas and access refuge habitats in extreme conditions (e.g. during extreme drying periods when water sources shrink or totally dry out).

Although plant species do not critically depend on physical linkages with other vegetation patches in the short–term (Bennett and Mulongoy 2006), their long–term survival can depend on the opportunity for establishment within adjoining or adjacent habitat patches in response to potential threats or periodic natural disturbances (e.g. drought, flooding or fire). Additionally, long–term continued existence of flora species is linked to the survival of fauna critical to its life cycle (i.e. pollinators or seed carriers), which in themselves can be at risk from fragmentation.



5.10.1. Regional Ecological Linkages

Regional ecological linkages that connect the project area to the wider linkage network of the Perth metropolitan region are identified by the Perth Biodiversity Project (PBP) (Del Marco *et al.* 2004). These linkages are shown in Figure 5.10-3 and incorporate:

- North–south connectivity between the southern side of the Swan River, through the project area and the Eastern Chain of the Beeliar Wetlands to Point Peron;
- East–west connectivity between Bibra Lake and Manning Lake in Hamilton Hill in the west; and
- East–west connectivity between Roe Swamp and the Southern River area in the east.

For the purposes of reporting, four regional ecological linkages (EL1 through EL4) have been identified. These regional linkages and their relationship to the PBP mapping (Del Marco *et al.* 2004) and the Greenway Corridors of Alan Tingay and Associates (1998) are summarised in Table 5.10-1.

Table 5.10-1: Regional Linkages

No.	Regional Ecological Linkage	Details	Scale	Greenway Corridor*	PBP Ecological Linkage**
EL1	Bibra Lake (BF 244) to Manning Lake (BF 247)	East–west, non–contiguous linkage	Regional	–	51
EL2	Bibra Lake (BF 244) to Jandakot Airport (BF 388) and Ken Hurst Park (BF 245)	East–west, stepping stone linkage	Regional	73	48
EL3	North Lake (BF 244) to Piney Lakes Reserve (BF 339)	North–south, stepping stone linkage	Regional	90	50
EL4	Bibra Lake (BF 244) to South Lake (BF 254) and beyond	North–south, semi–contiguous linkage	Regional	75	50

*numbers from Alan Tingay and Associates 1998

**numbers from Del Marco *et al.* 2004

BF – Bush Forever Site number

PBP – Perth Biodiversity Project

The project area is situated within Beeliar Regional Park, which is made up of various wetland areas and other landform units of the Swan Coastal Plain.

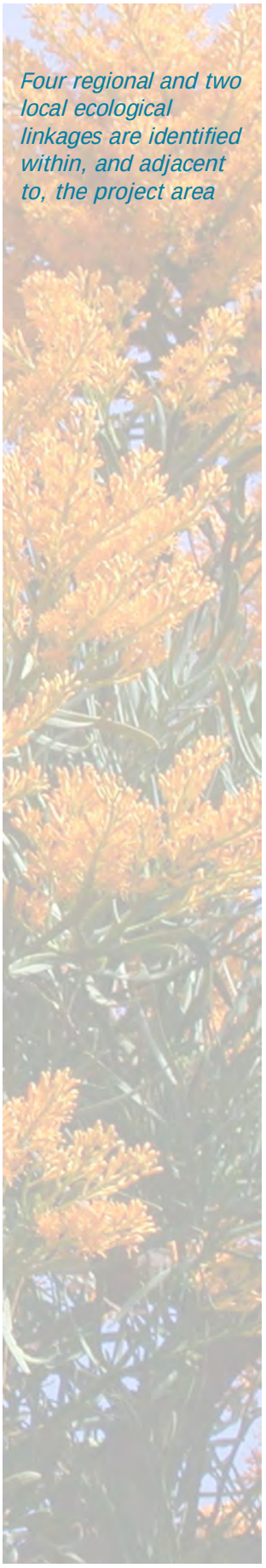
The first ecological linkage (identified as EL1) is a regional, but non–contiguous, ecological linkage trending east–west from Bibra Lake to Manning Lake near the coast. In its current form, EL1 is not viable to support species movement, apart from various avian species moving between separated tree canopies. This is mainly due to gaps in the sequence of constituent remnant vegetation areas along its length at ground level. It encompasses portions of land formerly zoned as road reserve in the MRS, most of which have now been sold and developed as urban land. The potential linkage is highly fragmented by roads, industry and housing. Its importance to ecological systems within the Beeliar Regional Park is limited, other than to provide for the movement of avian species.

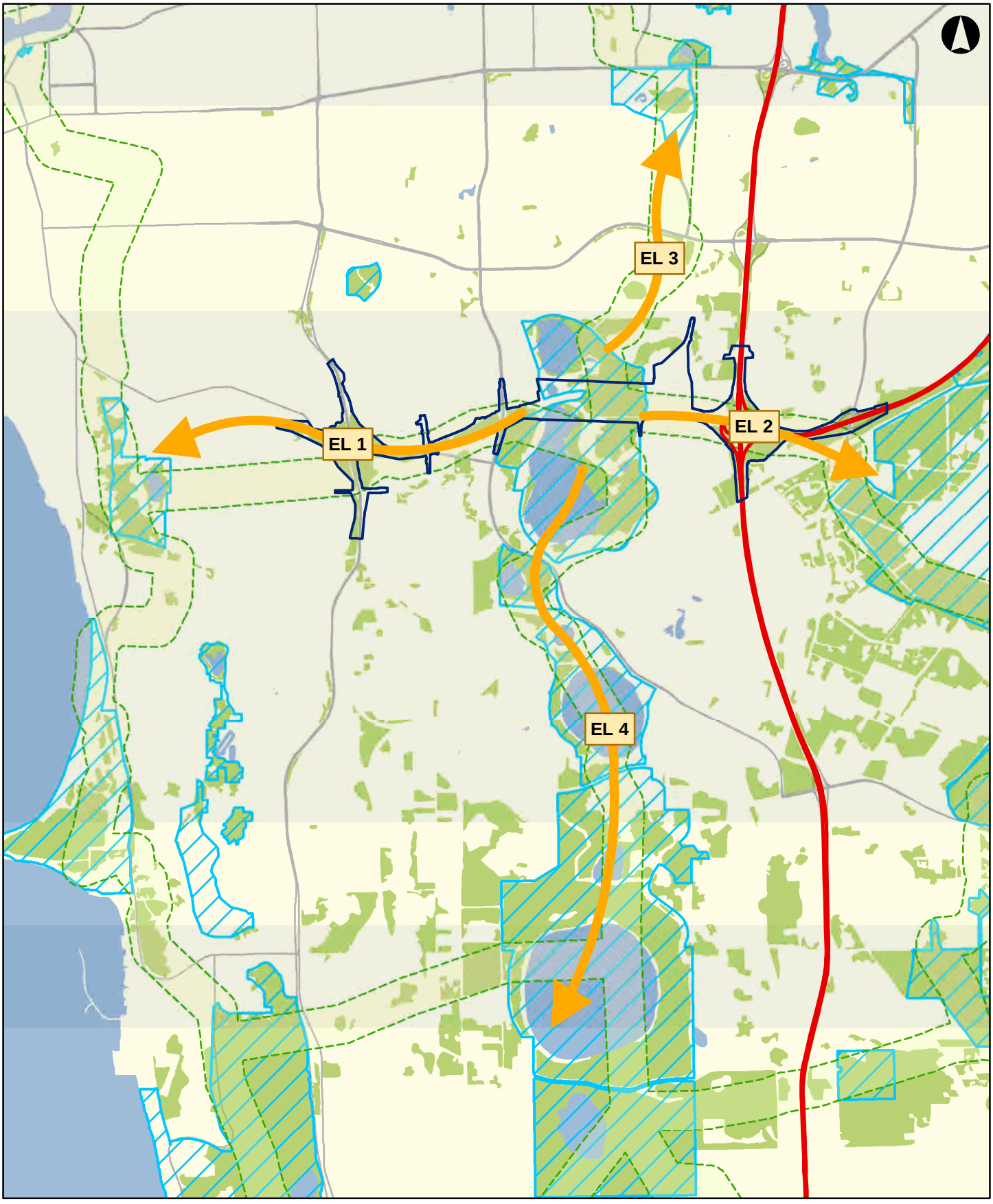
The second ecological linkage (identified as EL2) is the regional linkage (stepping stone) trending east–west from Bibra Lake to Jandakot Airport Reserve and associated surrounding bushland reserve areas. Jandakot Airport Reserve contains some of the best remaining examples of *Banksia* woodland on the Swan Coastal Plan. Maintaining connectivity between this area and Bibra Lake is likely to be important in maintaining ecosystem processes in the region. The linkage connects to essential habitat for migratory and nomadic fauna species, and provides access to feeding resources for Carnaby's Black Cockatoos. The EL2 linkage extends further eastward through Harrisdale to the Champion Lakes area. Its importance to ecological systems within the Beeliar Regional Park is slightly greater than that of EL1, as it provides an important linkage to Jandakot Regional Park.

The third ecological linkage (identified as EL3) is the regional linkage (stepping stone) trending north–south from Bibra Lake through Murdoch University to Piney Lakes Reserve. The linkage extends further northward to the Canning River and Bush Forever Site 333. However, this linkage is fragmented by urban infrastructure and is likely to be routinely utilised by avian species only. It has moderate importance to the ecological systems of the Beeliar Regional Park, mainly by reducing the gap between the northernmost extent of the Regional Park and Bibra Lake.

The final ecological linkage (identified as EL4) is a north–south trending linkage that extends to South Lake and Bush Forever Site 254, and on through the Eastern Chain of Beeliar Wetlands, including Thomsons Lake (Ramsar listed), the Wellard area and incorporating other wetlands in the chain down to the Spectacles and Lake Cooloongup (east of Rockingham). This linkage is generally contiguous and intact, and its importance to the ecological systems of the Regional Park is considered significant.

Four regional and two local ecological linkages are identified within, and adjacent to, the project area





Regional Ecological Linkages

South Metro Connect

Figure 5.10-3

0 0.5 1 1.5 2

Kilometres

1:65,000 (A4)

- Regional Ecological Linkage
- Project Area
- Regional Ecological Linkages (Provided by Perth Biodiversity Project 2003)
- Bush Forever Sites
- Remnant Native Vegetation

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5.10.2. Local Ecological Linkages

In addition to the regional ecological linkages identified above and in order to adequately assess impacts of the proposed project, local ecological linkages have been identified (Table 5.10-2) and are illustrated in Figure 5.10-4. The importance of these linkages to the ecological systems of the Beeliar Regional Park is significant.

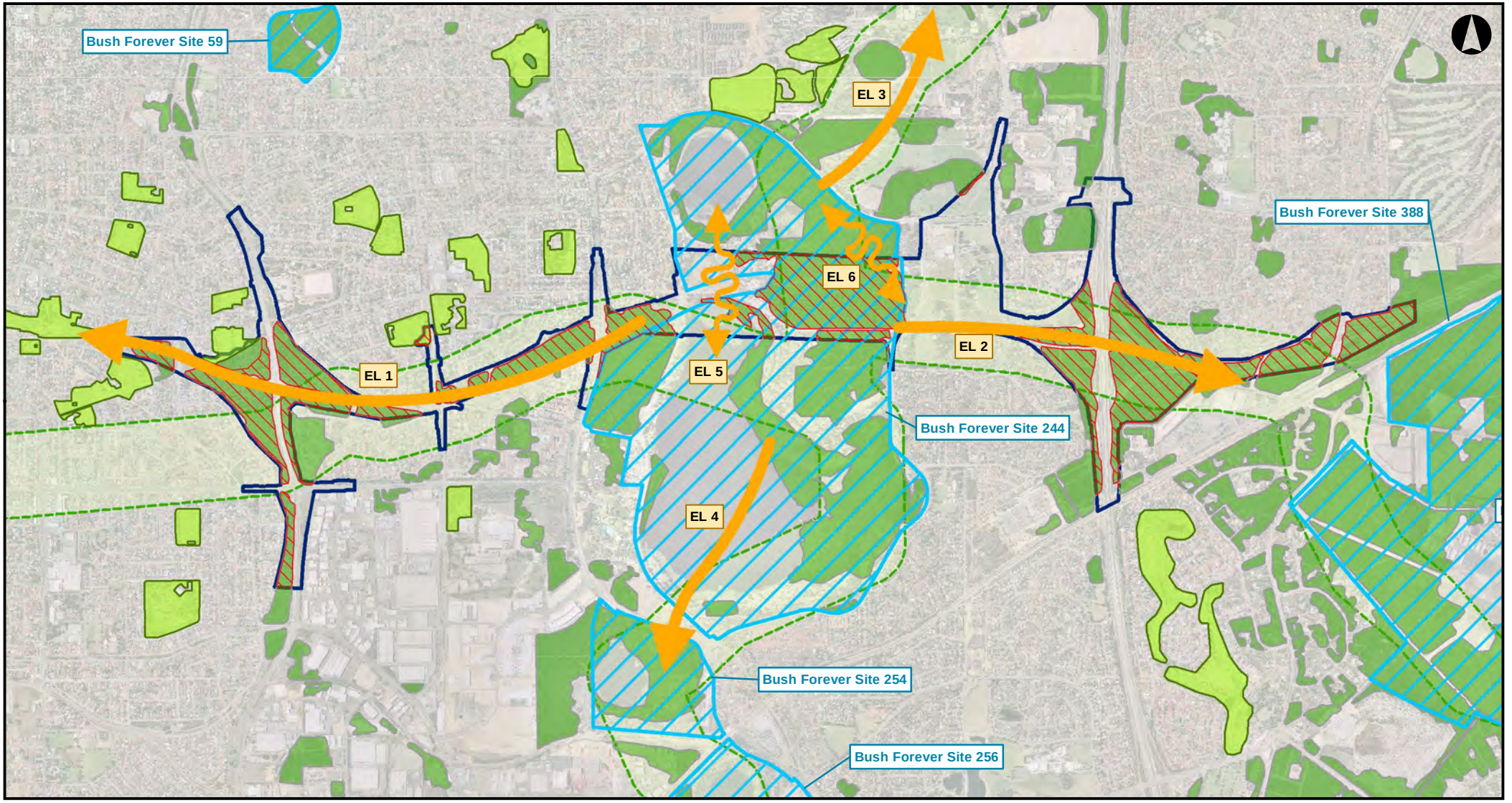
Table 5.10-2: Nominated Local Ecological Linkages

No.	Local Ecological Linkage	Details	Scale
EL5	North Lake to Bibra Lake	North–south, hydrological linkage	Local
EL6	Upper Roe Swamp to Lower Roe Swamp	North–south, hydrological linkage	Local

5.10.3. Regional Habitat Areas

Regional habitat areas are large urban parkland and bushland reserves set aside and protected (by legislative and policy frameworks) from development for the purpose of nature conservation. These areas can have a variety of tenures such as Crown Lands vested in State government agencies or local governments, as well as private lands where the agreement of the landowner is obtained (CALM 2005b). Most of these areas are managed by the DEC as regional parks (Moir 1995; Dooley and Pilgrim 2009). Regional parks and their constituent habitat areas make up approximately 73,000ha or 10.4 percent of the Perth metropolitan region. These areas are designated as Regional Open Space (Dooley and Pilgrim 2009). Key regional habitat areas located within or near the project area are:

- North and Bibra lakes and areas associated with Bush Forever Site 244 – an area of 128.2ha of bushland and wetlands located within Beeliar Regional Park (EL1 through EL6);
- Manning Lake, adjacent bushland and associated Bush Forever Site 247 – an area of 50.6ha located in Hamilton Hill/Spearwood and at the western extent of residual land set aside for the former Fremantle Eastern Bypass (EL1);
- Jandakot Bushland – an aggregate of over 600ha of bushland including Jandakot Airport Reserve (Bush Forever Site 388) and other adjacent bushland areas such as Ken Hurst Park (Bush Forever Site 245); Acourt Road Bushland, Banjup (Bush Forever Site 389); and Bush Forever Site 390, Fraser Road bushland, Banjup (EL2);
- Piney Lakes Reserve, Winthrop (Bush Forever Site 339) – a combined area of 50ha of bushland plus 17 additional hectares of recreational open space (EL3);
- Sir Frederick Samson Park, Samson (Bush Forever Site 59) – an area of approximately 16ha of bushland (no linkage); and
- South Lake (Bush Forever Site 254) – a wetland area south of Bibra Lake and forming part of the Eastern Chain of the Beeliar Wetlands (EL4).



Ecological Linkages of the Project Area

South Metro Connect

Figure 5.10-4

0 250 500 750 1,000

Metres

1:32,000 (A4)

- Remnant Native Vegetation Within Project Area
- Bush Forever Sites
- Regional Ecological Linkage
- Local Ecological Linkage
- Other Local Greenspace (Parks & Recreation)
- Remnant Native Vegetation
- Regional Ecological Linkages (Provided by Perth Biodiversity Project 2003)
- Project Area

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5.10.4. Main Species Groups Utilising Ecological Linkages

Ecological effects of fragmentation are species–specific and depend on the size of the functional linkage; movement (range and method) of an animal species and, for flowering plants, their pollinators; as well as refuge requirements. According to Ahern (2004) the movement of animal species can be divided into three main types:

- Local movements – within the home range on a small scale (i.e. foraging, hiding from enemies and optimising living conditions);
- Dispersal – from a place of birth to the site of reproduction, often away from the family group, without return to the place of birth; and
- Migration – movement back and forth on a regular basis usually with the seasons.

A recent broadscale study found that ecological linkages are critical to maintaining viable and biologically diverse faunal assemblages, especially at–risk fauna on the Swan Coastal Plain (Davis *et al.* 2008). The study identified key species or groups that are particularly dependent on ecological linkages. Several of these species have been recorded during project surveys or may occur within the project area. Although additional species–specific research is required to better define and understand fauna use of ecological linkages, these species or groups generally include:

- Large–bodied reptiles, such as goannas, snakes, bobtails and possibly dragons;
- Vagrant bird species, such as fairy wrens (*Malurus* spp.); and
- Remaining mammal species identified by vertebrate fauna surveys, including the Common Brushtail Possum (*Trichosurus vulpecula*), Southern Brown Bandicoot (*Isoodon obesulus fusciventer*) and Western Grey Kangaroo (*Macropus fuliginosus*).

Table 5.10-3 highlights the linkages that are likely to be used by relevant vertebrate fauna species. Carnaby's Black Cockatoo, Forest Red–tailed Black Cockatoo and the Peregrine Falcon have been excluded from this table as they are not considered to be dependent on these linkages. While these species may utilise habitat within the linkage for foraging, they do not depend on them to move between remnant habitats.

Table 5.10-3: Indicator Fauna Species Likely to Depend on Ecological Linkages

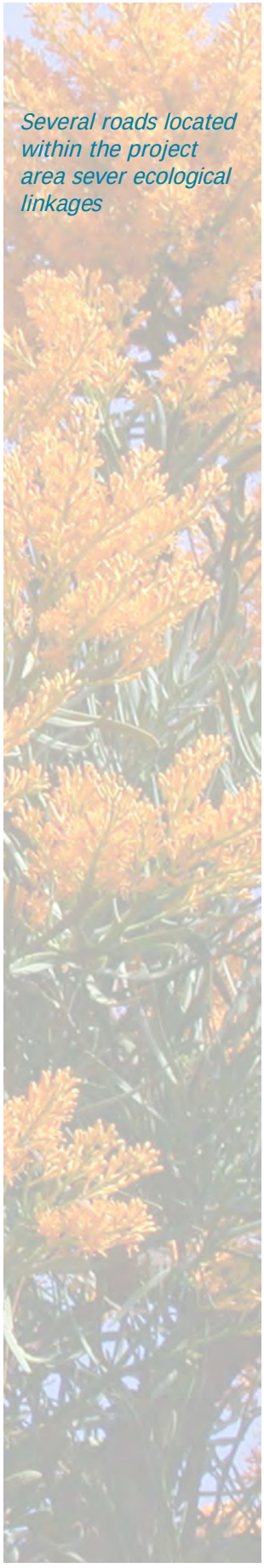
Species	Status	Important Habitat in Study Area	Purpose of Use	Available Habitat in Project Area (ha)	Available Remnant Habitat in Adjacent (Local) Area Along Linkages	Likelihood of Use
Conservation Significant Species						
Western Brush Wallaby (not recorded but could potentially occur)	P4	*Eucalyptus–Banksia* woodland	Requires large foraging areas/ continuous reserves	94ha	EL2/Linkage 48 (East) Jandakot Airport, Bush Forever Site 388 and 389 (650ha and 306ha)	Populations (if present) could be considered fragmented/isolated due to urbanisation (housing) and existing road networks. Unlikely to utilise linkage 48 eastward from project area due to lack of connectivity Unlikely – due to extensive fragmentation by road networks and housing
					EL3/Linkage 50 (North) Bushland west of Roe Swamp heading north (east of North Lake) Bush Forever Site 244 (part of Beeliar Wetland Chain, 402ha) Scattered pockets of remnant bushland in Murdoch University Piney Lakes Reserve – Bush Forever Site 339 (68 ha) and Booragoon Lake Bush Forever Site 337 (13ha) Wireless Hill Reserve – Bush Forever Site 336 (40ha)	May use linkage 50 but only as far as Murdoch University bushland. Remnant habitat further north is highly isolated Possible – due to the availability of suitable habitat in this area Unlikely – insufficient patch size, habitat and lack of connectivity of patches Possible – due to the availability of suitable habitat in this area Unlikely – due to extensive fragmentation by road networks and housing
					EL4/Linkage 50 (South) Bushland west of South Lake, Bush Forever Site 254 (44ha) Bushland west of Kogolup Lake, Thomsons Lake Nature Reserve, bushland surrounding Banganup Lake, all part of Bush Forever Site 391 (744ha)	May utilise linkage 50 southward from project area Possible – due to the availability of suitable habitat in this area Possible – if suitable habitat is present

Species	Status	Important Habitat in Study Area	Purpose of Use	Available Habitat in Project Area (ha)	Available Remnant Habitat in Adjacent (Local) Area Along Linkages	Likelihood of Use
					EL1/Linkage 51 (West) Bushland west of Bush Forever Site 244 (part of Beeliar Wetland Chain, 402ha) to bushland west of North Lake Road Bushland west of North Lake Road to Stock/Forrest Road interchange Bush Forever Site 247 (86ha)	Unlikely to utilise linkage 51 westward from project area due to lack of connectivity Possible – although road network may be a limitation Unlikely – insufficient patch size, habitat and fragmentation by road network Unlikely – due to extensive fragmentation by road networks and housing
Southern Brown Bandicoot	P5	All woodland habitats: *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia* and *Eucalyptus–Melaleuca*	May require large areas/ continuous reserves for foraging and also dispersal during breeding season Monitoring indicates relatively low habitat range for this species (Appendix N)	153ha	EL1/Linkage 51 (West) EL2/Linkage 48 (East) EL3/Linkage 50 (North) EL4/Linkage 50 (South)	Populations (if present) could be considered fragmented or isolated due to urbanisation (housing) and existing road networks Unlikely to utilise linkage 48 eastward and 51 westward from project area due to lack of connectivity May utilise linkage 50 southward from project area and northward but only as far as Murdoch University bushland. Remnant habitat further north is highly isolated
					EL4/Linkage 50 (South) South Lake, Little Rush Lake, Yangebup Lake, Kogolup Lake, Thomsons Lake Nature Reserve, Banganup Lake – Bush Forever Sites 254 (44ha), 256 (186ha) and 391 (744ha)	Likely – where suitable habitat is present

Species	Status	Important Habitat in Study Area	Purpose of Use	Available Habitat in Project Area (ha)	Available Remnant Habitat in Adjacent (Local) Area Along Linkages	Likelihood of Use
Faunal Groups/Other Species						
Mammals – Western Grey Kangaroo		All woodland habitats: *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia* and *Eucalyptus–Melaleuca*	Requires large areas of vegetation and corridors that connect smaller areas of vegetation for foraging and possibly dispersal during breeding season	152ha	EL1/Linkage 51 (West) EL2/Linkage 48 (East) EL3/Linkage 50 (North) EL4/Linkage 50 (South)	Populations could be considered fragmented/isolated due to urbanisation (housing) and existing road networks Unlikely to utilise linkage 48 eastward and 51 westward from project area due to lack of connectivity May utilise linkage 50 southward from project area and northward but only as far as Murdoch University bushland. Remnant habitat further north is highly isolated
Birds – honeyeaters, spinebills, wattlebirds		All habitats that contain flowering resources: *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia* and *Eucalyptus–Melaleuca,* parkland, roadside batters	Likely to use linkages as additional foraging habitat – nectar sources and access to additional foraging areas. May also be important for dispersal during breeding season	163ha	EL1/Linkage 51 (West) EL2/Linkage 48 (East) EL3/Linkage 50 (North) EL4/Linkage 50 (South)	May utilise all linkages (48, 50 and 51) to and from project area due to mobility of this group
Birds – insectivores, vagrants that may visit small urban isolates (1–6ha) (Rufous Whistler, Western Gerygone, fairy wrens)		All woodland habitats: *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia* and *Eucalyptus–Melaleuca*	Likely to use linkages as additional foraging habitat – nectar sources and access to additional foraging areas. May also be important for dispersal during breeding season	152ha	EL1/Linkage 51 (West) EL2/Linkage 48 (East) EL3/Linkage 50 (North) EL4/Linkage 50 (South)	May utilise all linkages (48, 50 and 51) to and from project area due to mobility of this group

Species	Status	Important Habitat in Study Area	Purpose of Use	Available Habitat in Project Area (ha)	Available Remnant Habitat in Adjacent (Local) Area Along Linkages	Likelihood of Use
Reptiles – particularly snakes (Dugite, Tiger snake), larger bodied reptiles (bobtails, dragons)		All woodland habitats: *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia* and *Eucalyptus–Melaleuca*	May require linkages due to large home ranges and high resource requirements (frogs, lizards, birds, mammals)	152ha	EL1/Linkage 51 (West) EL2/Linkage 48 (East) EL3/Linkage 50 (North) EL4/Linkage 50 (South)	Populations could be considered fragmented/isolated due to urbanisation (housing) and existing road networks Unlikely to utilise linkage 48 eastward, and 51 westward from project area due to lack of connectivity May utilise linkage 50 southward from project area and northward but only as far as Murdoch University bushland. Remnant habitat further north is highly isolated
Reptiles – Oblong Turtle		Bibra Lake, North Lake, South Lake and surrounding *Eucalyptus–Xanthorrhoea*, *Eucalyptus–Banksia* and *Eucalyptus–Melaleuca* woodlands and parkland	Require wetland habitats for foraging with linkages/connectivity to upland habitats for breeding/nesting	65.4ha	General	Populations could be considered fragmented/isolated due to urbanisation (housing) and existing road networks
					EL3/Linkage 50 (North) Bushland west of Roe Swamp heading north (east of North Lake) Bush Forever Site 244 (part of Beeliar Wetland Chain, 402ha) Piney Lakes Reserve Bush Forever Site 339 (68 ha) and Booragoon Lake Bush Forever Site 337 (13ha)	May use linkage 50 but only as far as northern extent of Beeliar Regional Park Possible – due to the availability of suitable habitat in this area Possible – due to the availability of suitable habitat in this area
					EL4/Linkage 50 (South) South Lake, Little Rush Lake, Yangebup Lake, Kogolup Lake, Thomsons Lake Nature Reserve, Banganup Lake – Bush Forever Sites 254 (44ha), 256 (186ha) and 391 (744ha)	May utilise linkage 50 southward from project area Possible – if suitable habitat is present

Sources: Davis et al (2008), Van Dyck and Strahan (2008) and Wilson and Swan (2008).



Several roads located within the project area sever ecological linkages

5.10.5. Existing Severances

Several roads located within the project area cause severances of ecological linkages. These roads include Hope Road (between North and Bibra lakes), Coolbellup Road, North Lake Road, Stock Road, Farrington Road and Kwinana Freeway. These existing severances are likely to contribute to a reduction in linkage viability within the project area. The following recorded vertebrate fauna are especially likely to use the ecological linkages:

- Goannas;
- Snakes;
- Fossorial skinks, burrowing snakes and lizards;
- Southern Brown Bandicoot (*Isoodon obesulus fusciventer*); and
- Western Brush Wallaby (*Macropus irma*) (not recorded, but has the potential to occur in the project area).

Medium to large–sized birds are likely to fly over existing roads and the integrity of the local linkages is thereby maintained for these species. Kwinana Freeway provides a greater challenge for smaller bird species. Due to historical fragmentation, there is evidence that populations of larger species have declined or become locally extinct (e.g. Western Grey Kangaroo, Western Brush Wallaby) within the project area because they are only able to survive in the larger areas that existed prior to urban encroachment.

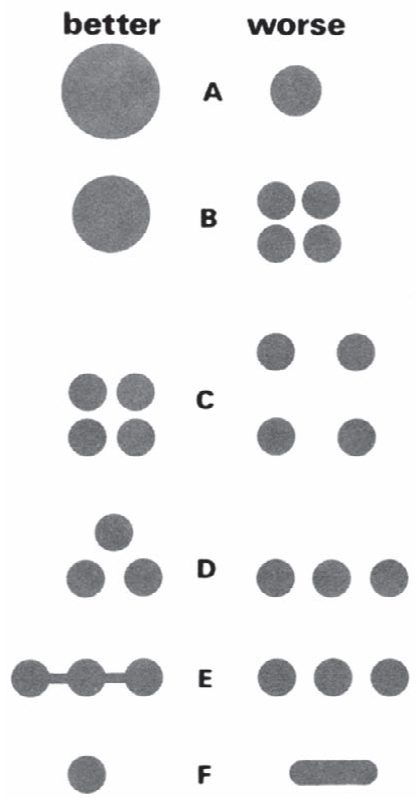
5.10.6. Long–term Viability of Ecological Linkages

Ecological linkage viability requires an ecological system that is able to support a range of living organisms that it naturally maintains over the longer term. Viability depends on the inherent resilience of remnant bushland within the linkages to resist or recover from the effects of fragmentation, invasive weeds, fire, diseases, pests and other disturbances (Del Marco *et al.* 2004).

An important factor influencing viability is the level of management. Small, degraded areas may be viable with intensive management. However, the level of management and associated funding required to maintain the viability for smaller areas may be better used to improve management and associated biodiversity outcomes for larger areas, or areas that are determined to be critical stepping stones. Five easily measured components of viability are:

- Size;
- Shape;
- Perimeter to area ratio;
- Condition; and
- Connectivity.

As shown in Figure 5.10-5, a set of simple spatial rules illustrates the above components in terms of better or worse case scenarios for ecological linkage components (Diamond 1975).



Source: Diamond 1975

Figure 5.10-5: Spatial Rules for the Design of Linkage Components

Many of the ecological linkage components (remnant corridor patches, excluding habitat areas) within the project area do not have optimal sizes, shapes or area to perimeter ratios, as they occupy road reserves. Without intensive management, the inherent spatial forms of these linkage components reduce the long-term viability of the ecological linkages located within the project area.

Generally, a minimum corridor width of 500m is recommended in order to maintain a viable and sustainable ecological linkage (Del Marco *et al.* 2004). Corridor widths for most components of ecological linkages within the project area are already less than the suggested minimum, so they will likely require management to maintain viability over the long term.

Presently, ecological linkages within the Beeliar Regional Park (EL4, EL5 and EL6) are managed by the DEC. Components of ecological linkages outside the Beeliar Regional Park (EL1, EL2 and EL3) are managed by local government. Remnant vegetation within the Cities of Cockburn and Melville are maintained and enhanced under long–term, strategic green plans (Alan Tingay and Associates 1999 and 2000).

The viability characteristics (size, shape, perimeter to area ratio, condition and connectivity) of EL1, EL2 and EL3 are less than optimal in the present form. Therefore, the long–term viability of EL1, EL2 and EL3 is currently likely to be under threat.

Without management, the long term viability of project ecological linkages is currently under threat

5.10.7. Conclusion

The review of the function and effectiveness of ecological linkages that traverse the project area indicates that EL4 is the only regional linkage that provides a contiguous link with adjacent habitat, with all other regional linkages heavily fragmented and disjointed. Local ecological linkages EL5 and EL6 both provide important ecological function on a local scale.

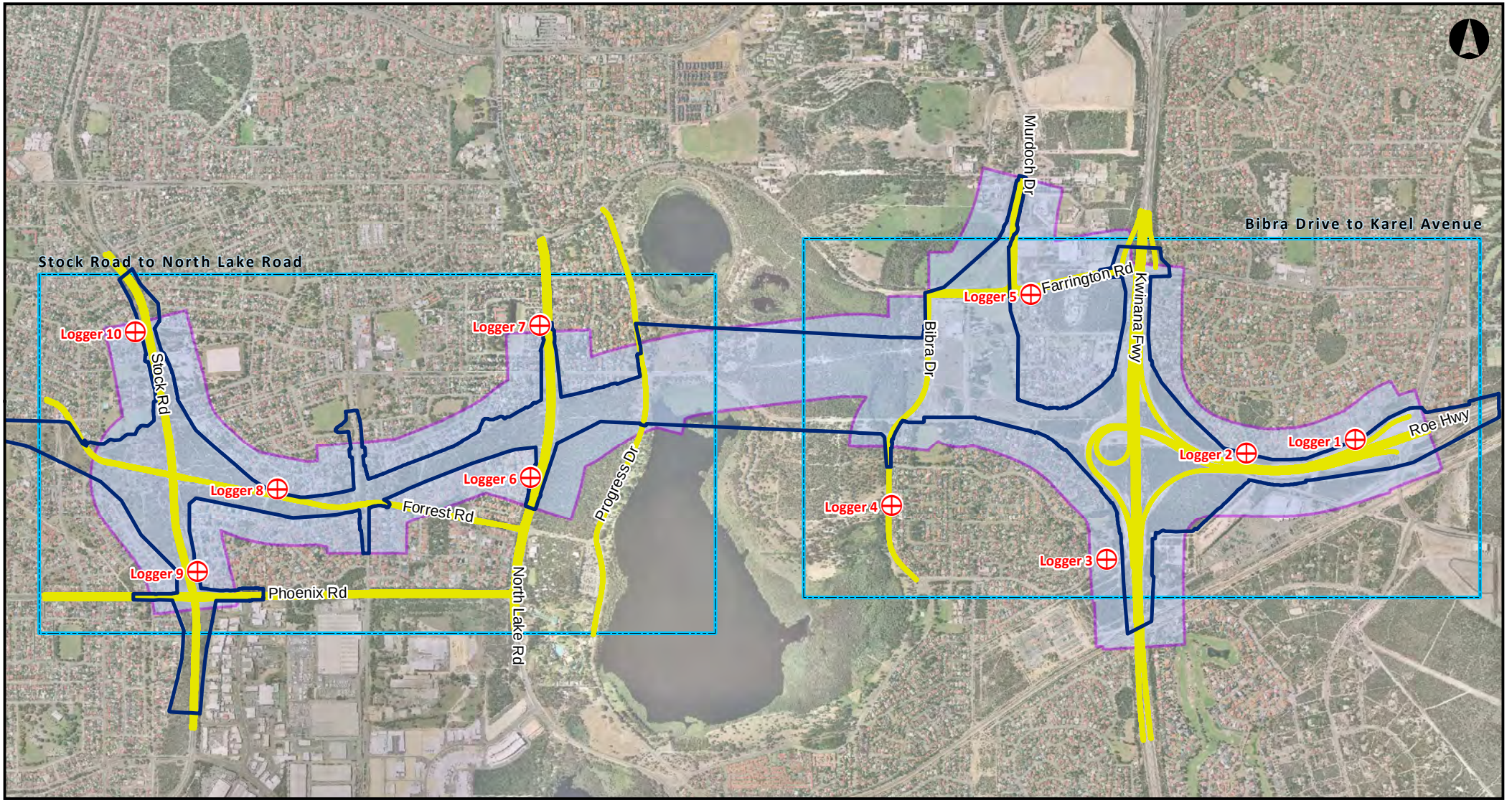
5.11. Noise

The study area is generally characterised by a suburban setting containing elements of traffic noise from nearby transport routes and minor roads. The major sources of noise within the project area include existing transport corridors comprising Kwinana Freeway, North Lake Road, Stock Road and Roe Highway. In addition, minor roads within the study area comprise Murdoch Drive, Bibra Drive, Forrest Road, Farrington Road, Coolbellup Avenue, Sudlow Road and Progress Drive.

Noise sensitive receivers in the study area comprise residential dwellings as well as the Blue Gum Montessori School and Hamilton Hill Senior High School educational facilities.

Noise assessment was carried out by examining locations along Roe Highway, Kwinana Freeway, Farrington Road, Bibra Drive, Forrest Road, North Lake Road and Stock Road. These measurements provided existing regional conditions and were used to calibrate the noise model used to calculate road traffic noise emissions along the study area. In addition to the above roads, the model also considers the noise emissions from Murdoch Drive, Phoenix Road, Progress Drive, Coolbellup Road and Sudlow Road. The study area for noise impacts is indicated in Figure 5.11-1.

Kwinana Fwy, North Lake Rd Stock Rd and Roe Hwy contribute to existing noise levels



Noise Monitoring Locations

South Metro Connect

Figure 5.11-1

0 250 500 750 1,000

Metres

1:27,500 (A4)

- Noise Measurement Location
- Project Area
- Roads considered in Existing noise environment study
- Noise Contour Figure Extent
- Study Area

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5.11.1. Noise Descriptors

Road traffic noise is measured as an energy averaged A–weighted sound pressure level over daytime and night time periods ($L_{Aeq(Day)}$/$L_{Aeq(Night)}$). It is defined as a constant sound pressure level that is equivalent to a given time–varying sound over that measurement period (i.e. it has the same amount of sound energy). This is presented graphically in Figure 5.11-2.

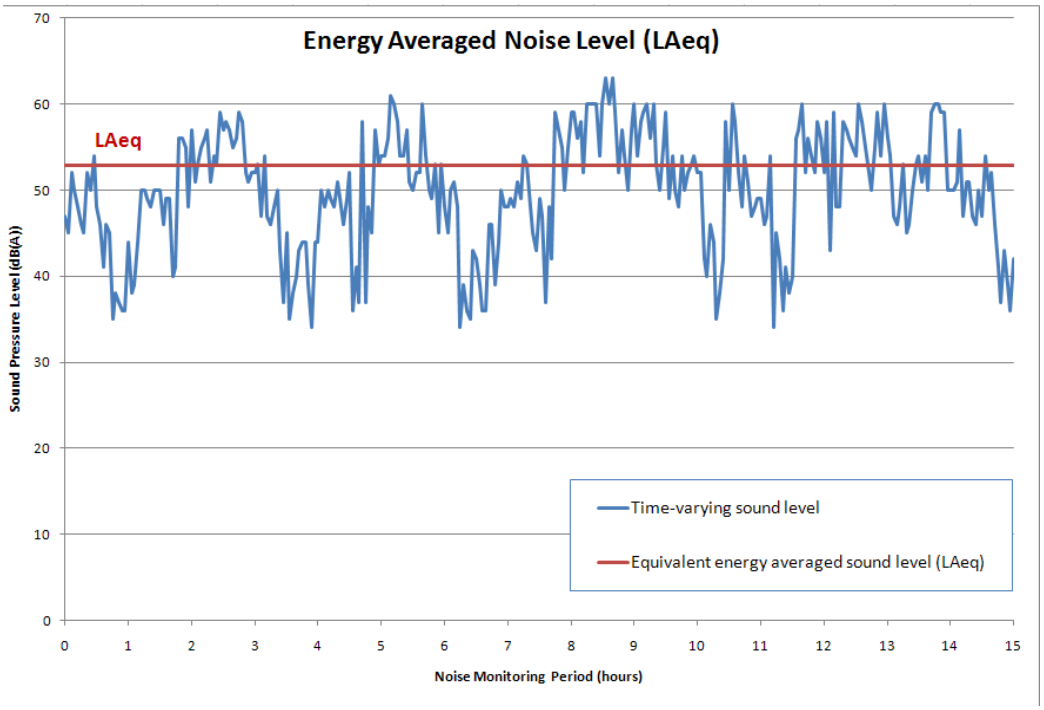


Figure 5.11-2: Energy Averaged Sound Pressure Level

Daytime noise level from road traffic ($L_{Aeq(Day)}$) is measured as the energy–averaged noise level over a 16 hour period between 0600hrs and 2200hrs. Similarly, the night time period ($L_{Aeq(Night)}$) is measured as the energy–averaged noise level over an 8 hour period between 2200hrs and 0600hrs.

The A–weighted sound level which is exceeded for 10% of a measurement period is represented as an L_{A10} level. This is measured over each hour and the $L_{A10(18hr)}$, which is the average value over an 18 hour daytime period, is then determined. An A–weighted sound level includes the 'A' frequency weighting in the measurement of a sound, to approximate the frequency response of the normal human ear. For most people, the noise level needs to change by 2dB for a change to be just perceptible and by 10dB for it to appear to be twice, or half, as loud.

5.11.2. Noise Monitoring

Noise measurements were taken at ten sites within the study area, in order to quantify the existing noise environment. The locations were chosen to represent noise emissions from major and minor roads in the vicinity of the project corridor. The selected noise monitoring locations are graphically presented in Figure 5.11-1. Noise monitoring was carried out over consecutive days for a period of one week. The summary of noise monitoring results is presented in Table 5.11-1.

Table 5.11-1: Noise Measurement Summary

Monitoring Location	Major Traffic Noise Source	Existing Noise Exposure Levels – dB(A)				Daytime vs Night Time Noise Level Difference – dB(A)
Ref No.		$L_{A10,18hr}$	$L_{Aeq,24hr}$	$L_{Aeq,(Day)}$	$L_{Aeq,(Night)}$	
Logger 1	Roe Highway	60.1	57.3	58.3	52.6	5.7
Logger 2	Roe Highway	59.4	56.6	57.7	53.2	4.5
Logger 3	Kwinana Freeway	59.2	58.6	59.7	55.1	4.6
Logger 4	Bibra Drive	63.8	59.6	61.1	51.6	9.5
Logger 5	Farrington Road	55.9	53.5	54.7	47.0	7.7
Logger 6	North Lake Road	53.6	50.5	51.8	45.1	6.7
Logger 7	North Lake Road	57.4	54.6	56.0	47.9	8.1
Logger 8	Forrest Road	60.4	57.0	58.3	51.1	7.2
Logger 9	Stock Road	58.1	54.8	56.2	46.1	10.1
Logger 10	Stock Road	56.8	54.1	55.5	46.6	8.9

The noise measurements obtained from the loggers were used to calibrate a computer model of the existing noise environment and calculate existing transport noise emissions in and around the nominated roads within the study area. The roads that were modelled in the existing noise environment study are shown in Figure 5.11-1.

5.11.3. Existing Noise Conditions

Noise modelling of existing transport corridors was carried out using the United Kingdom Department of Transport *Calculation of Road Traffic Noise* (CoRTN) (1988) algorithm as implemented by the SoundPLAN 6.5 noise modelling software suite. In calculating road traffic noise propagation, the model was set to take into account variables such as traffic volume and mix, type of road surface, vehicle speed, road gradient, ground absorption and shielding from ground topography and intervening structures, such as noise barriers and existing dwellings. Detailed description of all modelling input parameters, their sources and the assumptions used to derive them are documented in Appendix U.

The CoRTN calculation predicts noise levels based on the $L_{A10,18hr}$ statistical noise descriptor. Noise data collected provided measurements to calibrate the CoRTN outputs used to calculate the relevant $L_{Aeq,(Day)}$ road traffic noise emission descriptors. Receiver locations, ground topography, current road alignment and other cadastral data (e.g. property boundaries) were derived from aerial photographs and electronic information supplied by Main Roads.

The noise model was set to calculate noise levels at the ground level of all dwellings within a 200m radius of the proposed project envelope. A summary of the existing noise environment within the study area is presented in Table 5.11-2.

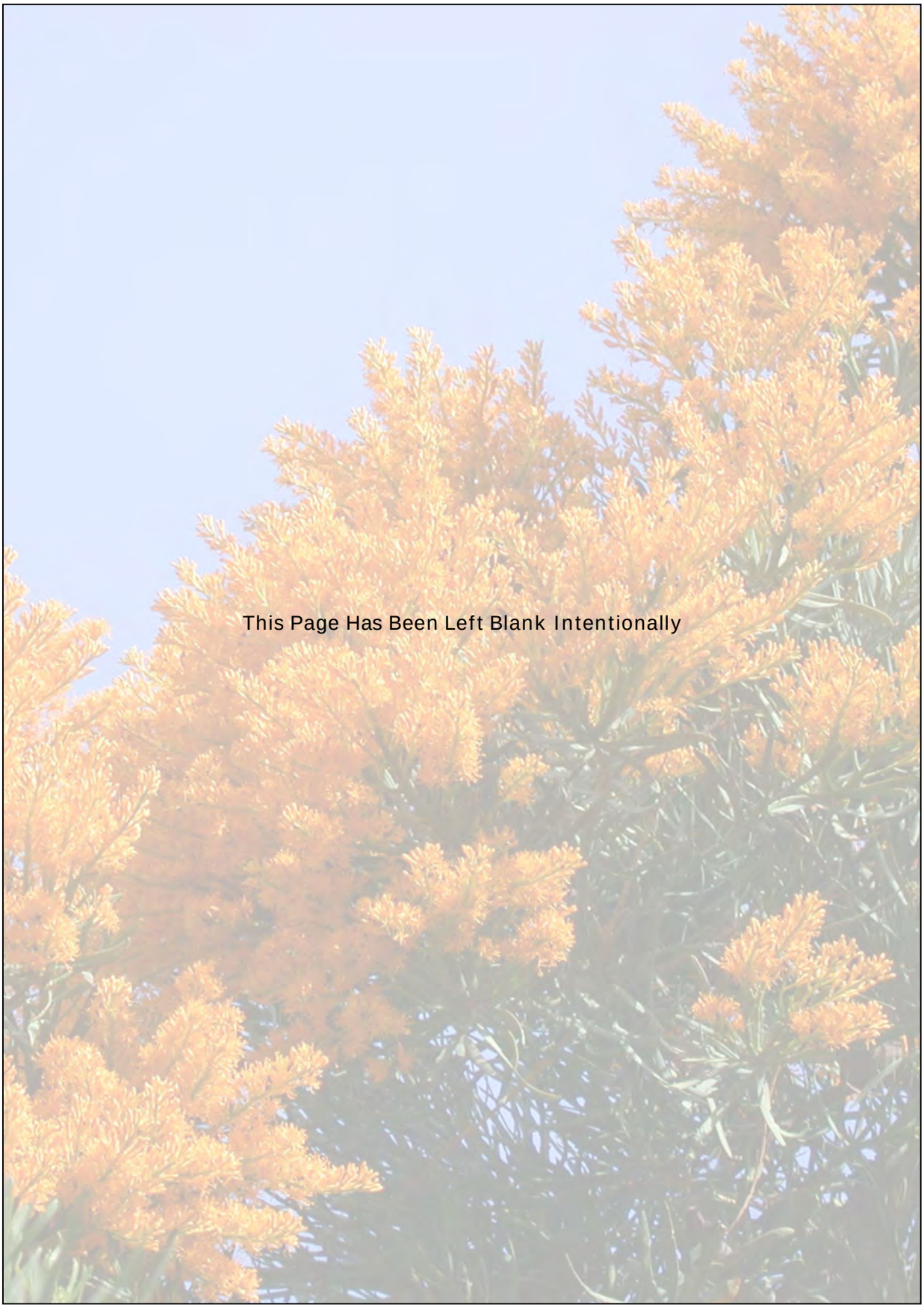
Table 5.11-2: Calculated Existing Daytime ($L_{Aeq,16hr}$) Noise Levels

Number of Noise Sensitive Receivers					$L_{Aeq,(Day)}$ Noise Level	
Total Modelled	<55dB(A)	>55dB(A)	>60dB(A)	>65dB(A)	Median	Maximum
1,472	1,317	145	10	0	49dB(A)	65dB(A)

The results show that the majority of noise sensitive receivers within the study area are currently exposed to 55dB(A) or less, with a median noise exposure of 49dB(A). Ten percent of the receivers are exposed to $L_{Aeq,(Day)}$ noise levels above 55dB(A). Less than one percent of the receivers are above 60dB(A) and these receivers are situated adjacent to existing transport corridors of Roe Highway, Forrest Road and Stock Road.

Noise modelling results adjacent to existing roads (within a 200m buffer on either side of existing roads) are presented graphically in Appendix U. Noise levels beyond the contours indicated in Appendix U are generally below 48dB(A). The above results are based on noise calculation at the ground level of noise sensitive receivers, in accordance with State Planning Policy 5.4*: Road and Rail Transport Noise and Freight Considerations in Land Use Planning* (SPP 5.4) (WAPC 2009c). It is noted that noise levels predicted at the ground floor may not be representative for upper floors of multi–storey dwellings, particularly if the ground floor is shielded from the road by a residential boundary fence. Where this is the case, the noise exposure at upper levels will be greater than those reported above.

The Noise modelling report is currently undergoing independent peer review. The outcome of this review will be submitted to OEPA prior to completion of the public review period.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5.12. Air Quality

The main aspects of the existing environment that can influence the level of air pollutants adjacent to a roadway include:

- Existing conditions due to a presence of other air pollutant sources, such as private, commercial or industrial facilities that emit similar air pollutants to road traffic;
- Local meteorological conditions and terrain features; and
- Regional sources of air pollution.

Meteorological conditions in the area surrounding the proposed project are affected by several factors, such as terrain and land use. On a small scale, wind speed and direction are largely affected by topography. On a broader scale, wind speed and direction are influenced by factors such as synoptic scale winds (which are modified by sea breezes from the Perth coast in the afternoon and evening) and morning easterly winds arising from valley drainage flows over the Darling Scarp.

The climatic data for the project area are summarised in Section 5.6.1. Long–term average wind roses from the Bureau of Meteorology (BoM) site are provided in Figure 5.6.2and Figure 5.6.3.

From November to April, the weather in Perth is hot, dry and windy. These conditions disperse pollutants in the air. In the cooler months, from May to October, the wind is weaker, so there is less dispersion of pollutants. In addition, the region's topography and prevailing conditions are such that there is an increased potential for pollution levels during cooler months.

Air quality at sensitive receptors depends on their proximity to roads and industry. For receptors close to main roads during peak hours, vehicle emissions may be the primary source of air pollution. A review of ambient air quality within the project area is provided in Appendix V.

The closest ambient air monitoring station to the project area is located at South Lake station, approximately 2km to the south. A variety of pollutants are monitored at the South Lake station, which is operated by DEC.

The suite of pollutants of concern therefore includes carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (as PM_{10} and $PM_{2.5}$) and hydrocarbons (i.e. air toxics). Generally, these vehicle emissions are generated by combustion processes and fuel evaporation. Carbon monoxide and hydrocarbons are produced from incomplete combustion of fuels; whereas nitrogen oxides are produced when nitrogen from the air is oxidised at high temperature and pressure in the combustion chamber. Particulate matter is produced by incomplete combustion of fuels, additives in fuels and lubricants, worn material that accumulates in the engine lubricant, and brake and tyre wear.

Pollutants of concern include carbon monoxide, nitrogen oxides, particulate matter and hydrocarbons

Ambient $PM_{2.5}$ levels currently exceed the NEPM standard

Summary data for 2006 from the South Lake monitoring station compared with the National Environment Protection Measure (NEPM) goals (as specified in the Draft Ambient Air State Environmental Policy 2009) are provided in Table 5.12-1. The data demonstrate that the concentrations of NO_2 and CO recorded at the station are well below the relevant NEPM maximum concentration. Measured PM_{10} concentrations are also below the maximum.

Monitoring results from the South Lake ambient air monitoring station operated by DEC indicate that current measured ambient $PM_{2.5}$ levels exceed both the 24 hour and annual average NEPM standard. This is likely to be a consequence of nearby industrial sources.

Table 5.12-1: Summary Data from South Lake Monitoring Station

Pollutant	Averaging Period	Max Conc.	99th percentile	95th percentile	90th percentile	50th percentile	NEPM
Nitrogen dioxide ($\mu g/m^3$)	1 hour	0.045	0.039	0.031	0.028	0.016	0.12
Carbon monoxide (ppm)	8 hour	2.5	2.4	1.6	1.0	0.2	9
PM_{10} ($\mu g/m^3$)	24 hour	45.3	39.8	34.4	29.0	17.8	50[a]
$PM_{2.5}$ ($\mu g/m^3$)	24 hour	30.5	21.5	14.6	12.8	8.1	25[b]
	Annual average	8.7					8[b]

Source: DEC 2006b

[a]no more than five exceedances per year

[b]advisory standard

[c]annual average

Air toxics are not currently measured at the South Lake station. However, in early 2004 the Minister for the Environment announced that a study would be undertaken into air toxics levels in the Perth metropolitan region. In response to the Minister's announcement, the then Department of Environment (now the DEC) began an air toxics study. The study included measurements of five compounds identified in the Air Toxics NEPM at various monitoring locations.

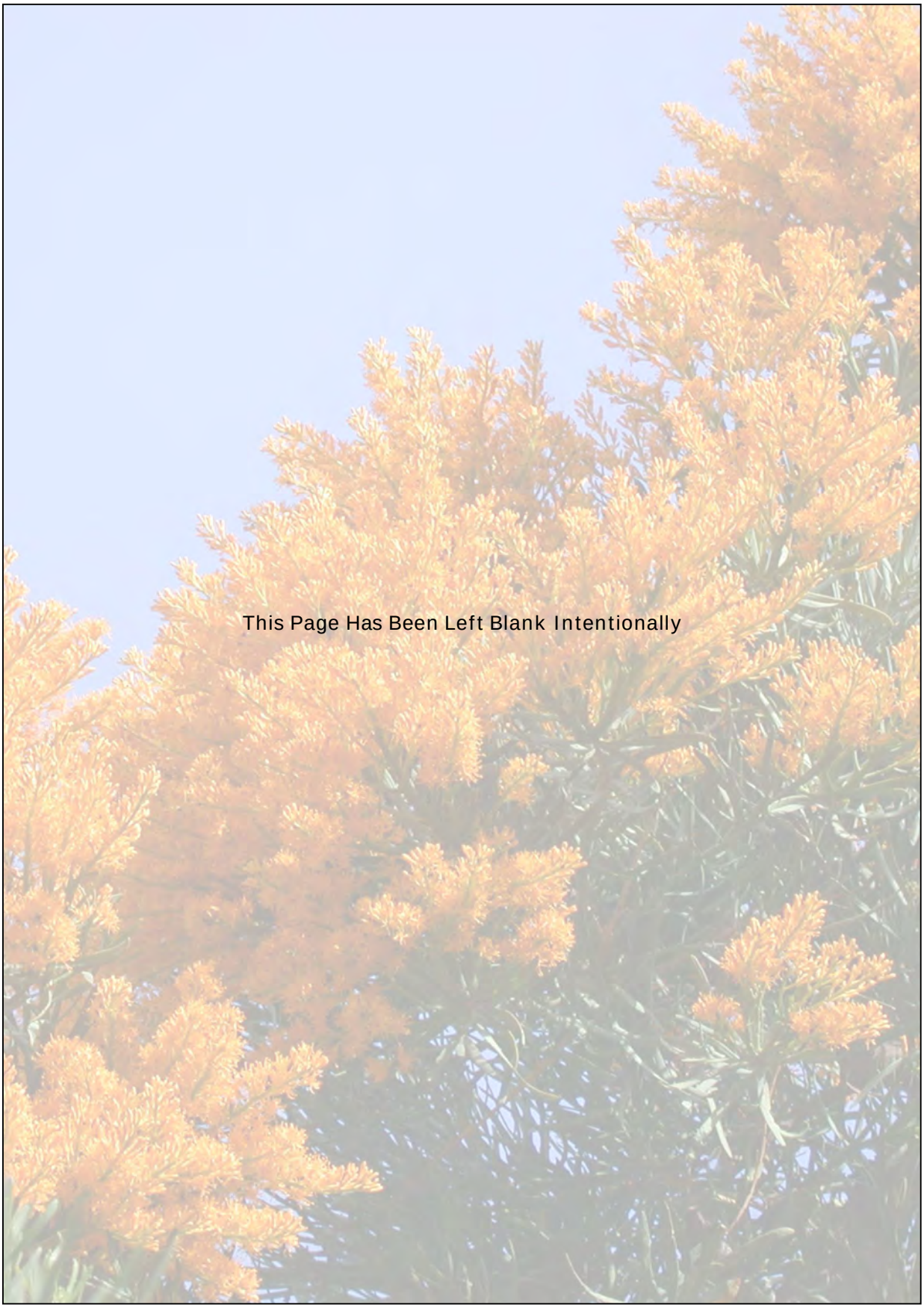
Monitoring sites included one in the Perth CBD (Queens Building), which is located approximately 14km to the north of the project area, as well as a site at Hope Valley situated approximately 10km south of the project area. Summary data from November 2005 to May 2006 from these two monitoring stations compared with the Air Toxics NEPM investigation levels (where applicable) is provided in Table 5.12-2. There have been no exceedances of the relevant Air Toxics NEPM levels recorded for the measured pollutants at either Perth regional monitoring station.

Table 5.12-2: Summary of Potentially Toxic Air Constituents

	24 Hour Average Concentration at Queens Building		24 Hour Average Concentration at Hope Valley		Air Toxics NEPM Investigation Level	
Pollutant	Highest	2nd Highest	Highest	2nd Highest	24 Hour Average	Annual Average
Benzene (ppb)	1.2	1.1	0.4	0.3	n/a	3.0
Benzo(a)pyrene (µg/m^3)	0.65	0.59	0.22	0.22	n/a	0.3
Formaldehyde (µg/m^3)	5.1	4.3	4.1	4.0	50	n/a
Toluene (ppb)	3.7	2.8	0.6	0.5	1,000	100
Xylenes (ppb)[a]	1.7	1.4	1	0.9	250	200

Source: DEC 2006b (Data are estimated based on readings from graphs)

[a]As m and p xylene which are the most abundant measured xylenes at the two stations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5.13. Greenhouse Gas Emissions

Greenhouse gases (GHGs) are a group of gases that are known to contribute to an increase in the natural warming of the Earth. A range of GHGs are recognised internationally by the Intergovernmental Panel on Climate Change (IPCC) and include commonly identified anthropogenic greenhouse gases carbon dioxide, methane and nitrous oxide, as well as a number of artificial gases. Artificial gases incorporate the Montreal Protocol gases, namely hydrofluorocarbons, perfluorocarbonated compounds and fluorinated ethers. Water vapour is also a significant greenhouse gas, but in most cases is not considered anthropogenic.

GHGs in the atmosphere include carbon dioxide and methane resulting from land use change and the burning of fossil fuels. Increases of concentrations of these GHGs are very likely to have been the cause of observed warming in the climate system (IPCC 2007), which is broadly described as climate change. Climate change is a complex global issue requiring cooperative solutions to manage the impacts resulting from increased concentrations of GHGs in the Earth's atmosphere.

Since 1990, the IPCC has provided regular scientific assessments of past, present and future climate scenarios. Four scientific assessments have been undertaken to date: in 1990, 1996, 2001 and 2007. A fifth assessment report is due in 2014. In its fourth assessment report, the IPCC concluded that:

- Warming of the climate system is unequivocal;
- Most of the warming in the past 50 years is very likely (more than 90 percent in probability) due to the observed increase in greenhouse gas concentrations from human activities, such as the burning of fossil fuels and land use change; and
- It is very likely that changes in the global climate system will continue well into the future, and that they will be larger than those seen in the recent past (IPCC 2007).

As previously discussed in Section 5.6.1, while available data indicate that North and Bibra lakes have historically had similar water levels to current recorded levels, a declining trend in rainfall and water levels is apparent (Appendix W). However, independently from climate change processes, land use changes around the Beeliar Wetlands have resulted in considerable change to the appearance and function of the wetland area. In particular, urbanisation around the wetlands from the late 1950s until the late 1980s has affected the size and shape of the natural water features and vegetated areas within the region, as evidenced by historical photographs. At the same time, the Perth metropolitan region has experienced a general drying trend, reducing water availability within the wetland catchment.

Fire management practices have varied considerably over time. The edges of North and Bibra lakes and adjacent lands were burnt periodically by indigenous inhabitants to generate social benefits (Australian Heritage Commission and National Trust of Australia 2001). The urban development in the area has increased the incidence of unplanned fires other than prescription fires (Dooley *et al.* 2006). Fire and weed regimes have a complex association with the amount of carbon in an ecosystem over time.

There are no major existing anthropogenic GHG emission sources in the project area. Latest national and State greenhouse accounts (DCC 2009) reported Western Australian GHG emissions as 77.5Mt CO_2-e in 2007, excluding emissions and removals from 'Land Use, Land Use Change and Forestry' (LULUCF). When emissions and removals from LULUCF were included, the total emissions were estimated to be 76.3Mt CO_2-e.

In October 2007, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the BoM released *Climate Change in Australia: Technical Report 2007*, which provides the most recent climate change projections for Australia. Details of these projections are discussed in Appendix W. For the purposes of this study, Special Reference Emission Scenario (SRES) Marker A1B scenarios have been used to identify projected impacts of climate change for the years 2030, 2050 and 2070. The A1B scenario is a medium emissions scenario, which is commonly used in climate change projections and assumes rapid economic growth. In this scenario, global population peaks around 2050 and declines thereafter. The 50th percentile, also known as best or median estimate, has been used where a range of percentiles are available (Table 5.13-1).

Table 5.13-1: Climate Change Projections (Median) for the Southern Perth Region

Climate Variable	2030 Mean Change	2050 Mean Change	2070 Mean Change
Temperature	+0.9 °C	+1.5 °C	+2.0 °C
Rainfall	-7%	-12%	-16%
Evaporation	+2.3%	+3.9%	+5.4%
Wind speed	+0.05%	-0.08%	-3.61%
Humidity	-0.6 %	-1.0%	-1.4%

Source: CSIRO 2007

In addition to an increase in the average temperature for Perth, there are significant increases in the projected proportion of hot days, or days above 35°C, by 2030 and again by 2070. Perth currently experiences an average of 28 hot days per year. This is projected to increase to 35 hot days by 2030, according to the A1B projections, and up to 54 days by 2070 (projections based on A1FI scenario, which has the same population and economic growth predictions as A1B, but has an energy supply which continues to be dominated by the fossil fuels).

Whilst overall rainfall is projected to continue to decline, the mean number of rain days is also expected to decrease, resulting in lower total rainfall, but rainfall intensity is likely to increase. As a result, the likelihood of extreme rainfall events may increase, with shorter bursts of higher intensity rainfall.

5.14. Visual Amenity

A landscape evaluation was conducted to provide the context for a visual impact assessment. Key outputs of the visual landscape evaluation are landscape character units (LCUs) for the project area and visual management objectives for individual LCUs. Appendix X outlines the methodology for, and the results of, the visual impact assessment, as well as conclusions and recommendations.

A field investigation was undertaken to confirm the locations of representative publicly accessible viewpoints, where the proposed project would be visible.

The visual amenity impact assessment was undertaken in accordance with guidance outlined in:

- *Visual Landscape Planning in Western Australia; a manual for evaluation, assessment, siting and design (WAPC 2007); and*
- *Guidelines for Landscape and Visual Impact Assessment produced jointly by the Landscape Institute and the Institute of Environmental Management and Assessment (Land Institute 2002).*

5.14.1. Landscape Context

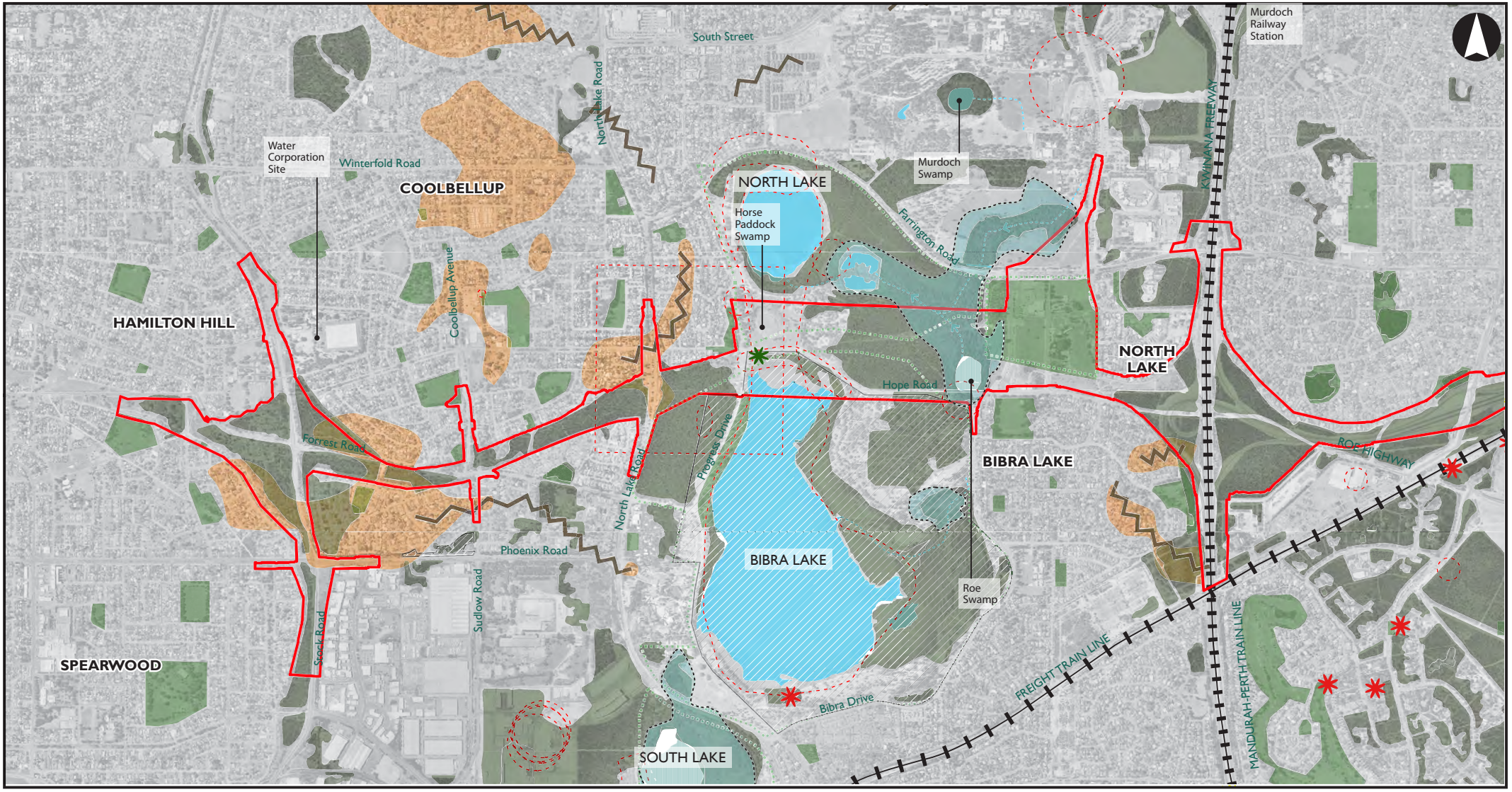
The proposed project is located in Perth's southern metropolitan region in the City of Cockburn, 6km south–east of Fremantle. The proposed project principally traverses low density residential suburbs and Beeliar Regional Park. These two land uses and other prominent features are illustrated in a combined visual and landscape context plan (Figure 5.14-1). The MRS and City of Cockburn Town Planning Scheme are presented in Figure 3.3-1 and Figure 3.3-2, respectively.

The project area is located along an east–west transect that crosses from low to moderately sloping Bassendean Sands near Kwinana Freeway, down into relatively flat topography and minimal slopes in the Eastern Chain of the Beeliar Wetlands and then up into the moderate topography and slope of the Spearwood Dunes in the western portion of the project area (Figure 5.14-2). Slopes within the project area are generally low to moderate, and elevation ranges approximately zero to sixty metres Australian Height Datum (AHD). The landform and a slope analysis are provided in Appendix X.

Within the broader landscape context, the Eastern Chain of the Beeliar Wetlands is separated from its western counterpart by a prominent ridge of the Spearwood Dunes, around the Hamilton Hill and Samson suburbs. This ridge system (Figure 5.14-1) runs parallel to the coast and provides visual and physical separation between the coast and inland areas. The ridge provides elevated views over Cockburn, to the Darling Scarp in the east, as well as glimpses of Perth CBD.

The project area comprises a significant proportion of public open space, recreation and conservation areas within a context of low density housing of 1970s, 1980s and 1990s aged stock. Typical housing types include face brick or rendered walls and clay tile roofs. In selected areas, a smaller proportion of newer, two storey houses contrast with the older single storey stock.

The inherent natural and green/blue character of the lakes, wetlands and surrounding open spaces contrast with the residential suburbs. Within these green areas, the views are often 'closed' or 'framed' by dense fringing vegetation. The lakes and adjacent remnant vegetation makes up Bush Forever Site 244 (Figure 5.14-1), which is an important natural element in the local landscape.



Landscape Context

South Metro Connect

Figure 5.14- 1

1:20,000

0 .1 .2 .4 .6 .8 1Km

Legend

- Project Boundary
- Bushland Forever Protection Area
- Beeliar Regional Park
- Remnant Vegetation
- Permanent Wetlands
- High Ground
- Seasonally Inundated Wetlands
- Conservation Reserve Under Council Control
- Aboriginal Sites
- Ridge Lines
- Rare Flora
- Norfolk Island Pine Trees

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SouthmetroConnect

Topography

South Metro Connect

Figure 5.14-2

0 0.25 0.5 0.75 1

Kilometres

1:42,000 (A4)

Datum: GDA94 Projection: MGA z50

Project Area

0m 10m 20m 30m 40m 50m 60m 65m

AHD

(Map Note : Slope derived from 1m Bare Earth LIDAR

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SouthmetroConnect

5.14.2. Visual Context

Community facilities and services are illustrated on the combined visual and landscape context plan (Figure 5.14-1). Users may be in localities within and adjacent to the project area where the landscape and visual context is important for aesthetic appreciation. Key community facilities and services that attract users who are familiar with the surrounding landscape include:

- Beeliar Regional Park, including the Cockburn Wetlands Education Centre and extensive network of bikeways and footpaths;
- Murdoch Pines Golf and Recreation Park;
- Adventure World;
- Local schools, such as Blue Gum Montessori School on Hope Road and Hamilton Senior High School; and
- Local parks within the suburbs, including Meller Park, Matilda Birkett Reserve and Tempest Park.

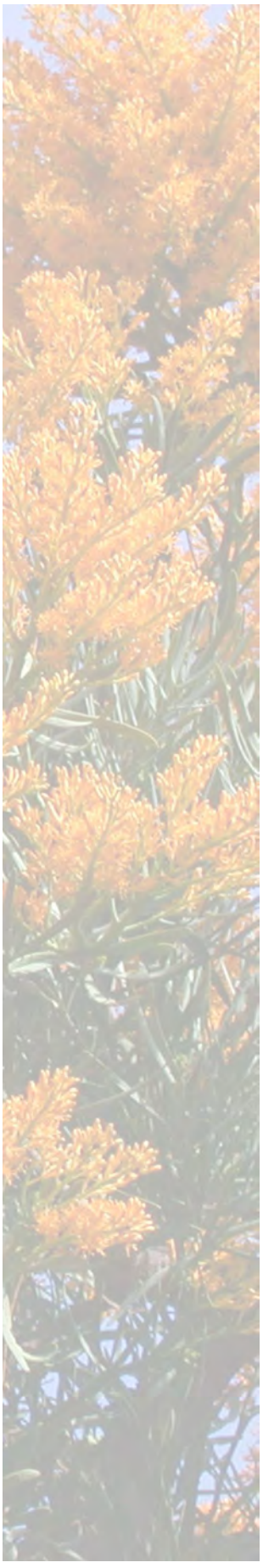
Community facilities where landscape appreciation is less important to users, but are still considered key visual receptors, include:

- Kwinana Freeway and Perth to Mandurah Railway, located to the east of the study area;
- Murdoch Activity Centre, located to the north–east of the study area; and
- Coolbellup shopping and community centre, located to the north of the project area.

5.14.3. Key Community Visual Values

Available literature and the results from community engagement were reviewed as a basis for determining visual values of the project area. Following an extensive and publicised community engagement programme, the visual elements identified as most highly–valued were:

- The natural landscape of parts of the project area as a valuable educational resource;
- The recreational value of parts of the project area, including the visual experience of walking along trails and the visual connectivity between North and Bibra lakes;
- The value of the visual expression of the existing vegetation, particularly as it relates to fauna habitat;
- Tranquillity around lakes;
- 'Garden' views;
- Green landscaping (trees); and
- Sweeping views across Bibra Lake, where they exist.



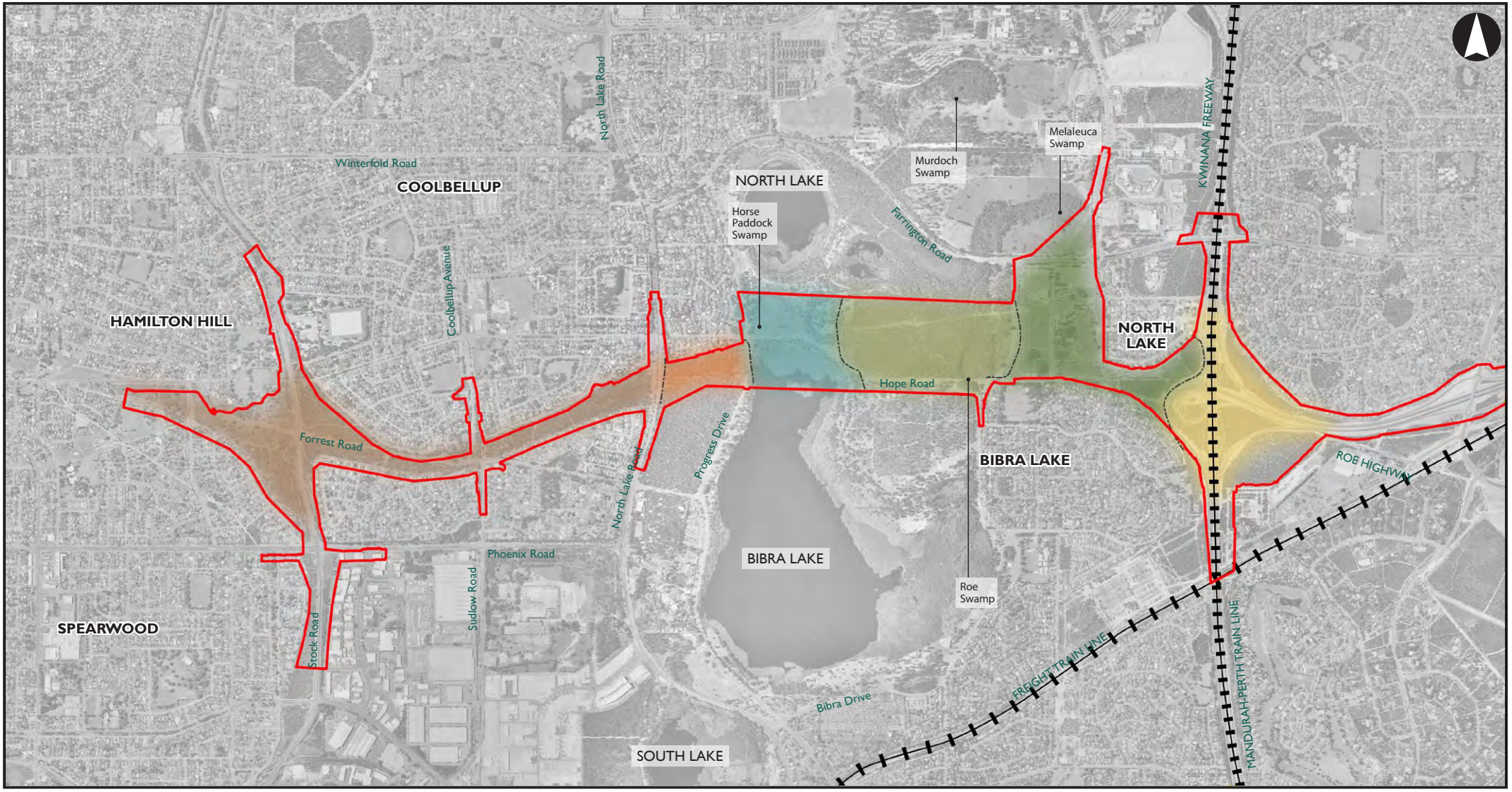
During various workshops and information days attended by community members and stakeholders, a number of interests and concerns pertaining to visual amenity of built infrastructure were identified. These are summarised as follows:

- Ensure that embankments are properly landscaped;
- Provide landscaping and aesthetic features between noise barriers and properties;
- Use artwork, landscaping and/or vegetation to screen noise walls;
- Acknowledge Aboriginal heritage in artwork;
- Provide for an increased awareness of heritage sites (educational);
- Redevelop open space;
- Provide visually appealing signage;
- Continue environmental education; and
- Blend infrastructure into the natural environment.

5.14.4. Landscape Character Units

This section presents the broad assessment of the existing landscape character of the project area. The landscape character is separated into six landscape character units (LCUs) (Figure 5.14-3). Photographs of the LCUs are shown in Figure 5.14-4. They are separated as follows:

- LCU1 – Stock Road to North Lake Road Bushland;
- LCU2 – North Lake Road to Progress Drive Bushland;
- LCU3 – Bibra Lake;
- LCU4 – Bibra Lake Bushland;
- LCU5 – Hope Road Reserve; and
- LCU6 – Roe Highway and Kwinana Freeway Interchange.



Landscape Character Units

South Metro Connect

Figure 5.14- 3

1:20,000

0 .1 .2 .4 .6 .8 1Km

Legend

- Project Boundary
- Stock Road to Northlake Road Bushland LCU1
- North Lake Road to Progress Drive Bushland LCU2
- Bibra Lake LCU3
- Bibra Lake Bushland LCU4
- Hope Road Reserve LCU5
- Roe Highway & Kwinana Freeway interchange LCU6

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LCU 1 – Stock Rd to North Lake Rd Bushland

LCU 2 – North Lake Rd to Progress Drive Bassett Reserve

LCU 3 – Bibra Lake

LCU 4 – Bibra Lake Bushland

LCU 5 – Hope Road Reserve

LCU 6 – Roe Highway Kwinana Freeway Interchange

Figure 5.14-4: Typical Views of the Landscape Character Units

5.14.4.1. LCU1 – Stock Road to North Lake Road Bushland

This narrow, bushland–covered character unit varies in width from about 100m (at the western end) to 300m (at the Stock Road intersection). It has an enclosed character, as it is covered by Karrakatta woodland. This precludes views across the reserve to the adjacent, low density suburbs. Locally, LCU1 is perceived as informal bush–rich parkland with high aesthetic and visual amenity values. The visual quality of this woodland is defined as 'ecosystems that contain widely spaced trees with their crowns not touching'. By definition and as confirmed on site, LCU1 provides a green and naturalistic visual barrier between two residential communities. Sensitive landscape receptors include remnant vegetation. Sensitive visual receptors include:

- Residential communities in Coolbellup and Hamilton Hill, (i.e. Sebastian Crescent, Forillion Avenue and Provincial Mews);
- Hamilton Senior High School; and
- Users of local parks, such as Matilda Birkett Reserve.

5.14.4.2. LCU2 – North Lake Road to Progress Drive Bushland

LCU2 is covered by native semi–mature bushland with high visual amenity and has the same visual quality as the bushland outlined in LCU1 (i.e. Karrakatta woodland). One point of visual distinction between LCU1 and LCU2 is that the topography of LCU2 is orientated in a south–easterly direction towards Bibra Lake. Given that the vegetation cover is intact, views from North Lake Road, in an easterly direction towards Bibra Lake, are generally not afforded. To the north, the suburban residential area of North Lake provides a defined visual edge to LCU2. Sensitive landscape receptors include remnant vegetation; while sensitive visual receptors include:

- Residential communities in North Lake (i.e. Madeleine Court, Lygon Court and Samual Court);
- Adventure World Amusement Park; and
- Users of local parks, such as Bassett Reserve.

5.14.4.3. LCU3 – Bibra Lake

LCU3 encompasses the Bibra Lake area. The southern parts of Bibra Lake are generally open with expansive views over the water. To the north, the lake edge is surrounded by a combination of low macrophytic vegetation (sedge) communities and a 20m–wide strip of open *Melaleuca* and other Karrakatta woodland. A few exotic tree species, such as Norfolk Island Pines, provide distinctive vertical elements within the landscape.

Wetland vegetation is located to the south and east sides of Bibra Lake and provides an attractive vegetated backdrop. The western part of LCU3 consists of formal parklands with passive recreational facilities. The portion of this LCU located north of Hope Road contains a variety of vegetation types in varying condition. Infrastructure such as high voltage power lines, local power/telegraph lines, roads, paths, fence lines, bollards, signage and associated vegetation clearing reduce the visual quality in this area. The character of the cleared areas is described as barren, exotic grassland that contrasts with the surrounding native vegetation.

Due to the open visual character over much of LCU3, accessible and attractive views are afforded across Bibra Lake. These views may be considered regionally important. The lake's southern and western sides are mostly parkland, providing classically beautiful landscape environs of open grass punctuated with large trees. Consequently, this area has a high recreational as well as visual value. Sensitive landscape receptors include remnant vegetation and the wetland ecosystems of Horse Paddock Swamp and Bibra Lake. Sensitive visual receptors include recreational users of North and Bibra lakes.

5.14.4.4. LCU4 – Bibra Lake Bushland

This LCU comprises native open Jarrah–*Banksia* woodland, which dramatically contrasts with the adjacent closed vegetation of Roe Swamp. The visual amenity of each vegetation type is similar; however, the effect of subtle differences in the topography (in the order of 1–2m in height) provides more visual variety to the appearance of the vegetation than that of LCU3. Soil surfaces within LCU4, where exposed, are grey to white coloured sands of the Bassendean System. These contrast with the green vegetation and the exposed areas of green and brown hues of the natural bushland. This LCU contains the highly valued Roe Swamp area and the Cockburn Wetlands Education Centre building and its surrounds. Sensitive landscape receptors include remnant vegetation and wetland ecosystems, such as Roe Swamp. Sensitive visual receptors include recreational users of North and Bibra lakes, as well as users of the Cockburn Wetland Education Centre.

5.14.4.5. LCU5 – Hope Road Reserve

The character of LCU5 is open parkland consisting of open grassland with occasional trees or groups of trees. These trees are remnants from the original open Jarrah–*Banksia* woodland. There are a number of visual detractors in the area, such as the local power poles and high voltage lines. Baker Court runs north from Hope Road and is an elevated, open location that provides a clear view towards the west over Bibra Lake and associated wetland vegetation. The Murdoch Pines Golf and Recreation Park, located to the north of the proposed project, provides a manicured, open turf setting that contrasts with the surrounding native landscape.

This LCU is considered to have lower visual amenity qualities than LCUs 1, 2, 3 and 4. This is due to land degradation and weed infestation. The lack of native vegetation cover in this LCU allows views from the project area to adjacent residential areas. As in LCU1, adjacent residential areas at Peterborough Circle are orientated north, away from the proposed project, presenting a back yard fence to the project area. Residents located to the south, along Hope Road, are orientated north and, in effect, their front gardens directly overlook the project area.

There is a section of good quality vegetation to the immediate west of the Kwinana Freeway/Roe Highway interchange at the eastern end of LCU5. This woodland area contains ground cover, shrubs and small trees. The wetlands include several high quality iconic species such as *Xanthorrhoea* (grass trees), which provide a high level of visual amenity. The size of the patch is approximately 200m by an average of 80m wide. It provides a partial visual screen between adjacent suburban residential areas. Sensitive landscape receptors include remnant vegetation. Sensitive visual receptors include:

- Residential communities in Bibra Lake and Peterborough Circle;
- Blue Gum Montessori School off Hope Road;
- Murdoch Pines Golf and Recreation Park;
- The Spanish Club;
- Lakeside Recreation Centre; and
- Users of local parks, such as Meller Park Reserve.

5.14.4.6. LCU6 – Roe Highway and Kwinana Freeway Intersection

The character of LCU6 is dominated by the infrastructure of a road interchange and Perth to Mandurah Railway. Landforms include the grade–separated interchange with several loops including the elevated bridge over Kwinana Freeway. LCU6 has a lower landscape and visual amenity value due to the aesthetically intrusive transport infrastructure and the presence of overhead power lines. However, the presence of sculptured light poles provides a distinctive and prominent landscape feature.

Patches of Jarrah–*Banksia* bushland remain in and around the existing interchange. However, most areas show the effects of previous clearing (around the cuttings and embankments of the interchange). These areas contain revegetation, which is starting to establish. The openness of LCU6 allows views from residential areas adjacent to the interchange. Vegetative cover between the interchange and the residential area near Peterborough Circle is ineffective at screening views of the interchange. Where revegetation is not yet established, views of exposed white/grey sandy soil prevail, lowering the overall visual amenity.

To the east of the interchange, the retention of remnant bushland provides a vegetative and visual buffer between the interchange and adjacent residential communities in Leeming. The sensitive landscape receptors for LCU6 are the public art (yellow lighting columns and bridge abutments) and the bushland area to the immediate south east of the interchange. Sensitive visual receptors include:

- Residential communities in Leeming and North Lake (i.e. Casserly Drive, Timber Ridge Road, Evergreen Crescent, Peterborough Circle); and
- Users of the Perth to Mandurah Railway.

5.14.5. Current Threats to Visual Amenity

Some of the study area's landscape is anticipated to undergo a number of major changes in the next 20 years, while other areas are predicted to undergo minor, incremental changes. Predicted future changes that may affect the existing character of the area include:

- Jandakot development: new residential community, industrial area and airport to the south–east of the proposed project;
- Murdoch Activity Centre: estimated to provide 30,000 jobs at Fiona Stanley Hospital, St John of God Hospital, Challenger TAFE and the police, immediately north–east of the proposed project; identified as a 'strategic specialised centre' in *Directions 2031: draft spatial framework for Perth and Peel* (WAPC 2009a);
- O'Connor Industrial Area to the north–west of the proposed project;
- Increasing the urban density of the area;
- Cockburn Coast: a significant urban regeneration project located south of Fremantle and overlooking the Indian Ocean. The project will involve the remediation and redevelopment of approximately 120 hectares of former industrial land as a new ocean–side community with an estimated population of 10,800; and
- Continued urban growth in the south–west subregion is anticipated by *Directions 2031: draft spatial framework for Perth and Peel* (WAPC 2009a).

A gradual trend of urban intensification is anticipated throughout the project area. This may result in further urban encroachment and acquisition of public and private open spaces. However, with the exception of the key developments described above, for the remainder of the wider study area these gradual urban intensification changes are considered to be of minor consequence.

5.15. Recreation and Education

Recreation and education are discussed collectively in this section, as referenced in EPA Bulletin 1088 (EPA 2003). They relate to the recreational activities and educational pursuits that the environs surrounding North Lake and Bibra Lake currently support.

5.15.1. Recreation

Recreational values include values of regional and local significance in relation to both active and passive recreational uses, focussing predominantly on recreation in the outdoor environment. Unless indicated otherwise, the study area is bound by Stock Road in the west, Winterfold and Farrington Roads to the north, Kwinana Freeway to the east and Parkway Road, Bibra Drive, North Lake Road and Phoenix Road to the south. This area comprises the majority of residential and recreational areas with the greatest potential to be affected by the proposed project.

Residences in the area predominantly fall within the City of Cockburn local government authority area. While the City of Cockburn does not appear to have prepared a public open space strategy or similar strategic plan for the provision of land for recreation purposes, it has prepared a number of plans relevant to the study area:

- *Strategic Plan 2006–2016;*
- *Sport and Recreation Strategic Plan (City of Cockburn 2009); and*
- *Bibra Lake Landscape, Recreational and Environmental Management Plan (Strategen 2009).*

5.15.1.1. Beeliar Regional Park

Regional parks are areas of regional open space that are identified by planning procedures as having regionally significant conservation, landscape and recreation values (Thompson Palmer 2006). Beeliar Regional Park is one such regional park in the south–west of the Perth metropolitan region, comprising 19 lakes in two main chains located parallel to the coast. North and Bibra Lakes and associated wetlands form part of the Eastern Chain of lakes in Beeliar Regional Park (Figure 5.15-1). The Regional Park excludes the MRS reserve for Roe Highway.

The *Beeliar Regional Park Final Management Plan 2006* (Thomson Palmer 2006) was prepared for the Conservation Commission of Western Australia. The plan provides broad direction and strategies for the protection and enhancement of values specific to Beeliar Regional Park. The plan identifies that Beeliar Regional Park provides diverse recreational opportunities in natural environments with a wide variety of natural features that are relatively undisturbed, yet close to urban areas. There are also a number of smaller recreation nodes, providing a diversity of recreation settings and facilities. The overall management strategy is to allow recreation and other uses of the park to occur to the extent that they do not adversely impact on the other values of the park.

5.15.1.2. Local Parks

A number of opportunities exist for passive and active recreation within local parks. For the purpose of this assessment, passive recreation refers to unstructured, informal and generally low impact physical activity, while active recreation refers to formal organised sport and associated activities.

Beeliar Regional Park

South Metro Connect

Figure 5.15-1

0 200 400 600 800

Metres

1:25,000 (A4)

- Project Area
- Beeliar Regional Park - Conservation and Protection
- Beeliar Regional Park - Sport and Recreation

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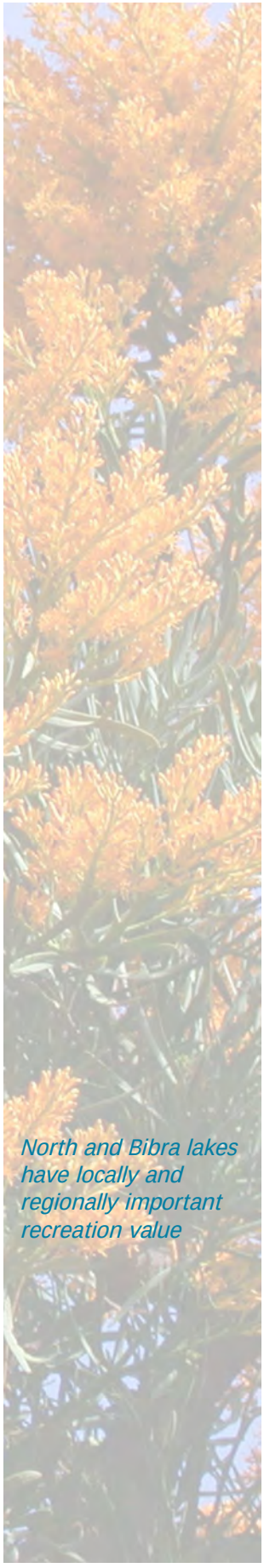
SouthmetroConnect



North and Bibra lakes have locally and regionally important recreation value

5.15.1.2.1. Passive Recreation

Passive recreation is a form of non–structured recreation, such as walking or using open spaces in a relaxed manner (e.g. picnics, meditation, birdwatching, walking). Passive recreation is experienced in places that offer contemplative, constructive, restorative and pleasurable human benefits, which foster appreciation and understanding of an open space and its natural beauty.

5.15.1.2.2. Local Park Recreation Opportunities

The City of Cockburn does not appear to have a strategic plan for the provision of public open space (POS) for passive recreation. A strategic plan would typically define the function of different POS types and their provision. Various other State planning policies and guidelines, such as *Liveable Neighbourhoods* (WAPC 2009d), provide guidance on the provision of POS for passive recreation. The descriptors typically used in these guidelines and policies to describe POS catering for passive recreation include local, neighbourhood, pocket or community park. These are generally small to medium parks servicing the regular low–key recreation needs of the immediate residential population with facilities such as play elements, lawn areas, seating and shade trees. Some parks provide for less intensive use. Other parks may serve as the recreational and social hub of a community that encourage picnicking, social gatherings and a range of informal group play and recreational activities. These parks are generally reserves vested in the City of Cockburn for recreation purposes and are zoned appropriately. They may also be land under the control of other authorities or freehold land owned by the City of Cockburn and effectively utilised as POS.

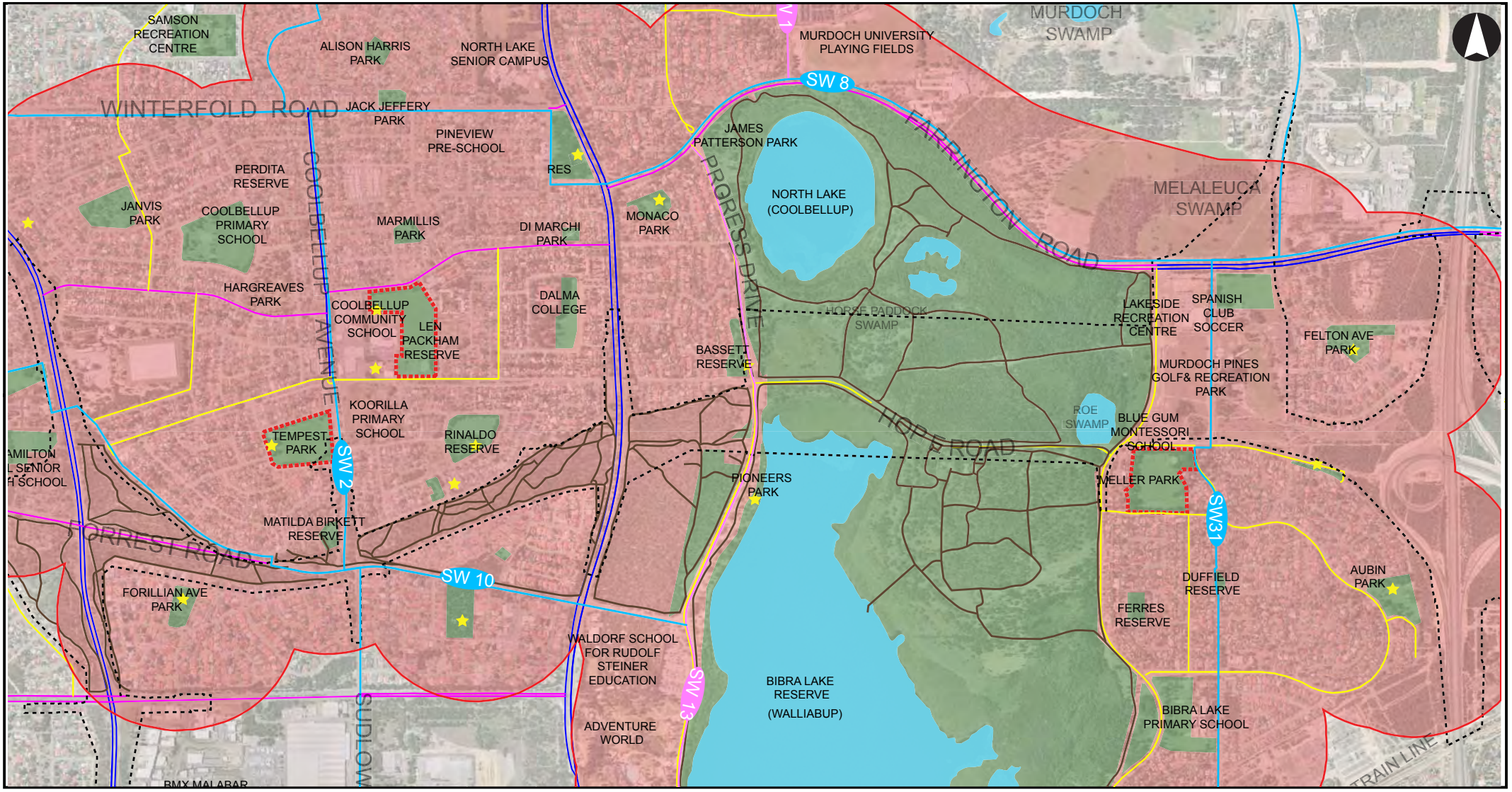
There are approximately 20 parks in the immediate vicinity between Stock Road and Kwinana Freeway that facilitate various passive recreation opportunities (Figure 5.15-2). The City of Cockburn has an inventory of its parks with an itemised list of facilities for each park available on its website (www.cockburn.wa.gov.au). Figure 5.15-2 also indicates a 400 metre catchment (approximately five minutes walking distance) to each of the parks adjacent to the project area. An assessment of the mapped catchments indicates that the area is generally well serviced by the distribution of POS. However, the adequacy of the size of the parks and their facilities in meeting the local community's passive recreation needs has not been determined.

5.15.1.2.3. North and Bibra Lakes and Surrounding Natural Areas

North and Bibra lakes and surrounding areas that form part of the Beeliar Regional Park have locally and regionally important passive recreation value. Approximately 3,000 people visit Bibra Lake Reserve every week. Two thirds of these people originate from the City of Cockburn, while the majority of the remainder come from other southern regional areas (Thompson Palmer 2006). Popular passive recreation activities include walking, walking the dog, riding bikes and birdwatching/observing wildlife (Thompson Palmer 2006).

Recreation and amenity has been identified as one of the key values of the Bibra Lake Planning Area (Strategen 2009). The area is a regionally significant recreation destination, which already contains substantial human use infrastructure, such as BBQ and toilet facilities, a children's playground and cycle paths. Bibra Lake and its surrounding environs are used for a variety of recreational uses, based mainly on the use of the outdoors and natural environment. Walking paths and boardwalks allow an opportunity for peaceful seclusion and to experience a bushland environment within a wider suburban area.

The *Bibra Lake Landscape, Recreational and Environmental Management Plan* (Strategen 2009) makes various recommendations for passive recreation for Bibra Lake that are supported by a master plan outlining the proposed developments, management zone and actions related to use and function, and a Programme of Works outlining capital costs required each financial year to implement the recommendations up until 2017.



Recreation Areas

South Metro Connect

Figure 5.15- 2

0 100 200 300 400

Meters

1:2000 (A4)

Legend

- PROJECT BOUNDARY
- PLAY EQUIPMENT
- BUSHLAND PATHS & TRACKS
- ACTIVE SPORTS RESERVES (IDETNITFIED IN CoC STRATEGIC PLAN 2006-2016 SPORTS & RECREATION PLAN)
- WATER BODY
- LOCAL PUBLIC ACCESSIBLE PARKS OR RESERVES
- 400 METRE (5MINUTE WALK) CATCHMENT TO RECREATION

PERTH BICYCLE NETWORK (SOURCE: DEPARTMENT OF TRANSPORT)

- SW 10 EXISTING
- SW 13 PROPOSED

BICYCLE FRIENDLY STREETS (SOURCE DEPARTMENT OF PLANNING & INFRASRUCTURE)

- BEGINNER
- INTERMEDIATE
- EXPERIENCED

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SouthmetroConnect

In relation to North Lake, a survey conducted in 2001 (Colmar Brunton 2001, as cited in Thompson Palmer 2006) identified that an estimated 43,000 visits occur to this lake annually, of which 86 percent were repeat visitors. It was identified that 87 percent of visitors to North Lake live locally and an additional 11 percent live in other areas. The main activities are walking, walking the dog and riding a bike.

5.15.1.2.4. Recreation within the MRS Road Reserve

The MRS road reserve does not form part of a formal management planning area for recreational purposes, but it provides for passive recreation. As the corridor is generally unfenced, public access is uncontrolled. Consequently the area has formed part of the passive open space network for the local area. Evidence of this human presence can be seen in the number of informal tracks across and along the corridor. Some of these paths have been formalised through the installation of concrete footpaths or as an extension of formal trails in the adjacent North and Bibra lakes reserves.

The road reserve forms part of the passive open space network for the local area

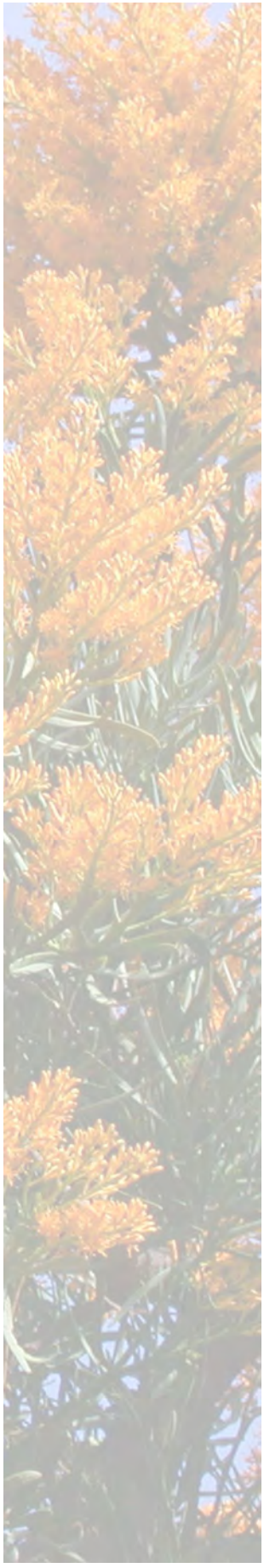
5.15.1.3. Active Recreation

Active reserves are lands set aside for the purpose of accommodating active recreation. There are no regional active recreation reserves inside or bounding the project area. The City of Cockburn is generally responsible for the provision of active reserve facilities for local residents. The City of Cockburn *Sport and Recreation Strategic Plan* (2009) identifies three active reserves nearby the project area currently providing for active recreation:

- Tempest Park on Coolbellup Avenue, north of the Roe Highway corridor section between Stock Road and Coolbellup Avenue;
- Len Packham Reserve on Cordelia Avenue, north of the Roe Highway corridor section between Coolbellup Avenue and North Lake Road; and
- Meller Park on Hope Road, south of the Roe Highway corridor and east of Bibra Drive.

Other locations providing sport and recreation facilities are (Figure 5.15-2):

- The Cockburn Indoor Cricket Centre on Stock Road, south of Phoenix Road;
- Malabar Park BMX track on Port Kembla Drive, south of Phoenix Road;
- The Spanish Club soccer field on Baker Court, between Bibra Drive and Kwinana Freeway;
- Lakeside Recreation Centre (State basketball team, netball, badminton and fitness facilities) on Bibra Drive, north of the MRS corridor;
- Murdoch Pines Golf and Recreation Park on Baker Court, north of the MRS corridor between Bibra Drive and Kwinana Freeway; and
- Bibra Lake Primary School (netball) on Bibra Drive, south of the MRS corridor (City of Cockburn 2009).



The *Sport and Recreation Strategic Plan* (City of Cockburn 2009) acknowledges that the City of Cockburn has a poor level of active reserve provision compared to other local government authorities, generally due to the relatively smaller size of their reserves. While a need to provide more facilities for a growing population and changing demographic exists, no additional opportunities have been identified in the *Sport and Recreation Strategic Plan* to increase the number of active reserves in the local district (although major developments are proposed for areas beyond the influence of the project area).

5.15.1.4. Other Recreational Facilities

Murdoch University, located north of the project area, has a large student population and workforce. Various recreation facilities are provided on campus for staff and students. Of specific relevance to recreation, playing fields, with facilities for rugby and cricket, are located adjacent to Farrington Road, north of North Lake.

Adventure World, located west of Bibra Lake and to the south of the project area, is a commercial theme park that offers various rides, water slides and other attractions. It predominantly attracts young people and families, particularly during the summer school holidays and is open between September and May.

Other commercial recreation enterprises located in the vicinity of Adventure World, include a paint ball facility south of Adventure World. Bungee West, which is not currently active, was located near the project area. Retro Chef Function Centre is located to the north of Adventure World. This centre holds private events, conferences and functions (e.g. wedding receptions). Additionally, in 2010, the Bibra Lake Fun Run attracted over 1,000 participants completing a 5.94km course.

The *Bibra Lake Landscape, Recreation and Environmental Management Plan* makes recommendations for establishment of new active recreation facilities including an exercise circuit, skate park and bike racks. The plan's recommendations indicate that the City of Cockburn is exploring opportunities on land currently owned by the City to the south of Adventure World to integrate a new recreational development (City of Cockburn 2010).

5.15.1.5. Access to Parks and Other Recreational Facilities

5.15.1.5.1. Regional Access

Regional recreation attractions consist of Beeliar Regional Park (North and Bibra lakes and surrounds), Adventure World and club sports on various active reserves. These attractions are well serviced by the existing regional road network, district roads and local distributor roads.

The Perth to Mandurah commuter train service runs along the Kwinana Freeway corridor. Murdoch Station at South Street is the closest station to the north of the project area. Cockburn Central Station is south of the project area at Armadale Road/Beeliar Drive. Bus routes 520 and 514 serve local residents and act as feeder routes to Murdoch and Cockburn Central train stations. These feeder routes are located on roads intersecting the project area, along Bibra Drive and Forrest Road.

There are also two high frequency regional bus services, 940 and the 99/98, routed around the edge of the project area. School buses also use roads within and near the project area. The existing standard and school bus networks within the project area are illustrated in Figure 5.15-3.

The Perth Bicycle Network (PBN) is an extensive plan that details a comprehensive network of cycling routes for the Perth metropolitan region that comprises local bicycle routes, Principal Shared Paths (PSP) and recreational shared paths. The network also includes all cycling related infrastructure throughout metropolitan Perth (DOT 2010). The locations of cycle routes and pathways, including bicycle friendly streets, are shown in Figure 5.15-2.

Strategen (2009) identifies provision and maintenance of an access network around Bibra Lake as a management objective for Bibra Lake. Numerous management actions relating to regional and local access, as well as parking, have been identified as follows:

- General – Undertake a comprehensive traffic and parking investigation and strategy to determine feasibility of road modifications and additional parking along Progress Drive. Include options to realign the southern end of Progress Drive to improve traffic flow and safety. Include options for reducing traffic speed along Hope Road and implementing traffic control measures;
- Parkland and Leisure Management Zones – Investigate options for improved bus services to Bibra Lake during peak visitor periods. This includes, but is not limited to, direct transfer buses from Murdoch and Cockburn Central train stations during summer school holidays;
- Leisure Management Zone – Include adequate parking in any development; and
- Education/Sustainability Management Zone – Upgrade parking facilities (Strategen 2009).

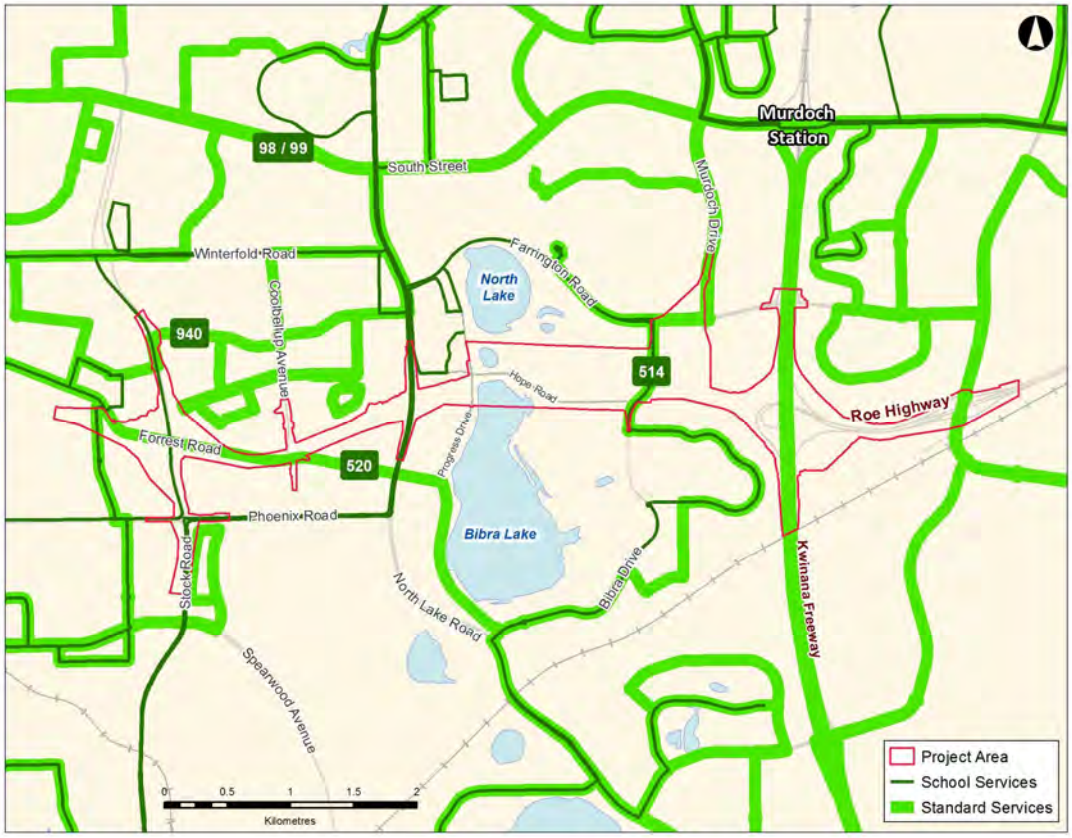


Figure 5.15-3: Existing Standard and School Bus Network

5.15.1.5.2. Local Access

The local road network provides adequate access to recreation facilities. There is a significant local footpath network throughout the project area. However, there are some situations where there is discontinuity in path networks. Some local paths also provide connectivity between residential areas across the MRS corridor along north–south roads and in other locations, particularly in the section west of Progress Drive.

The path network, which has been generally developed with residential communities, provides access to and around the Beeliar Regional Park. However, there are several informal trails and fire breaks used for pedestrian access located in this area. Many of these paths and trails intersect or run parallel to the MRS corridor.

Strategen (2009) identifies a number of management actions related to local access to recreation opportunities around Bibra Lake. These include:

- Conservation Management Zone:
  - Upgrade the existing boardwalk/bird hide on the north–eastern side of the lake and extend out to the edge of the water body in a looped circuit;
  - Upgrade the existing jetty on the eastern side of the lake;

- Upgrade and add to existing signage within the Conservation Zone, including a series of themed trails with new signs providing information on the environmental and heritage values of Bibra Lake. Upgrade existing pathways within the Conservation Zone through the addition of strategically located boardwalks, seating and viewing nodes; and
- Establish new pathways, in accordance with the Master Plan. This will allow greater variety of walking options, particularly for regular visitors to the area.

- Parkland Management Zone:
  - Establish the 'Von Bibra Promenade' on the section of Progress Drive adjacent to the parkland north of Gwillam Drive; and
  - Install traffic slowing measures to the pedestrian promenade area of Progress Drive.
- Improve kerbside and entry parking zone definitions around the perimeter of the Bibra Lake Reserve (including the unsealed area used for parking at the south–west corner of the reserve and the City of Cockburn carpark on the south–west corner of Progress Drive and Gwilliam Drive) through redesign and demarcation of parking bays (including installation of kerbing where appropriate); and
- Ensure main pathways are trafficable asphalt and allow access for maintenance vehicles (for weeding, planting, spraying etc.) and fire trucks.

5.15.2. Education

The educational values include values of regional and local significance with respect to both education provision and pursuits, and generally relate to accessing the environmental values and factors of the project area.

5.15.2.1. Education Providers

The flora, vegetation, fauna and wetlands contained within Beeliar Regional Park provide an educational resource for numerous education providers in the local, metropolitan and state areas (Table 5.15-1). This includes community organisations, primary schools, secondary schools and tertiary institutions.

The environmental values of the Beeliar Regional Park provide an educational resource

Table 5.15-1: Education Providers Known to Use Beeliar Regional Park for Education Pursuits

Education Providers	
Community	Cockburn Wetlands Education Centre Native Animal Rehabilitation Centre 1st Bibra Lake Scout Group Friends of Cockburn Wetlands Education Centre Wetlands Conservation Society Birds Australia Wildflower Society Orchid Society
Primary	Blue Gum Montessori School Coolbellup Community School Perth Waldorf School South Lake Primary School Southwell Primary School Success Primary School Bibra Lake Primary School Spearwood Alternative School
Secondary	Lakelands Senior High School North Lake Senior Campus Iona Presentation College
Tertiary	Murdoch University

The project area and surrounds are used to study a variety of science topics, relating to the natural environment. The area is used by education providers for, but not restricted to, the following educational pursuits:

- Birdwatching;
- Conservation and land management;
- Ecosystem assessment;
- Environmental biology (e.g. aquatic invertebrate studies);
- Environmental management;
- Environmental restoration and wetland rehabilitation;
- Macroinvertebrate studies;
- Climate change;
- Native wildlife rehabilitation;
- Vegetation mapping;
- Water quality analysis; and
- Wetland ecology.

A standard social research method was used to determine educational usage and potential impacts associated with the proposed project. The research was based on interviews with education providers (where possible), community engagement, stakeholder consultation and desktop studies.

5.15.2.2. Education Usages

5.15.2.2.1. Local Community Organisations

The Cockburn Wetlands Education Centre and Native Animal Rehabilitation Centre (Native ARC) are community organisations located in the Beeliar Regional Park. They provide services dedicated to wetland and wildlife education. Based in the park, the Wetlands Centre provides guided tours, lectures, training and conference facilities, as well as a limited library. It serves as a local wetland knowledge base for schools, tertiary institutions, community members and researchers. The centre offers:

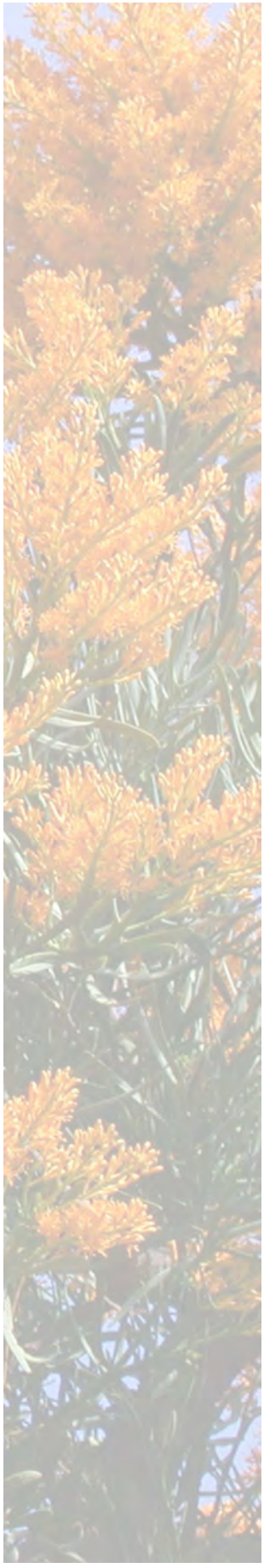
- A broad range of environmental education and training programmes to schools, the community and wetland professionals;
- Weekly excursions for school children, including a 1.3km guided walk from the centre through the bushland to Bibra Lake;
- An important facility for professional conferences on wetlands;
- A library with a collection of over 1,000 literary works on wetlands and related sciences; and
- A training facility for wetlands rehabilitation volunteers.

The centre was host to the Western Australian Wetland Management Conference on 2 February 2010. This event attracted wetland specialists from the CSIRO, the University of Western Australia, the DEC, Nijhumdweep Island Wetland Centre (Bangladesh), the Department of Fisheries and Perth Zoo.

Neighbouring the Cockburn Wetlands Education Centre, Native ARC provides native wildlife rehabilitation and education services for local residents and schools. It provides services for rescuing, treating and caring for injured, sick, orphaned and displaced native wildlife. It also provides educational programmes and research relating to native wildlife, working with school children and veterinary students from Murdoch University.

Most of the education providers and individuals who use Beeliar Regional Park as an educational resource do so by utilising the information and training sessions provided by the Wetlands Centre and Native ARC.

The 1st Bibra Lake Scout Group has over 60 members who meet weekly on Mondays, Tuesdays and Wednesdays at the Wetlands Centre.



The Friends of Cockburn Wetlands Education Centre assist the centre in environmental, educational and land care issues pertinent to the regeneration and conservation of the North and Bibra lakes reserves of the Beeliar Regional Park. They are keen birdwatchers and have monitored waterbirds on a quarterly basis since 1996. Between monitoring events they hold regular bird watching outings on Saturday mornings. They meet at the centre on the first Saturday of the month at 1000hrs.

The Wetlands Conservation Society is involved in a wide range of activities aimed at conserving Western Australian wetlands. These activities include education, submissions, wetland revegetation and excursions to wetlands. The society meets monthly at the centre.

Birds Australia and the Wildflower Society are both regular users of the Cockburn Wetlands Education Centre.

In addition to this, the City of Cockburn has plans to establish a Wetlands Precinct at Bibra Lake. For this precinct, the City of Cockburn proposes to construct an integrated environmental education facility at Bibra Lake, including new buildings and infrastructure for the Wetlands Education Centre and Native ARC (City of Cockburn 2010).

5.15.2.2.2. Local Primary and Secondary Schools

There are 11 confirmed local and metropolitan primary and secondary schools that utilise Beeliar Regional Park for birdwatching, conservation, land management and macroinvertebrate studies (Table 5.15-1). These schools predominantly use the services of the Wetlands Centre and Native ARC as a gateway for learning about the local environment.

Coolbellup Community School has a strong affiliation with Bibra Lake and surrounding wetlands. Science is a priority learning area for the school and the lakes and wetlands provide a practical learning environment for the students, based in the context of their immediate environment. The students work with the Native ARC to learn how feral domestic animals can have a negative impact on the natural environment. The Native ARC and Beeliar Regional Park constitute an important educational resource for the school.

In conjunction with the Department of Education and Training (DET), North Lake Senior Campus serves as a centre of professional development for school laboratory technicians from around the state. The technicians congregate annually at the school to participate in water quality assessment and vegetation profiling exercises in Bibra Lake and the Beeliar Regional Park.

5.15.2.2.3. Local Tertiary Education

Murdoch University utilizes North and Bibra lakes on a yearly basis for field work for over 500 students enrolled in environmental science, management, biology and restoration degrees.

The project area consists of conservation wetlands, flora and fauna in a suburban setting, as well as ecological linkages that provide connections to other natural areas along a green space. The area is often compared to more degraded and artificial systems in the region and used for other educational pursuits, including:

- First year students studying environmental biology conduct aquatic invertebrate surveys at Bibra Lake and/or North Lake, depending on water levels;
- Students studying environmental science assess water quality at Bibra Lake and/or North Lake depending on water levels, and compare to Chelodina Wetland and Frederick Baldwin Lake;
- Third year students taking the unit 'Managing Wetlands and Water' conduct a semester–long ecosystem assessment and environmental management project on the area; and
- Third year students studying environmental restoration assess restoration projects conducted by the Cockburn Wetlands Education Centre.

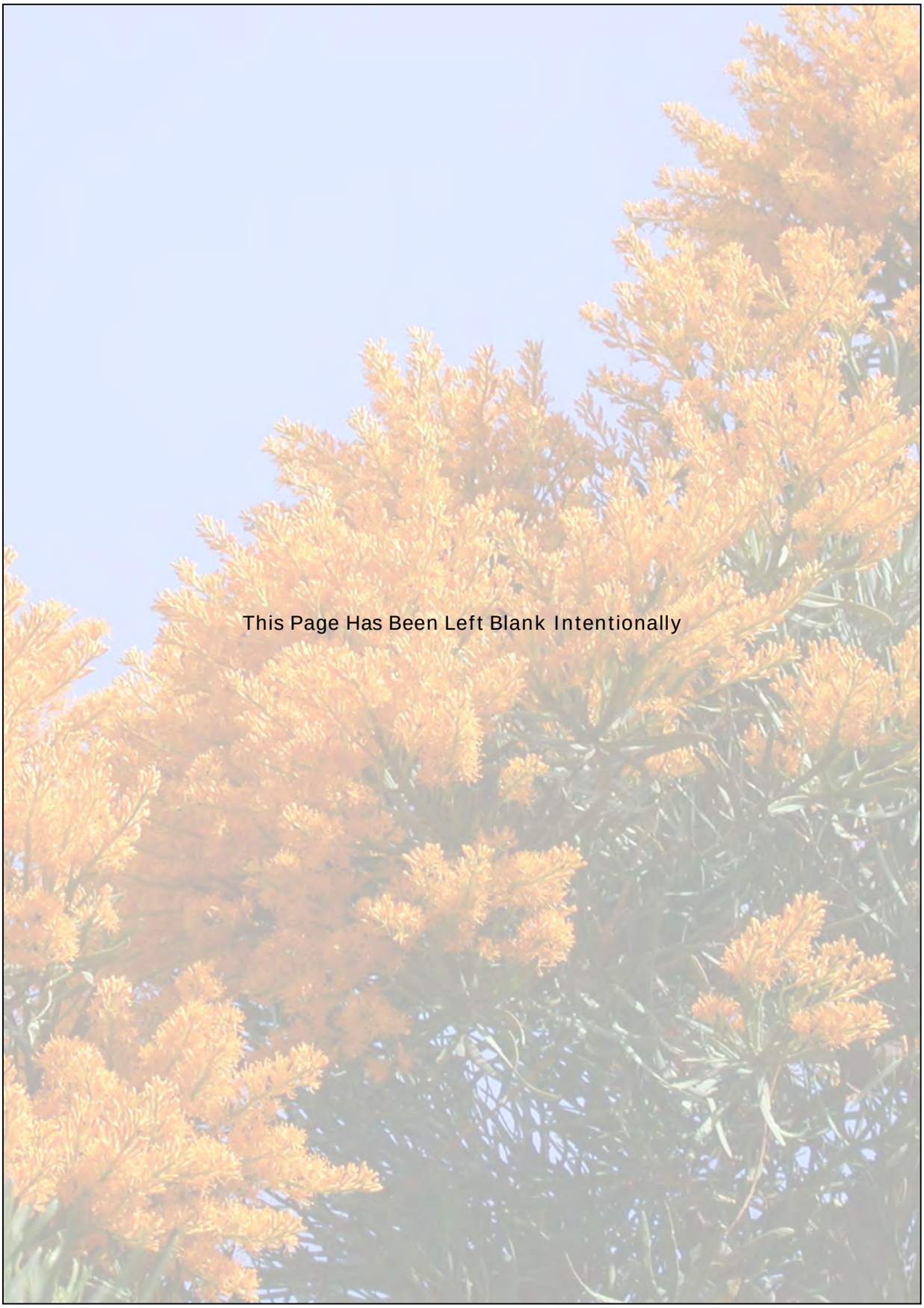
In addition to environmental science students, the Murdoch Veterinary School uses the south–east corner of Murdoch University land as grazing land for animals.

5.15.2.2.4. Metropolitan and State Providers

There are also a number of education providers from around the State who use Beeliar Regional Park as an educational resource. Iona Presentation College and the DET (through North Lake Senior Campus) use the lakes and wetlands for field trips and professional development exercises, including water quality testing and fauna surveys.

5.15.3. Conclusion

The investigation into the recreational and educational values of the project area highlights their importance to both the local community and the broader region. Educational values revolve around the natural setting of the project area. Recreational plans exist for much of the project area, but not the land that occurs within the MRS road reserve, which is, nevertheless, subject to informal, passive recreation.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5.16. Aboriginal Heritage

State and the Commonwealth legislation that regulate impacts on Aboriginal heritage include the Commonwealth *Aboriginal and Torres Strait Islander Protection Act 1984* and *Native Title Act 1993* and the State *Aboriginal Heritage Act 1972* (*AH Act*) and the *EP Act*.

5.16.1. Background

Prior to European settlement, land in south–west Australia was occupied by the Bibbulmun Nyungar people, collectively sharing the name of Nyungar (Goode 2010). The Nyungar lived a semi–nomadic, hunter–gatherer lifestyle highly dependent on the seasonal shifts of the surrounding environment. As a result, Nyungar society and culture developed a profound inter–connectedness with the landscapes of the South–West. They struggled to maintain traditional cultural practice in the face of the massive change brought by European settlement. However, an ongoing connection with their traditional landscapes has been maintained, including in the areas surrounding the project area (Goode 2010).

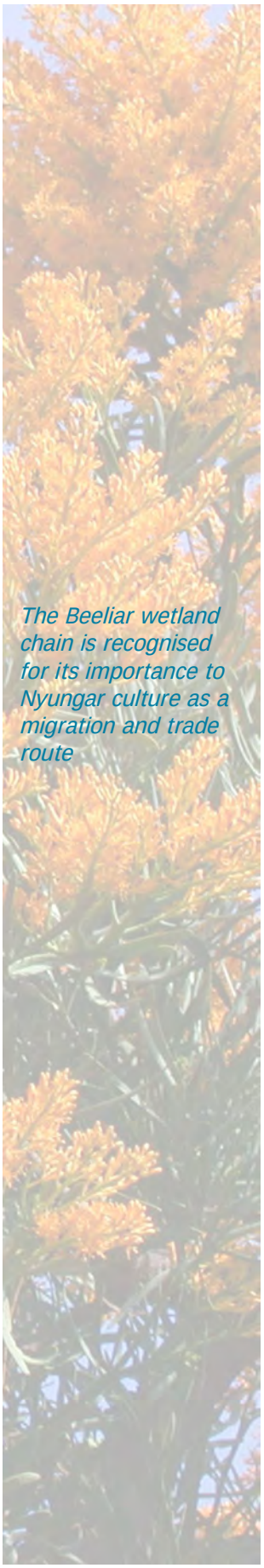
The Beeliar wetland chain is recognised for its importance to Nyungar culture, forming a link between the Swan and Murray Rivers, which facilitated migration and trade between these two areas (Polgaze 1986). At the time of colonisation, the project area was part of what Lyon (1883) referred to as the territory of Beeliar, seen as the territory of the Aboriginal leader Midgegoorang (Midjegooroo). Of the wetlands south of the Swan River, the majority of ethnographic information available relates to North and Bibra lakes (known by their traditional names of Coolbellup and Walliabup, respectively).

Nyungar society originates from 14 linguistic groups comprising four dialects and, although there are various spellings, 'Nyungar' is most commonly used today; other derivations of the group name include Nyoongar, Noongar, Nyungah, Nyoongah and Noongah (Goode 2008).

5.16.2. Aboriginal Heritage Under the *Aboriginal Heritage Act 1972*

A preliminary desktop Aboriginal heritage report was prepared in accordance with the *AH Act* (Goode 2010). The report also presented the outcomes of a Native Title search. The survey identified previously recorded Aboriginal heritage sites located within or adjacent to the project area and determined the significance of these sites to the Nyungar.

Consultation with Nyungar representatives and local groups has taken place throughout the duration of the PER process. Details of Aboriginal heritage surveys and consultation conducted in August 2010 have been compiled and evaluated through a separate process pursuant to the *AH Act*. The outcomes of this work are presented under a separate cover (ACHM 2010).



The Beeliar wetland chain is recognised for its importance to Nyungar culture as a migration and trade route

Eight Aboriginal heritage sites have been recorded within and adjacent to the project area

5.16.3. Aboriginal Sites

Aboriginal sites fall into two basic categories: archaeological (past Aboriginal use) and ethnographic (mythological significance). The Department of Indigenous Affairs (DIA) maintains a register of sites that records places and objects of significance to Aboriginal culture. Sites or places reported to the DIA are assessed and assigned one of seven categories of status. Sites located within the project area have been assigned three of the seven categories of status:

- Insufficient Information (I): places lodged with the Registrar that have insufficient information to complete an assessment under Section 5 of the *AH Act*. Provisions of the *AH Act* apply to these sites until they are assessed as places that either do or do not meet the criteria for registration as an Aboriginal heritage site, at which time their status is revised;
- Stored Data (S): places that have been registered but determined not to meet the criteria for registration as an Aboriginal heritage site pursuant to Section 5 of the *AH Act*. Such records may include sites where archaeological material was removed to another location or the information provided did not support the site's inclusion on the register; and
- Permanent Register (P): places that are assessed to meet the criteria for registration pursuant to Section 5 of the *AH Act*. Provisions of the *AH Act* apply to Permanent Sites.

Of the eight recorded sites located within and adjacent to the project area, five sites are registered on the Permanent Register, two as Stored Data and one with Insufficient Information (Goode 2010). Table 5.16-1 presents the Aboriginal heritage sites within and adjacent to the project area and their status.

Table 5.16-1: Registered Aboriginal Heritage Sites

Site Number	Site Name	Status	Recorder /Year	Access	Restriction	Archaeological /Ethnographic
3196	Lake Bibra: Forrest Road	Stored Data	Chapman 1977	Open	Not Restricted	Quarry
3293	Bibra Lake	Insufficient Information	Hallam, S 1974	Open	Not Restricted	Archaeological
3709	North Lake and Bibra Lake	Permanent Register	O'Connor, Bodney & Little 1985	Open	Not Restricted	Ethnographic
4107	Bibra Lake North	Permanent Register	Stranger, R 1973	Open	Not Restricted	Archaeological
4106	North Lake SW	Permanent Register	Hallam, S Smith, M & Stranger, R 1972	Open	Not Restricted	Archaeological
3294	North Lake N	Permanent Register	Stranger, R 1974	Open	Not Restricted	Archaeological
3295	North Lake Coolbellup	Permanent Register	Hallam, S Smith, M & Stranger, R 1972	Open	Not Restricted	Archaeological
3296	Hope Rd Swamp/Bibra Lake	Stored Data	Stranger, R 1974	Open	Not Restricted	Archaeological

Source: DIA 2009

Archaeological investigations have recorded various materials in the ground between North and Bibra lakes, indicating that these areas were historically used as camping areas. As shown in Figure 5.16-1, the registered Aboriginal Sites are situated within the central section of the project area and generally correspond to wetland areas. Three Aboriginal sites shown occur outside of the project area. Characteristics of each of the sites identified within and adjacent to the project area are detailed below (Goode 2010). Site numbers correspond to those indicated in Figure 5.16-1.

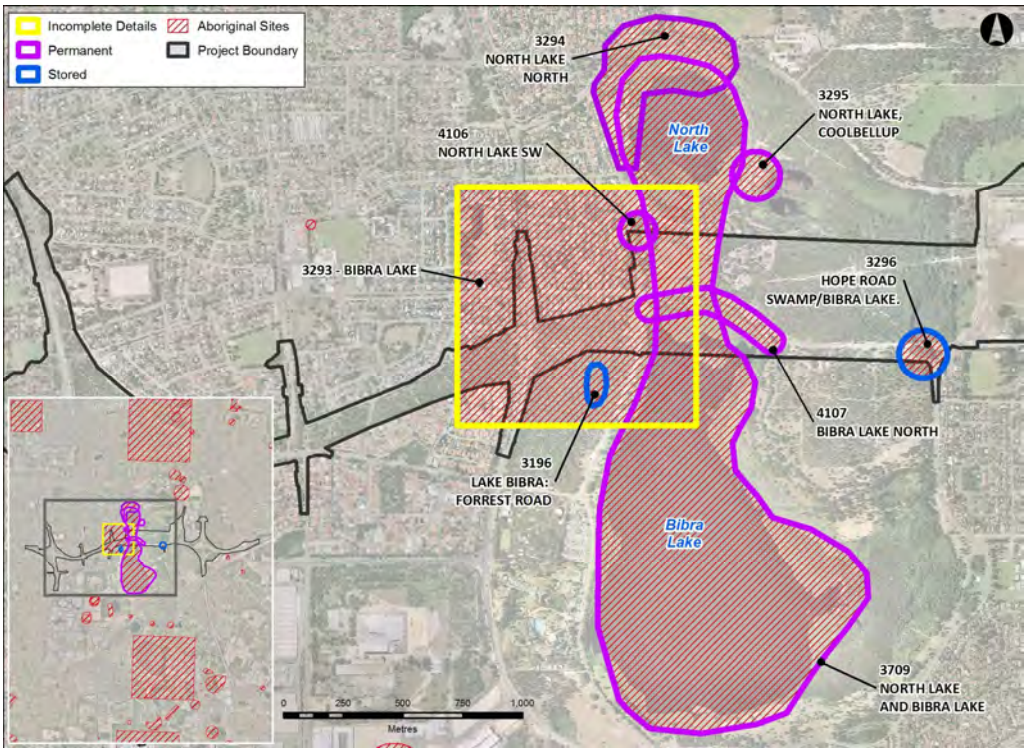


Figure 5.16-1: Aboriginal Heritage Sites

Site 3196 (Quarry)

Lake Bibra: Forrest Road was reported to be a quarry site during a quarry survey in 1977. The site was located in an industrial area. It was determined that the artefact scatter is not a site under the *AH Act* and it is therefore placed as stored data. This site is not located within the project area.

Site 3293 (Archaeological)

Bibra Lake was reported to be an artefact scatter in 1974; however, no further details exist regarding content size or location. An extract from the site file notes that artefact scatters are recorded at North and Bibra lakes and beside the small lake to the south–west of Bibra Lake.

Site 3294 (Archaeological)

North Lake N was reported to be an artefact scatter and campsite, which consisted of an extensive scatter of some 1270 artefacts consisting mostly of chips and utilised flakes, backed blades, flakes and adzes. All artefacts were collected and analysed. Landscaping has since occurred and a path cuts through the middle of the site. This site is not located within the project area.

Site 3295 (Archaeological)

This area of North Lake consisted of a sparse scatter of 53 artefacts consisting of adzes, bipolar pieces, flakes and chips scattered over an area on an open sandy rise adjacent to a permanent lake. These artefacts were manufactured from quartz, chert and glass and were all collected and analysed. The area has previously been highly disturbed by ploughing. This site is not located within the project area.

Site 3296 (Archaeological)

Hope Road Swamp/Bibra Lake was reported to be an artefact scatter and campsite. It consisted of a sparse scatter of seven artefacts mostly consisting of chips, flakes, fragments and adzes scattered over an area on a sand plain. The artefacts were manufactured from quartz. All seven artefacts were collected and analysed. This land has since been landscaped for recreational activities.

Site 3709 (Ethnographic)

North and Bibra lakes were reported to be camping and hunting places in combination with a mythological site. The site was recorded in 1985 in a survey for significant areas to Aboriginal people. The site is bounded by Bibra Drive to the south and east, Farrington Road to the north and Gilbertson Road to the west. The area has been re–landscaped after being previously disturbed from stock movements and erosion.

Nyungar mythology states that a creative Dreamtime spirit associated with water, the Waugal, inhabits the lakes and maintains their flow. Camping grounds were noted on the southern side of Hope Road near the north–eastern edge of Bibra Lake and along its southern shore. Bibra Lake was part of a trade and travel route from North Fremantle to the Canning River. It was renowned amongst Nyungar for excellent food supplies. As a result, it was a major population centre and birth site.

Site 4106 (Archaeological)

The North Lake SW site consisted of a sparse scatter of 40 artefacts, comprising mostly chips and utilised flake, micro adzes, bipolar pieces and battered pieces scattered over an area on a wooded sandy rise at the south–west corner of North Lake. The artefacts were manufactured from quartz, glass and a pottery shard.

Site 4107 (Archaeological)

This site consisted of an extensive scatter of 2,080 artefacts over an area on a bare sandy pasture between North and Bibra lakes. Consisting of mostly chips and utilised flakes, scrapers, backed blades, adzes and fabricators, the artefacts were manufactured from quartz with chert, glass and clay pipe fragments.

5.16.4. Native Title

Native Title is a concept in Australian law that recognises and protects the continued ownership of land by Australian Aboriginal or Torres Strait Islanders. The Commonwealth *Native Title Act 1993* establishes the ways in which future dealings affecting native title may proceed and establishes a mechanism for determining native title claims. Additionally, it provides for permits, the validation of past acts that have been invalidated because of the existence of native title claims, thereby clarifying the legal position of other land owners.

Presently, an unregistered native title claim covering the project area has been identified as the Single Noongar Area 1 (WC 03/6) Native Title Claim group. However, no registered Native Title applications that overlay or intersect the project area have been lodged with the Commonwealth Native Title Tribunal (Goode 2010).

5.16.5. Aboriginal Heritage Under the Environmental Protection Act 1986

Guidance on the assessment process for Aboriginal heritage under the *EP Act* is provided in EPA Guidance Statement No 41, *Assessment of Aboriginal Heritage* (2004d). This guidance statement, prepared in consultation with DIA to develop a common approach, ensures that changes to the biological and physical environment resulting from a proposal do not adversely affect matters of heritage significance to Aboriginal people. Whilst the focus of the *AH Act* is the protection of archaeological and mythological sites with social and heritage significance, the primary focus of the *EP Act* is to consider the potential for significant impacts on the environment (EPA 2004d).

5.16.6. Nyungar Environmental Values

An important relationship between Nyungar culture and the wetlands, flora, and fauna within the project area was identified. Figure 5.16-2 shows the sections of the project area that represent these environmental values.

Flora

Four genera of plants of significance to the Nyungar were identified, two of these at species level:

- *Kunzea glabrescens;*
- *Nuytsia floribunda;*
- *Melaleuca sp.; and*
- *Typha sp.*

Figure 5.16-2 indicates the extent of vegetation communities within the project area that are known to contain the above mentioned genera and species, with the exception of *Nuytsia floribunda*. This species was identified as having a high level of significance to Nyungar mythology (Goode 2008). A targeted survey was undertaken within the project area to specifically quantify potential impacts on *Nuytsia floribunda*, which is known to occur over a much wider extent both within and around the project area.

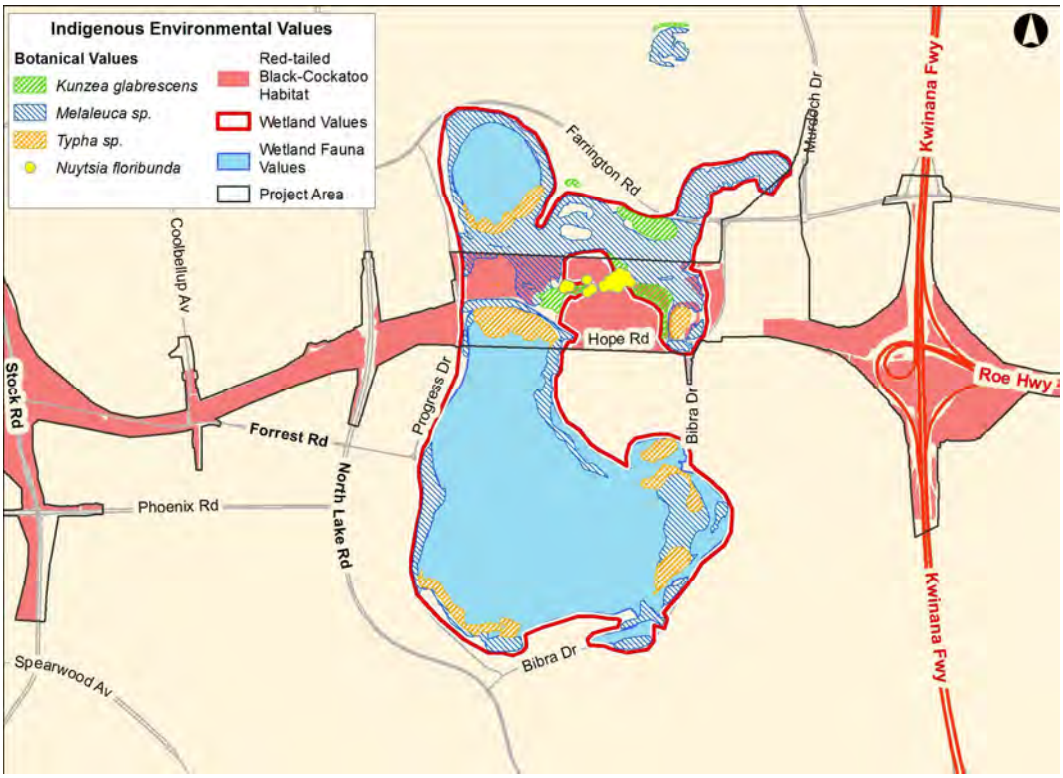


Figure 5.16-2: Nyungar Environmental Values of the Project Area

Fauna

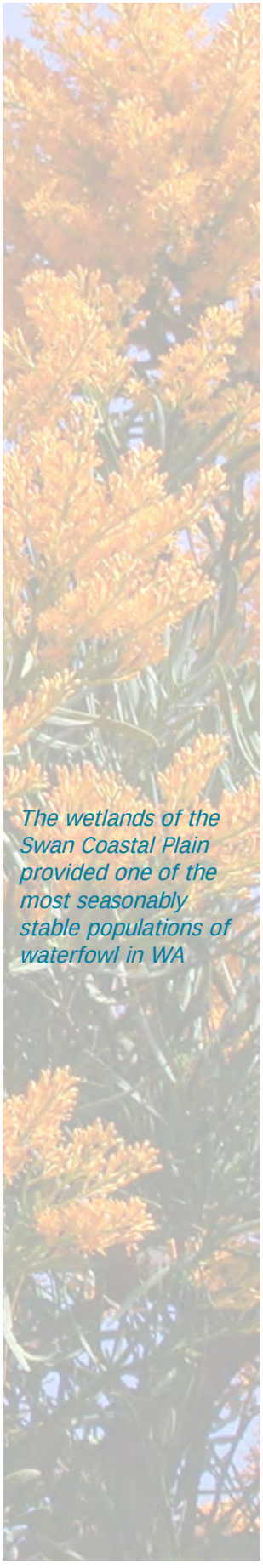
Fauna values were mapped on the basis of the extent of habitat available for wetland species (Figure 5.16-2). Habitat suitable for the Forest Red–tailed Black Cockatoo was mapped separately on the basis of the presence of *Corymbia callophyla* and *Eucalyptus marginata*.

Wetlands

Wetland values in Figure 5.16-2 were defined through a review of results from flora and fauna surveys and wetland investigations. These results were integrated with values outlined in the descriptions of registered Aboriginal heritage sites.

5.16.6.1. Nyungar Wetland Values

Rivers, pools and wetlands are central to sustaining Nyungar culture and society. They were sites of essential food sources and ceremony, and provided linkages for trade and travel routes through the surrounding, often arid landscape. These sites remain places of mythological and spiritual significance. Throughout the South–West, rivers continue to define the estates of the Nyungar people (Dortch 2002; Hallam 1975).



The wetlands of the Swan Coastal Plain provided one of the most seasonably stable populations of waterfowl in WA

The Nyungar people recognise the importance of water through the Waugal, a mythological rainbow serpent. In Nyungar mythology, Waugal created, occupied and maintained the rivers, springs and lakes. In the Waugal myth, the male and female serpents separated at Melville Water and the female Waugal travelled south to Bibra Lake (South West Metropolitan Tafe n.d.).

The Cockburn area formed part of an extensive communications network that linked Nyungar groups of the Swan Coastal Plain with groups to the north and south. The chain of lakes running from North Lake to Mandurah formed the main trade and travel route between the Swan and Murray rivers. Fremantle and Canning River were the two primary travel routes that met at Bibra Lake. These travel routes proceed south along the wetland chain.

Rivers, pools and wetlands continue to be important sources of food and connection to traditional landscapes for Nyungar. The majority of registered Nyungar archaeological sites are located near waterways (Beckwith Environmental Planning 2009).

North and Bibra lakes provided regular access to a fresh water supply for the Nyungar of the Swan coastal plain. Bibra Lake is a permanent fresh water site, whereas other lakes in the Beeliar wetland chain are more seasonal and saline (Polgaze 1986). The presence of a number of registered camp sites in the North and Bibra lakes area confirms the significance of the wetlands to Nyungar heritage.

5.16.6.2. Nyungar Fauna Values

The permanent fresh water wetlands of the Swan Coastal Plain provided one of the most seasonally stable populations of waterfowl in Western Australia and provided drought refuges for Nyungar societies. Lakes and estuaries in the region supported swans and ducks, and pelicans in winter. Hot, dry summers evaporated ephemeral inland water sources. There were large concentrations of waterfowl and other food sources such as tortoises, crustaceans and frogs (Meagher and Ride 1979).

Harvesting of these food sources occurred for extended periods. Water birds were speared or trapped with nooses and turtles were trapped in pits or tracked and retrieved from the mud (Polgaze 1986). In addition to using fauna for food resources, cloaks and bags were traditionally made with kangaroo skins and fastened with bone. Headdresses were decorated with emu or cockatoo feathers (Flugge 2004).

Forest Red–tailed Black Cockatoos reside in Nyungar mythology, which describes how the souls of their ancestors are carried to their resting place (Koorannup) by this species (Goode 2008).

Nyungar society and culture is broadly similar to other Aboriginal societies across Australia, in their close associations between individuals and plants and animals. These associations are complex and beyond the scope of this review. However, an association of primary relevance to the project are the conception sites of local Nyungar (Broome 1994). In addition, Nyungar's close associations with particular flora and fauna species preclude them from harming or killing these species.

5.16.6.3. Nyungar Botanical Values

Nyungar botanical values have social, cultural, mythological and resource–based components. Plants were used for food, fibre, timber, medicine, ceremony and social gatherings. Nyungar botanical knowledge included an understanding of species taxonomy, abundance and distribution, seasonality and resource usage (Nash 2007). A summary of flora occurring within the project area traditionally used by Nyungar people is presented in Table 5.16-2.

Table 5.16-2: Project Area Flora Used by Nyungar People

Common Name	Plant Species	Aboriginal Name	Use
Candlestick banksia	*Banksia attenuata*	Piara, biara – Chewy tree	Food
Bull banksia	*Banksia grandis*	Poolgarla, magnite, beera boolgalla, boorabup	Food, cultural
Milkmaid	*Burchardia congesta*	Kara	Food
Dodder laurel	*Cassytha racemosa*	Dodder Laurel	Food
Blood roots	*Haemodorum* sp.	Born	Food
Spearwood	*Kunzea glabrescens*	Kitja Boorn	Weapon
Tassel bush	*Leucopogon verticillatus*	Tassel Bush	Food
Zamia palm	*Macrozamia riedlei*	Jeeriji	Food, fire tinder
Paperbark	*Melaleuca* sp.	Yowarl	Shelter, wrapping
Christmas tree	*Nuytsia floribunda*	Mooja	Food, ceremonial
Bracken fern	*Pteridium esculentum*	Bracken Fern	Food, medicinal
Undertaker orchid	*Pyrorchis nigricans*	Djubak	Food
Berry saltbush	*Rhagodia baccata*	Berry Saltbush	Food
Twining fringe lily	*Thysanotus patersonii*	Tjunguri	Food
Bulrush	*Typha* sp.	Yangeti	Food, medicinal
Grasstree	*Xanthorrhoea preisii*	Balga, balka	Food, ceremonial

Source: Daw *et al.* 2007; Goode 2006; Polgaze 1986.

Nyungar have retained cultural and Nyungar botanical knowledge of natural wetland vegetation species. The Bulrush (*Typha orientalis*), or yanjiddi/yunjidi/yangeti, is an important food source located in the project area. Reliance on these resources for food is still within living memory for a number of senior Nyungar in the area. Yanjiddi was a staple food for the Nyungar that was harvested in April and May. The yanjiddi was prepared for the harvest by undertaking specific burning regimes in the summer months. Specific areas of the wetlands were burned in dry periods to improve the reed's rhizome flavour and to aid in cultivation (McDonald *et al.* 2005).

In Nyungar mythology the souls of their ancestors rest on the Christmas tree until they are carried away to their resting place – Koorannup - by the Red-tailed Black Cockatoo

The grass tree (*Xanthorrhoea preissii*), or Balga, also provided Nyungar people with a multitude of uses. The flowering stem provided an edible gum, honey and frame poles for huts. Similarly, the resin or gum from the trunk (known as tudibi) was used as a glue to fix spear heads and to make a hammer (kadjo) or adze that was blunt on one end and sharp at the other (Goode 2006). The trunks provided a valuable habitat for bardi grubs, which could be eaten raw or cooked. Dead trunks of the Balga made excellent firewood. Leaves were used as a thatch for huts and bedding, and provided a water resource by chewing on the fleshy bases of the needle. The leaves were smouldered in a small fire for smoking ceremonies to purify an individual or area (Yelakitj Moort Nyungar Association 2010).

The Christmas tree (*Nuytsia floribunda*), or Mooja tree, has important mythological associations for the Nyungar. In Nyungar mythology the souls of their ancestors rest on these trees until they are carried to their resting place, Koorannup. Disturbance to Mooja trees is thought to cause spiritual sickness amongst the Nyungar community; picking of flowers or resting under the tree is also thought to cause death (Goode 2008). This mythology is specific to the Nyungar. Other Aboriginal groups were known to eat the tissue beneath the Mooja bark, sweet gum secreted from the bark when cut and its roots. Additionally, Mooja wood was used in shield making and soaking the flowers created a sweet beverage (Daw *et al*. 2007).

There are also various *Melaleuca* species that remain important to the Nyungar. Bark was used to make a range of diverse utilitarian objects, such as mats, blankets, burial shrouds, wrappings, dishes, carrying vessels and shelters. Hunting implements, such as spears, were crafted from either tea tree or spearwood (*Kunzea glabrescens*). The spearwood trees were highly valued and were used for trading with distant Aboriginal groups (Polgaze 1986; City of Joondalup 2008).

5.16.7. Conclusion

A review of the records, along with consultation with Indigenous people with ties to the project area, has confirmed the presence of up to three registered sites that are at risk of disturbance within the project area. In addition, this process has identified the presence of habitat within the project area that is of environmental and cultural value to Nyungar people, which warrant consideration from an environmental impact perspective when planning the proposed project.

5.17. Summary of Investigations

Table 5.17-1 summarises the environmental investigations scoped as part of the ESD and presents the status and key outcomes of these studies.

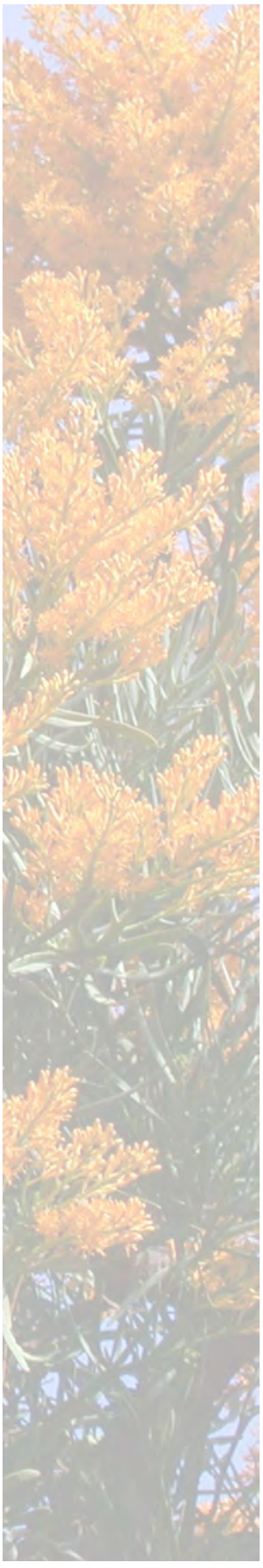


Table 5.17-1: Environmental Investigations Scoped as part of Environmental Scoping Document

No	Investigation	Status	Key Outcome(s)
Potential Contamination			
1	PSI, consisting mainly of: • Desktop study of historical land uses, potentially contaminating activities and the contaminated sites database Detailed visual site inspection of the project area	Completed	The desktop study identified: • Historical land uses (Table 5.4-1) • Historical activities (Table 5.4-2) • Sites registered in the DEC Database that may have resulted in potential contamination within or adjacent to the project area
2	Detailed Site Investigation (DSI), to confirm potential or actual contamination identified during the PSI and, as appropriate, develop and implement DEC–approved management plans	Scope to be developed and implemented during the detailed design stage of the project	Not applicable at this stage of the project
Acid Sulfate Soils (ASS)			
1	A desktop study and intrusive field investigations (soil coring and laboratory analyses) to assess the ASS characteristics of high risk and representative sites, and to establish baseline environmental conditions	Completed except for restricted access in high risk area and the new Murdoch Drain re–alignment	Some PASS and AASS encountered Further assessment required in high risk area owing to restricted access
2	Field screening of soil samples at 0.25m intervals to record texture, pH_F, pH_{FOX}, reaction rate and change in pH	Completed at 0.5m intervals in test pits.	The tested soils are unlikely to be PASS or AASS Two of the four sampling locations indicate that the sediment has the potential to oxidise further and produce sulphuric acid, if exposed There is no clear indication of AASS or PASS in the samples from the other two sediment sampling locations
3	Water analyses for a suite of approved ASS analytes in conjunction with the water quality analysis	Groundwater not encountered in test pits	Further assessment required for new Murdoch Drain realignment

No	Investigation	Status	Key Outcome(s)
4	Submission of at least one sample per borehole to the laboratory for SPOCAS testing, based on field screening	Completed	Four of the five test pit samples indicated net acidity levels above the DEC recommended guideline criterion of 18.7mol H^+/t, signifying the occurrence of potential and existing acidity All the four sediment samples indicated net acidity levels above the DEC recommended guideline criterion of 18.7mol H^+/t, signifying the occurrence of potential and existing acidity
5	Studies will assess areas where ASS is present and will be affected during anticipated excavation activities	Partly completed Detailed sampling of high ASS risk areas will be undertaken prior to construction and will inform preparation of the ASS Management Plan	Some PASS and AASS encountered Further detailed sampling will be undertaken prior to construction
6	Liming rates will be provided to enable construction contractors to manage the effects of ASS	Completed based on currently available information. Further assessment required in high risk area owing to restricted access. Detailed sampling of high ASS risk areas to determine accurate lime dosing requirements will be undertaken prior to construction to inform the preparation of an ASS Management Plan	Based on current level of detail available, it is expected that lime dosing requirements will be minimal, other than possibly for the realignment of part of the Murdoch Drain
7	Special attention will be placed on ASS investigations within the Bassendean Sand area of the project and on potential dewatering activities	Partly completed	No planned dewatering activities

No	Investigation		Status	Key Outcome(s)
Contaminant Spills/Hazardous Substances				
1	Road safety audit to assist in modifying occurrence of crashes		Completed	Design conforms to safety standards aimed at minimising risk of accidents during operation. Specific safety characteristics of design are detailed in Section 6.4.3.2
2	Risk assessment to identify risk of and management required in the event of a spill		Preliminary risk assessment conducted to determine likelihood of spilling of dangerous goods	1:47 year possibility of a dangerous goods truck crashing on a stretch of the proposed project adjacent to a wetland environment. Management measures to reduce the risk of harm to the environment in the event of a spill are discussed in Section 6.4.4.4
Wetlands and Associated Hydrogeology				
1	Procure City of Cockburn surface model and SILO rainfall data for inputs into MIKE SHE model		Obtained both City of Cockburn ground surface model and SILO rainfall data as main inputs to MIKE SHE Model	Surface and groundwater model (MIKE SHE) reflects existing ground surface and true rainfall records for 100 years
2	An assessment of potential cumulative effects of the proposed project, in combination with past projects (i.e. Farrington and Hope Roads), on surface water flows		A comparison of changes in surface water flows was undertaken	The construction of new road infrastructure within the wetland area appears to have had little overall effect on surface water movement. Findings are presented in Section 5.6
3	Collect baseline water quality data for nutrients, metals and elements pesticides, herbicides, hydrocarbons, organics and biological components	Various outfalls	Stormwater was collected at 13 outfalls on 7 occasions between April and August	The quality of the stormwater was variable and contained contaminants above naturally occurring concentrations. Details are provided in Section 5.7 and Appendix I
		Wetlands	Surface water samples were collected from 6 sites on 3 occasions in spring, summer and winter	The quality of the surface water was variable and contained contaminants above naturally occurring concentrations. Details are provided in Section 5.7 and Appendix I
		Sediments	Sediment samples were collected from 12 sites on 2 occasions	The sediment samples contained contaminants above naturally occurring concentrations. Details are provided in Section 5.7 and Appendix I

No	Investigation		Status	Key Outcome(s)
		Groundwater bores	Groundwater samples were collected from 17 sites on 5 occasions	The quality of the groundwater samples was variable and contained contaminants above naturally occurring concentrations. Details are provided in Section 5.7 and Appendix I
4	Conduct investigatory drilling and testing to determine groundwater contour levels as well as to assist the design of temporary and/or permanent groundwater control system(s)		Over 40 additional bores were installed to determine groundwater contour levels.	Groundwater contours are provided in Section 5.6 and Appendix D
5	Assess adverse effects on wetlands from potential dewatering operations		A commitment has been made to disallow dewatering activities during construction	Dewatering will not occur in wetland areas.
6	Install monitoring wells between proposed alignment and nearest wetland		Bores were installed between the proposed alignment and nearest wetland except where it would disrupt indigenous heritage sites	These bores were used in the water quality study and the stratigraphy/GDE study. Results are provided in Sections 5.2, 5.6 and 5.7 and Appendices D & I
7	Existing groundwater monitoring network is unlikely to allow adequate characterisation; thus additional bores may be necessary.		Over 40 additional bores were installed to aid characterisation.	These bores were used in the water quality study and the stratigraphy/GDE study. Results are provided in Sections 5.2, 5.6 and 5.7and Appendices D & I
8	Literature review	Wetland ecological processes	Completed	Outcome of investigations presented in Sections 5.2 and 5.6
		Local and intrabasin hydrological processes	Completed	Outcome of investigations presented in Sections 5.2 and 5.6
		Dependency of wetlands on the surrounding environment	Completed	Outcome of investigations presented in Sections 5.2 and 5.6

No	Investigation		Status	Key Outcome(s)
		Link between wetland functions/characteristics and the surrounds	Completed	Outcome of investigations presented in Sections 5.2 and 5.6
9	Studies to address information gaps.	Geologic and stratigraphy that in turn affects groundwater flow	Completed	Outcome of investigations presented in Sections 5.2 and 5.6 and reported in Appendix D
		Intrabasinal investigations	Completed	Outcome of investigations presented in Sections 5.2 and 5.6 and reported in Appendix D
		Ecological values of Roe Swamp and North and Bibra lakes (i.e. geomorphic shape, hydrological and hydrochemical functions, and stratigraphy)	Completed	Outcome of investigations presented in Sections 5.2 and 5.6 and reported in Appendix D
		Map groundwater dependent species/ecosystems, and delineate water dependencies (i.e. groundwater, surface water and vadose)	Completed	Outcome of investigations presented in Sections 5.2 and 5.6 and reported in Appendix D
10	Establish appropriate environmental water requirements		Completed	Outcome of investigations presented in Sections 5.2 and 5.6 and reported in Appendix D
11	Determine fundamental mechanisms and processes in and around the wetland systems		Completed	Outcome of investigations presented in Sections 5.2 and 5.6 and reported in Appendix D & I
12	Limited groundwater chemistry sampling		Extensive groundwater chemistry sampling has been undertaken	The quality of the groundwater samples were variable and contained contaminants above naturally occurring concentrations. Details are provided in Section 5.7and Appendix D & I
13	GDE Studies	Plant water dependency classifications	Completed	Addressed in Section 5.8 and reported in Appendix D

No	Investigation		Status	Key Outcome(s)
		Rooting depth of the vegetation, if known	Completed	Addressed in Section 5.8 and reported in Appendix D
		Vegetation and species mapping	Completed	Addressed in Section 5.8 and reported in Appendix D & K
		Soil moisture retention characteristics	Completed	Results presented in Section 5.8 and Appendix D
		Hydrological and stratigraphic data	Completed	Addressed in Section 5.8 and Appendix D
14	Surface water levels and flow velocities		Completed	Addressed in Section 5.6 and reported in Appendix H. Flow velocities not readily available from modelling output but inferences to be made
15	Surface water flow rates (e.g. from one side of a drainage path to the other)		Completed	Addressed in Section 5.6 and Appendix H
16	Groundwater elevations and depth below ground level		Completed	Addressed in Section 5.6 and reported in Appendix D
17	Vegetation water use		Completed	Used as calibration parameter for predictive modelling (Appendix G). Addressed in Section 5.8
18	Percent soil moisture contents		Used as calibration parameter for predictive modelling	Used as calibration parameter for predictive modelling. Results presented Appendix D
19	Monitoring for model calibration	Install and monitor surface water flow gauge and rain gauge at discharge locations	Low surface water flows considered unnecessary for modelling calibration	SILO, DoW and additional sourced data deemed sufficient for modelling requirements. Addressed in Section 5.6
		Collect groundwater and surface water levels data.	Completed.	Addressed in Section 5.6. Additional data is available from DoW monitoring stations within the project area
20	Treatment train analysis using MUSIC model		Completed	Results presented in Appendix H and discussed in Section 6.4

No	Investigation	Status	Key Outcome(s)
Flora and Vegetation			
1	Desktop studies	Completed	Study results are illustrated in Table 5.8-1
2	Reconnaissance field survey	Completed	Defined scope for detailed spring flora survey
3	Detailed spring flora survey	Completed	The following were recorded within the project area: • 7 Priority flora, 6 of which are locally native • 15 other flora of interest • 129 introduced or non–endemic species (3 are Declared Plants) • 40 vegetation communities. None of the vegetation communities are equivalent to State TECs, State PECs or Commonwealth TECs 18 communities are locally significant due to supporting populations of Priority flora, regionally significant species and significant flora of the Perth Metropolitan Region 16 vegetation communities are considered locally significant due to being associated with ESAs 10 communities are considered significant due to limited representation Significant species under the *EPBC Act* were not recorded Approximately 55 percent of the project area is mapped as 'Degraded' condition or worse, with approximately 27 percent of the project area mapped as between 'Good' and 'Very Good' condition
4	Assessment of permanent quadrats representative of recorded vegetation communities during summer, autumn and winter	Completed	No unexpected results or significant flora were recorded Vegetation types of the project area demonstrate attributes typical of vegetation of the south–west region, with most species growing, proliferating and flowering during spring and early summer months

No	Investigation	Status	Key Outcome(s)
5	Identification of total number of hectares (including mapping) of each listed threatened flora species habitat to be cleared and retained under preferred option	Completed	Priority flora habitat has been determined. Targeted surveys for relevant Priority flora were carried out during spring 2010
6	Detailed DRF surveys	Completed	No DRF species were identified during the 2009 or 2010 targeted surveys
7	Collection of data during surveys that supports related fauna assessments	Completed	Spatial mapping of significant populations of *Lomandra hermaphrodita* and a density survey throughout the project area has been completed Detailed gridding where Graceful Sun–moth was recorded and several selected areas determined that *L. hermaphrodita* is widespread in some vegetation throughout the project area No *Lomandra maritima* was recorded within project area
8	Baseline assessment for the occurrence of *Phytophthora* Dieback	Completed	No infestations of *P. cinnamomi* were identified within interpretable areas of the project area. Soil type and levels of disturbance within sections of the project area provide a possibility for the pathogen to be present and remain undetected
9	GDE and vegetation survey data will be used to assist with identifying land packages suitable for offsetting impacts which cannot be mitigated through other mitigation considerations	Completed	Studies and results presented in Appendix D and K and discussed in Section 5.8
Fauna			
1	Desktop review	Completed	Review identified 258 potential vertebrate fauna species and several conservation significant invertebrates
2	Identify size of area of fauna habitat to be cleared and retained	Completed	See Section 6.7
3	Attempt to define a threshold noise level for significant affects on fauna behaviour	Complete	Results of study reported in Appendix T

No	Investigation		Status	Key Outcome(s)
4	Information/mapping which identifies black cockatoo habitat to be cleared and retained		Completed	Project area contains 177ha of black cockatoo foraging habitat and 605 potential breeding trees, of which 71 contain nest hollows suitable for black cockatoos. Results provided in Appendix M and discussed in Section 6.7
5	Field surveys over two seasons	Trapping for mammals, reptiles and amphibians	Completed	6 native amphibians, 3 native mammals (excluding bats), 21 native reptiles and 5 introduced mammals recorded. Details provided in Appendix M and discussed in Section 5.9 and 6.7
		Avifauna survey	Completed	Systematic fauna survey recorded 88 birds, reported in Appendix M and discussed in Section 5.9
		Bat ID	Completed	5 bat species recorded, reported in Appendix M and discussed in Section 5.9
		Nocturnal *sp* ID	Completed	Results provided in Appendix M and discussed in Section 5.9
		Opportunistic surveys and sightings	Completed	Results provided in Appendix M and discussed in Section 5.9
		ID and collection of secondary evidence	Completed	Results provided in Appendix M and discussed in Section 5.9
6	Targeted surveys	Southern Brown Bandicoot	Completed	Records throughout the project area. Results provided in Appendix N and discussed in Section 5.9
		Water Rat	Completed	Not recorded in project area. Unlikely to occur
		Perth Lined Lerista	Completed	Recorded in project area. Results provided in Appendix M and discussed in Section 5.9
		Carnaby's Black Cockatoo	Completed	Recorded in project area. Substantive foraging habitat occurs in project area. No known roost sites or evidence of breeding. Details provided in Appendix M and discussed in Section 5.9
		Baudin's Black Cockatoo	Completed	None recorded. Highly unlikely to occur in project area

No	Investigation		Status	Key Outcome(s)
		Forest Red–tailed Black Cockatoo	Completed	Recorded in project area. Substantive foraging habitat occurs in project area. No known roost sites or evidence of breeding. Details provided in Appendix M and discussed in Section 5.9
		Native fish	Completed	None recorded
		Long–necked Turtle	Completed	23 confirmed individuals recorded (captured) at Bibra Lake. Details provided in Appendix R and discussed in Section 5.9
		Graceful Sun–moth	Targeted surveys (2010 and 2011) completed	One population (6 individuals) recorded in north–western quadrant of the Stock Road and Forrest Road intersection. Additional records made in the north–eastern quadrant. Results provided in Appendix P and discussed in Section 5.9
7	Targeted migratory shorebird surveys		Surveys conducted at 13 Beeliar Wetlands	82 migratory and wetland birds identified as likely to be present in the study area. Reported in Appendix O and discussed in Section 5.9
8	Short–range endemic and targeted invertebrate surveys		Completed	No conservation significant species recorded to date except for the Graceful Sun–moth (see above). Results presented in Appendix P and discussed in Section 5.9
9	Aquatic macroinvertebrate assemblage surveys		Completed for 5 wetlands adjacent to the project area	Diverse assemblages recorded across different wetlands. Indicator species suggest the wetlands are eutrophic. Results presented in Appendix Q and discussed in Section 5.9
Ecological Linkages				
1	Detailed literature review		Completed	Four regional ecological linkages (EL1 through EL4) traverse the project area. Outcome of literature review is presented in Section 5.10
2	Further definition of known and unknown ecological linkages		Completed	Two local linkages defined within project area. Details provided in Section 5.10 and 6.8
3	Monitoring of movement and definition of vertebrate demographics (i.e. Southern Brown Bandicoot)		Completed	Long distance movements by Southern Brown Bandicoot recorded in the project area suggest that males in the study area are capable of travelling long distances and that, in certain circumstances, their movements are not inhibited by existing man–made barriers (e.g. major roads). Details provided in Appendix N

No	Investigation	Status	Key Outcome(s)
4	Consideration of the particular factors relevant to different species	Completed	Ecological effects of fragmentation are species–specific and depend on the size of the functional linkage; movement (range and method) of an animal species and, for flowering plants, their pollinators; as well as refuge requirements. Details of investigations are presented in Section 5.10 and 6.8
5	Study of the groundwater and/or surface water connections between water bodies	Completed	Groundwater contours indicate that the wetlands play a role in the flows of groundwater with water flows to and from wetland basins directed by wetland sediment. Groundwater contours and additional outcomes of investigations are presented in Section 5.2 and 5.6and are reported in Appendix D and G
Noise			
1	Monitoring of existing noise along major transport routes in the vicinity of the project area. Results of noise monitoring will be used to prepare a computer noise model of existing traffic in the area.	Completed	Noise measurements taken at ten sites within the study area. Results of monitoring presented in Section 5.11 used in modelling
2	Concept design impact assessment based on modelling of potential noise emissions to assess the magnitude of noise impacts across the project area.	Completed	Future scenarios with and without the proposed project modelled, in accordance with SPP 5.4, Outcomes are provided in Section 6.10
3	Design and assessment of noise mitigation options along the project area to achieve compliance with applicable noise criteria	Completed	In accordance with SPP 5.4, noise walls have been designed to meet the noise mitigation target and limit criteria at noise sensitive receivers adjacent to the proposed project
4	Assess noise impacts on recreational values using the outputs of noise model	Completed	In the absence of noise criteria for recreation areas within the SPP 5.4 noise policy, noise impacts at recreation areas are assessed against daytime outdoor noise objectives for noise sensitive receivers in Section 6.10
5	Consideration of potential impacts of noise on fauna using noise predictions	Completed	Section 6.7and Appendix T present an assessment of the effects of traffic noise on fauna
6	Qualitative assessment of potential construction noise and vibration impacts along the project area and recommendation of further studies for the detail design phase	Completed	Further to qualitative assessment, mitigation and management for potential noise and vibration generating activities are presented in Section 6.10. A detailed, quantitative assessment of construction noise and vibration impacts will be undertaken at the detail design phase

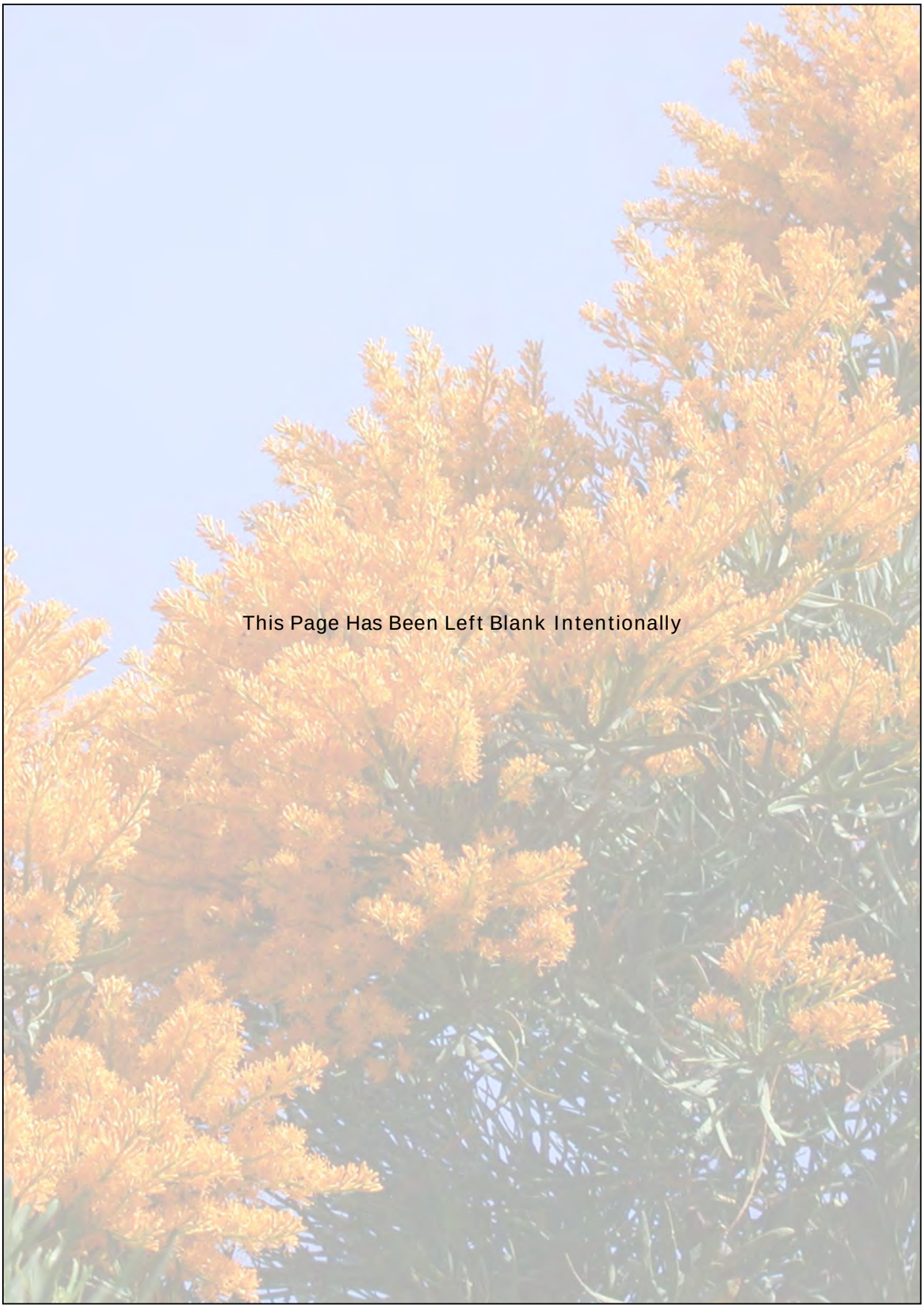
No	Investigation	Status	Key Outcome(s)
Air Quality			
1	Estimation of criteria pollutant emissions	Completed	The predicted ground level concentrations of CO, NO_2, PM_{10}, and five air toxics are within relevant NEPM ambient air criteria. In addition, the 24 hour average NEPM criterion of 25µg/m^3 is met for $PM_{2.5}$. Conversely, the maximum predicted ground level concentration of $PM_{2.5}$ during both operating years is higher than the annual NEPM criteria (8µg/m^3), however, the measured background $PM_{2.5}$ level is already above the NEPM goal Predicted criteria pollutant emissions are presented in Table 6.13-1 and discussed in Section 6.13
2	Development of an air dispersion model	Completed	Air dispersion modelling was used to predict ground–level concentrations of CO, NO_2, particulate matter (i.e. $PM_{2.5}$ and PM_{10}) and the five air toxics based on traffic forecasts. Results presented in Section 6.13
3	Comparison of model results with relevant criteria to predict potential impacts	Completed	Predicted ground level concentrations of CO, NO_2, PM_{10}, $PM_{2.5}$ and five air toxics are presented in Table 6.13-1 and discussed in Section 6.13
4	Investigation of mitigation and management strategies to minimise impacts to air quality	Completed	Proposed mitigation measures are provided in Section 6.13
5	Modelling of criteria pollutants including PM_{10} $PM_{2.5}$, NO_X, CO and six air toxics (1, 3 butadiene, benzene, toluene, xylenes, formaldehyde and benzo(a)pyrene))	Completed	Predicted ground level concentrations of CO, NO_2, PM_{10}, $PM_{2.5}$ and five air toxics are presented in Table 6.13-1 and discussed in Section 6.13
6	Air modelling to determine likely impact of proposed project on air quality	Completed	Modelling results presented in Section 6.13 and Appendix V
Greenhouse Gases/Climate Change			
1	Baseline risk assessment of the vulnerability of the region to climate change	Completed	Results of outcomes presented in Section 6.14 and Appendix W

No	Investigation	Status	Key Outcome(s)
2	Estimation of carbon emissions from construction based on final design (carbon footprint)	Completed	Results of outcomes presented in Section 6.14 and Appendix W
3	Estimation of carbon emissions during operation compared with a no–build scenario	Completed	Based on projected traffic movements throughout the Main Roads network, the construction of the proposed project will result in total savings of 62.4 kt of CO_2-eq annually by 2031 as compared to the no build scenario
4	Estimation of the carbon content of native vegetation to be cleared	Completed	The calculated total emissions predicted from this source were calculated as 3,479t CO_2-eq (carbon dioxide equivalent units), ±50%
5	Estimation of observed impacts of climate change on Beeliar Wetlands	Completed	Outcomes presented in Appendix W
6	Review of historical climate changes on wetlands within the project area based on previous studies, local history recollections and other available literature	Completed	Results of historical climate observations and observed changes provided in Appendices D and W
7	Baseline modelling of surface and groundwater; as well as projected surface water flows during extreme weather events	Completed	Results of surface and groundwater modelling and projected surface water flows in extreme events presented in Section 5.6, Appendix G and Appendix W
8	Investigations of higher risk of dieback, weed invasion and fire due to increased traffic and climate change on the surrounding Bush Forever areas	Completed	Climate change and dieback, weeds and fire are discussed in Appendix W
9	Investigations of the potential die off of dieback from the expected higher summer temperatures and associated benefits	Completed	Discussion presented in Appendix W
10	Assessment of cumulative effects of climate change with respect to other project factors	Completed	Risk Assessment and Vulnerability study detailed in Appendix W

No	Investigation	Status	Key Outcome(s)
Visual Amenity			
1	Identification of a project area which will contain the likely significant impacts of the proposed project on the visual resource (Zone of Theoretical Visibility), to provide location of representative viewpoints	Completed	Visual Impacts Assessment used a number of Zones of Theoretical Visibility to describe and determine impacts on visual amenity. Details provided in Appendix X
2	Field survey to inform visual baseline	Completed	Field survey results presented in Appendix X
3	Strategic character assessment of the proposed road corridor to inform the visual baseline	Completed	Landscape character was separated into six landscape character units. These are described in Section 5.14 and Appendix X
4	Identification of mitigation or management measures to reduce the potential effects of light spill on nearby residential communities and fauna	Completed	Mitigation measures to reduce potential effects of light spill are presented in Section 6.12
5	Analysis of sensitivity of each representative viewpoint and assessment of the likely scale of change in the view resulting from the proposed project	Completed	Analysis of sensitivity presented in Appendix X
6	Preparation of visualisations to illustrate likely impacts of the proposed project on stakeholders	Completed	Visualisations illustrating likely visual impacts provided in Appendix
Traffic and Local Connectivity			
1	Review of relevant studies and policies to identify outstanding issues	Completed	Review of relevant studies presented in Section 2
2	Consultation with Main Roads to determine Intelligent Transport System (ITS) requirements	Completed	ITS requirements have been included in the road design
3	Attainment of traffic forecasts for the preferred option and assessment of the results for anomalies	Completed	Results of analysis of traffic forecasts are provided in Section 2.2. Detailed traffic data used to develop preferred option

No	Investigation	Status	Key Outcome(s)
4	Review of existing connection of roads, pedestrian and cycle paths, and public transport	Completed	Outcomes of existing connectivity review presented in Section 5.15
5	Assessment of the possible effects of the proposed project on local connectivity	Completed	Potential impacts on local community connectivity assessed in Section 6.11. Improved standard of local paths and roads anticipated
6	Investigation of pedestrian, cyclist and public transport requirements	Completed	Investigation into pedestrian, cyclist and public transport requirements is presented in Section 5.15. Results of community engagement concerns are presented in Appendix X and Section 3
7	Identification of significant transport impacts and suggestion of mitigation measures	Completed	Assessment of significant transport impacts presented in Section 6.11. Mitigation suggested for all predicted impacts
Aboriginal Heritage			
1	Detailed desktop investigation	Completed	Outcome of investigations presented in Section 5.16
2	Holding of information workshops and focus group meetings with Nyungar groups and individuals identified through the South West Aboriginal Land and Sea Council and the Department of Indigenous Affairs	Completed	Results of consultation between Aboriginal groups and the proponent have been documented in a separate and concurrent process in accordance with the *AH Act*
3	Environmental investigations will, where appropriate, provide consideration for the Aboriginal heritage values associated with environmental factors and determine how these impacts may affect Aboriginal heritage	Completed	Aboriginal heritage values associated with environmental factors include: • Nyungar Water Values • Nyungar Fauna Values • Nyungar Botanical Values • Nyungar Mythological Values Outcomes of all assessed impacts are presented in Section 6.9

No	Investigation	Status	Key Outcome(s)
4	The assessment will demonstrate that concerns raised by Aboriginal stakeholders, who have participated in the investigations, have been adequately considered and management has been proposed to minimise those impacts	Completed	Management and mitigation of concerns raised by Aboriginal stakeholders, outside of those documented in separate and concurrent processes in accordance with the *AH Act*, are presented in Section 6.9
5	Aboriginal heritage investigations will be used to develop an understanding of the link between environmental values of the project area and their association with Aboriginal heritage and culture	Completed	The relationship that exists between flora, fauna and wetlands of the project area and relative environmental values held by Nyungar people are presented in Section 5.16 and Section 6.9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6. Predicted Impacts, Management and Mitigation

Construction and operational aspects of the proposed project will result in impacts on the biological and physical environment of the project area. Section 6 presents an assessment of the potential and predicted impacts on environmental factors that are associated with various aspects of the proposed project.

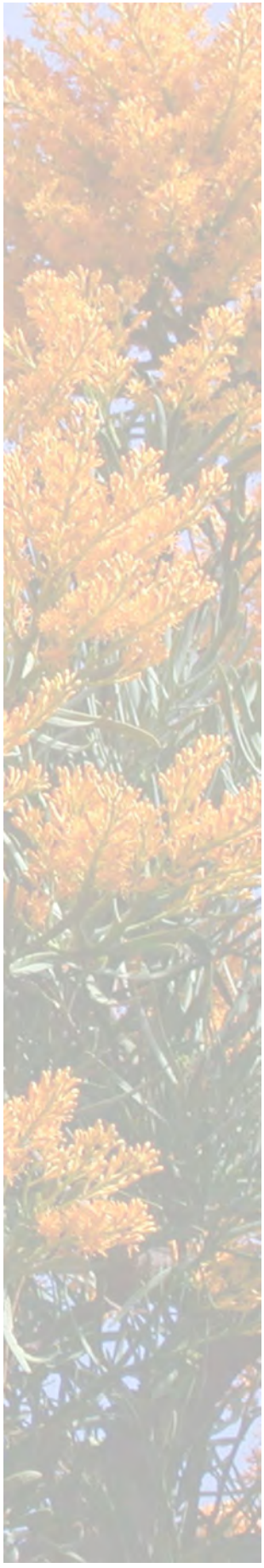
6.1. Structure of Impact Assessment

Section 6 is divided into a series of chapters that discuss the potential and predicted impacts on key environmental values within the project area. This chapter (Section 6.1) outlines the structure of the impact assessment and describes the key concerns of the Environmental Protection Authority (EPA), as they were identified in Bulletin 1088 (EPA 2003). Section 6.1.2 describes the key project activities, during the construction and operational phases of the project.

Subsequent chapters present the impact assessments for each relevant environmental factor and identify appropriate management strategies to mitigate those impacts. Each of the key factors is considered in the order that they are identified in Bulletin 1088. Other factors identified in the Environmental Scoping Document (SMC 2010) and described in Section 5 are then discussed in subsequent chapters. In recognition of the interrelationship between wetlands, geochemistry and water movement, the wetlands section is followed by sections specifically relevant to these factors. The order is as follows:

- Wetlands (Section 6.2);
- Surface and Groundwater Movement (Section 6.3);
- Water Quality (Section 6.4);
- Acid Sulfate Soils (ASS) and Existing Ground Contamination (Section 0);
- Flora and Vegetation (Section 6.6);
- Fauna (Section 6.7);
- Ecological Linkages (Section 6.8);
- Aboriginal Heritage (Section 6.9);
- Noise (Section 6.10);
- Recreation and Education (Section 6.11);
- Visual Amenity (Section 6.12);
- Air Quality (Section 6.13); and
- Greenhouse Gas Emissions (Section 6.14).

Each chapter proceeds with a summary of the EPA's description of the factor as it was presented in Bulletin 1088. Where relevant, the EPA's stated objective is included. Where there is no stated EPA objective, relevant policy or guidance is noted. It is against this objective that the subsequent impact assessment is evaluated.



The potential impacts that may occur as a result of the proposed project are then discussed. Potential impacts were identified for each aspect through a review of relevant literature, the community engagement programme and during discussions with stakeholders. They recognise the various impacts that *may* occur as a result of construction and operational activities. In many cases, the proposed project has been designed to avoid or minimise an impact or the risk of a potential impact occurring. Where potential impacts have been overcome during design development, a brief description of the design feature(s) applied to avoid or minimise them is provided.

This is then followed with a detailed account of the predicted and, where possible, quantified impacts arising from each key project aspect.

For each factor, management measures aimed at minimising the predicted impacts are presented, along with an assessment of the residual impacts remaining after management and mitigation have been employed, where applicable. Also considered, where relevant, are impacts that occur as a result of the management or mitigation of an unrelated impact. Environmental management measures have been applied in accordance with the following hierarchy of control:

- Avoid the impact;
- Minimise the severity of the impact;
- Rectify by repairing the impacted site as soon as possible;
- Reduce the impact over time; and
- Offset significant residual impacts.

Finally, each section concludes with a discussion that considers whether the EPA objectives have been met, highlighting the residual impacts for which approval is being sought. A table summarises the predicted impacts, appropriate management and mitigation strategies, and quantifies the residual impacts.

Offset requirements for the mitigation of residual impacts are described in Section 10.

6.1.1. Summary of EPA Concerns (Bulletin 1088)

In 2003, the EPA issued Bulletin 1088 under Section 16 of the *Environmental Protection Act 1986* providing environmental advice on the key environmental values associated with the alignment of Roe Highway Stage 8 and likely impacts arising if construction was undertaken (EPA 2003). The advice was issued in response to a request by the then Minister for Planning and Infrastructure to the Minister for the Environment and Heritage to seek EPA's confirmation of the environmental values that would be impacted by Stage 8 if it were to be constructed. The Bulletin identifies the key environmental values associated with the Roe 8 alignment and the likely impacts if it were constructed.

It should be noted that, as there was no actual design provided for assessment, the Bulletin considered impacts on the basis of the size of the entire road reserve, and did not take into account the reduction in project footprint that may occur as a result of design modifications or impact avoidance.

The key environmental values identified by EPA in Bulletin 1088 are:

- Wetlands;
- Vegetation and Flora
- Fauna;
- Ecological Linkages;
- Aboriginal Heritage;
- Residential Amenity; and
- Recreation and Education.

The sections below present a summarised account of the values and concerns identified in Bulletin 1088. The report is available in full via the EPA web site.

6.1.1.1. Wetlands

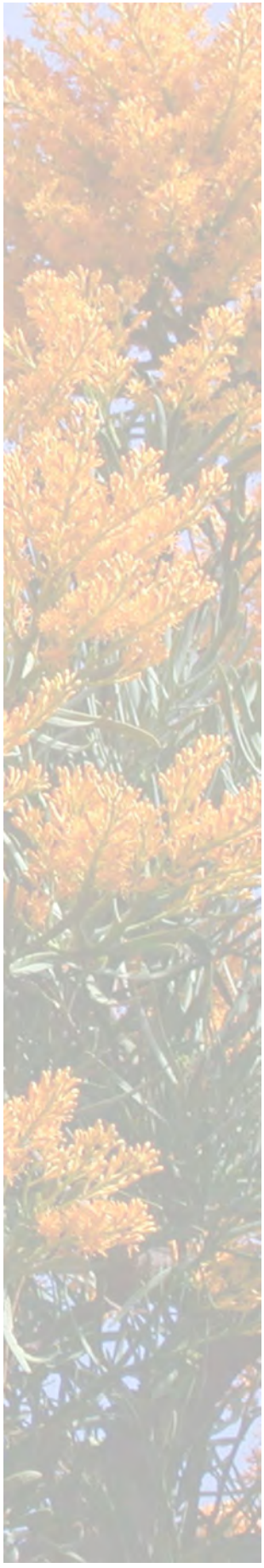
Bulletin 1088 (EPA 2003) highlights that the alignment traverses part of the Eastern Chain of the Beeliar Wetlands. It notes that several of the wetlands within or adjacent to the alignment are classified as Conservation Category Wetlands or protected under the *Environmental Protection (Swan Coastal Plain) Lakes Policy 1992*, or both, and support an array of wetland vegetation communities. It also notes that the conservation values associated with North Lake, Bibra Lake and surrounding wetlands has long been recognised with its inclusion in System Six area M93 and subsequently, Bush Forever Site 244. The EPA reports that with 80% of Swan Coastal Plain wetlands having been lost, the remaining wetlands are expected to be managed in accordance with the principles of ecologically sustainable development.

The report notes that construction within the alignment for Roe Highway Stage 8:

- Would result in the filling and clearing of parts of wetlands that are identified as both Conservation Category Wetland and also subject to an Environmental Protection Policy. Such wetlands are considered to be of high conservation and environmental significance;
- Was assessed to directly impact a portion of Horse Paddock Swamp, a portion of Bibra Lake and a sizeable portion of Roe Swamp; and
- Would create severance in the wetland linkages between Bibra Lake and North Lake; between Roe Swamp and North Lake, as well as the rest of the wetland complex located further to the north. This would result in significant indirect impacts on the values and functions of the various wetlands within the area and on the unity of the Eastern Chain of the Beeliar Wetlands.

6.1.1.2. Vegetation and Flora

The report notes that the alignment for Roe 8 would result in the clearing of vegetation within Bush Forever site 244, as well as vegetation to the east and west of this. On a broad scale, the EPA notes that the alignment encompasses 15 to 20ha of Bassendean Complex – Central and South; 60 to 70ha of Karrakatta Complex – Central and South and Herdsman Complex, with construction likely to affect these vegetation complexes.



At a more detailed level, EPA reports that the area contains a diverse array of varied and complex vegetation units, in reasonable ecological condition overall. The Bulletin further notes:

- The vegetation within the alignment is not well represented within the Eastern Chain of the Beeliar Wetlands and is therefore considered to be regionally significant in relation to its structural complexity, floristic assemblages, gradations from wetland to upland as well as the ecological pattern it represents;
- The dense wetland vegetation associated with Roe Swamp potentially plays a role in moderating the chemistry of groundwater inputs from the east, making protection of the vegetation a high priority;
- A significant amount of the vegetation within the Roe Swamp complex would be cleared, leading to significant impacts on the wetland's functions and values, fauna habitats and ecological linkages that it maintains with North Lake and the wetland complex located to the north; and
- The substantial size of the area increases the long term viability of the vegetation in the area, which would be reduced as a result of fragmentation.

6.1.1.3. Fauna

The Bulletin highlights a diverse array of fauna that exists within and adjacent to the alignment. Of particular note:

- Around 122 native bird species have been recorded, 24 of which were found to be uncommon;
- Bush Forever identifies that the area supports significant populations of the Australasian Shoveler, Hardhead, Blue–billed, Musk and Pink–eared Ducks, as well as several migratory bird species covered by the Japan–Australia Migratory Bird Agreement (JAMBA) / China–Australia Migratory Bird Agreement (CAMBA) agreements;
- The area is known to support the Quenda (Southern Brown Bandicoot), the brushtailed possum, a diverse group of reptiles, 1 species of tortoise, 8 species of frog and the Swan River Goby Fish;
- North Lake is the only urban wetland known to support fresh water sponges;
- The size of the area and variability of the fauna habitat within it contributes to the areas significance;
- The area maintains a high degree of ecological integrity despite some historical and current degradation, with the only barrier to terrestrial fauna movement being Hope Road; and
- The wetlands provide an important summer refuge when wetlands in more arid areas dry up, as well as providing an ideal environment for many species of bird to breed.

The Bulletin identifies the following impacts as a result of construction within the alignment for Stage 8:

- Loss of habitat and breeding areas;
- Severance in some strategic linkages between the area's wetlands and upland vegetation, impacting on fauna movement within the area; and
- Fragmentation of the various fauna habitats would potentially impact on their viability.

6.1.1.4. Ecological Linkages

EPA notes that the area containing North Lake, Bibra Lake and its surrounding wetlands are recognised in Bush Forever and the Beeliar Regional Park Management Plan (2001 – 2011) (Thompson and Palmer 2006) as being part of several greenways linkages.

The first linkage moves in a north–south direction along the Eastern Chain of the Beeliar Wetlands. Another comes from the south west, connecting the area to the western side of the Beeliar Regional Park, specifically Lake Coogee. A third linkage from North Lake to the west is also identified.

The report notes that the linkages are important in order to maintain the diversity and vigour of the Beeliar Regional Park's ecological systems. It recognises that major arterial roads and other infrastructure limit the linkages within the Beeliar Regional Park, and with other parks.

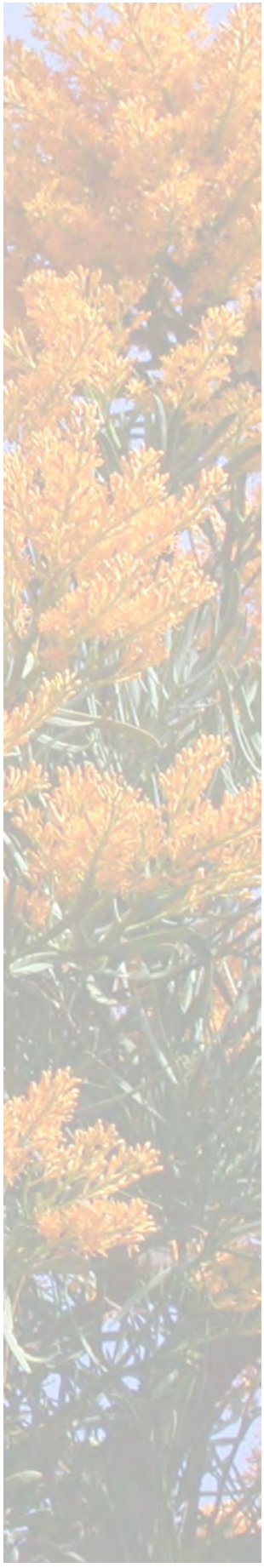
It notes that construction within the alignment will have a significant impact on:

- The direct linkages between North Lake and Bibra Lake and the surrounding wetlands in the immediate area;
- The linkages within the Eastern Chain of the Beeliar Wetlands and subsequently the eastern side of the Beeliar Regional Park; and
- The ecological linkages within the immediate area and the regional park as a whole, resulting in diminished diversity and ecological systems for the area and the Regional Park in the long term.

6.1.1.5. Aboriginal Heritage

The EPA notes that archaeological sites at North and Bibra lakes provide evidence of a major former trade route between the Swan and Murray River areas and that the area is recognised as a significantly important cultural site for the Beeliar people, and the most important historical site within the Perth metropolitan area south of the Swan River.

Archaeological evidence indicates that the perimeters of the lakes were camping areas with a diversity of activities being undertaken, supporting the site's ethnographic importance. The EPA reports that the lakes are known to hold importance as mythological and spiritual locations and that the alignment passes through the Bibra Lake mythological site and a known archaeological site.



The potential to disturb currently unknown archaeological sites is highlighted, along with the observation that there would be a severe impact on Aboriginal tourism trails between the two lakes if construction within the alignment occurs.

6.1.1.6. Residential Amenity

Bulletin 1088 notes the proximity of the alignment to residences and sensitive land uses on either side within the sections west of Progress Drive and east of Bibra Drive. It highlights the likely impact the changing noise environment will have on residences and sensitive land uses in the vicinity of the corridor, both as a result of construction of new road, as well as the replacement of the existing Forrest Road. The EPA also raises the issue of noise and vibration during construction.

6.1.1.7. Recreation and Education

The EPA makes note of the fact that the environs surrounding North Lake and Bibra Lake currently support a variety of recreational activities, including cycling, walking, exercising and picnicking as well as educational pursuits for school and university students. The Cockburn Wetlands Educational Centre is located close to the alignment, and is utilised by Bibra Lake Scouts, the Wetlands Conservation Society, Friends of Ken Hurst Park and the Wildlife Conservation Society. The Native Animal Rehabilitation Centre is also located within the Wetlands precinct. The EPA considers that construction within the alignment for Stage 8 of Roe Highway would detract significantly from the recreational and educational values of the area.

6.1.2. Project Activities

Aspects are defined as the activities related to a project that are likely to result in an impact. Aspects can occur during the construction phase and through the operational life of the development. The proposed project will cause impacts as a result of the aspects described in this section.

6.1.2.1. Construction Phase Activities

The construction phase of the proposed project will commence with the installation of fauna–proof fencing designed to minimise ingress of fauna to the works area and prevent work activities from straying outside of the construction area.

Following the establishment of fencing, the following series of activities will be undertaken:

- Installation of noise walls on property boundaries, where appropriate;
- Accommodation works at affected properties;
- Vegetation removal;
- Topsoil stripping;
- Creation of storage areas for topsoil and vegetation/mulch;
- Creation of storage areas for lime for acid sulfate soils (ASS) treatment (if required);
- Traffic diversions;
- Excavation of road cuttings;
- Transport of cut/fill;
- Services relocations (water, sewerage, gas, electricity and telecommunications)
- Construction of retaining walls;
- Placement of fill, compaction of embankment foundations and other earthworks;
- Transport of contaminated materials;
- Pile driving;
- Construction of structures – formation of foundations;
- Construction of structures – concrete pours;
- Pavement construction;
- Surfacing – asphalt laying;
- Filling of existing Murdoch Drain;
- Excavation of new Murdoch Drain alignment;
- Installation of noise walls adjacent to roadway;
- Removal and rehabilitation of existing redundant roads;
- Construction of power poles;
- Stringing of power lines;
- Construction of drainage networks and basins;
- Construction of bioretention basins;
- Hard and soft landscaping; and
- Installation of barriers, pavement markings, lighting and other roadside furniture.

6.1.2.2. Operational Phase Activities

The following aspects of the project have the potential to result in impacts throughout the life of the proposed project. The asset design life is 100 years for structures and 40 years for pavements; however, it is expected that it will remain in operation for substantially longer. The operational phase aspects include:

- Freight transport;
- Private vehicle transport;
- Physical presence of road;
- Street lighting;
- Maintenance of bioretention basin;
- Maintenance of landscaping;
- Road maintenance;
- Furniture maintenance (e.g. retaining walls, removal of graffiti, street lights, barriers);
- Fire break maintenance; and
- Power line maintenance.

6.2. Wetlands

The EPA objective with regard to wetlands is:

> *To maintain existing ecological functions and environmental values.*

The EPA places great importance on the protection of the remaining 20 percent of wetlands on the Swan Coastal Plain. Bulletin 1088 (EPA 2003) notes that the EPA expects that the remaining wetlands are:

> *Managed according to the principles of ecologically sustainable development regardless of land use or activity* (EPA 2003).

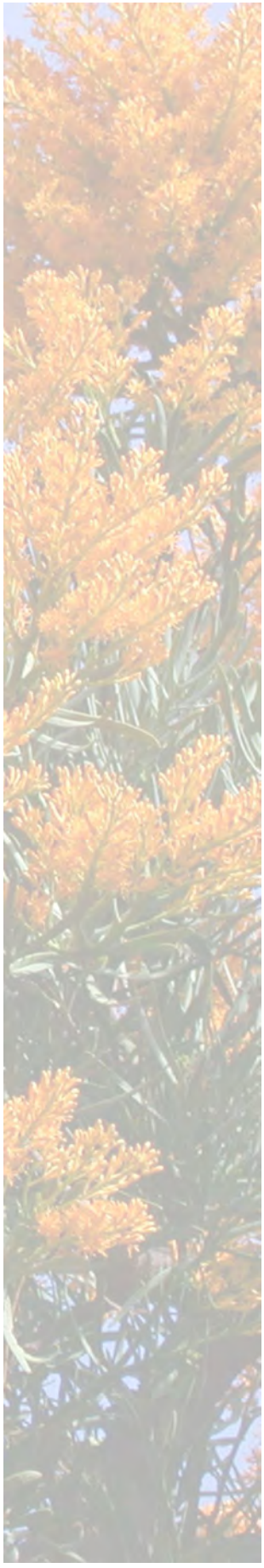
In Bulletin 1088, the EPA stated the following in relation to the construction of the proposed project:

- The construction of the alignment for the extension of Roe Highway would involve the clearing and filling of certain areas that are considered to be of high conservation and environmental significance (i.e. conservation category wetlands and areas protected by an Environmental Protection Policy). In particular, construction of the extension of Roe Highway would directly impact the southern portion of Horse Paddock Swamp, the northern section of Bibra Lake and a sizeable area of Roe Swamp.
- Construction of the Roe Highway extension in this area would indirectly impact other wetland areas located outside the alignment through severance of wetland linkages between North and Bibra lakes, between Roe Swamp and North Lake, and the rest of the wetland complex located further north. This severance would result in significant impacts on the values and functions of the wetlands adjacent to the highway extension, and on the unity of the eastern Beeliar Wetland chain.

Position Statement No. 9 *Environmental Offsets* (EPA 2006a) defines Environment Protection Policy (EPP) Wetlands and Conservation Category Wetlands (CCWs) as 'critical assets'. Critical assets must be protected and conserved in order for the:

- State to fulfil its statutory and policy requirements;
- State to remain sustainable in the longer term; and
- EPA to comply with its general principles for advice and decision making.

The EPA holds a presumption against recommending approval for proposals that are likely to have significant adverse impacts on 'critical assets', while acknowledging that in certain circumstances, such impacts may be approved by State Government Ministers where they relate to essential community services, including transport infrastructure (EPA 2006a).



Under these circumstances, the EPA's advice is that approval of a project of this nature should be made conditional on the:

- Consideration or demonstration (to the maximum extent possible) of on–site impact mitigation; and
- Development and implementation of an acceptable offsets package for significant, residual adverse impacts.

In a legislative and policy context, the mapped wetland areas of Roe Swamp and Horse Paddock Swamp (both CCWs) are also identified as Environmentally Sensitive Areas (ESA) pursuant to the *Environment Protection (Clearing of Native Vegetation) Regulations 2004*. By requirement, the ESA includes both the defined CCW and a 50m radius around the wetland (the buffer).

Wetland functionality is influenced by the environmental factors of geology, hydrology and hydrogeology; as well as flora, vegetation and fauna assemblages that depend upon the wetland ecosystems. The following section describes the impacts on the identified wetland attributes, functions and values contained within the project area.

6.2.1. Potential Impacts

A range of potential impacts on wetlands were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. Design solutions were developed for the following potential impacts:

- Drilled piles may result in the oxidation of ASS and generating consequent liberation of acid in the wetlands – piles for bridges will not be drilled; and
- Road maintenance could result in herbicide overspray – weed control will be undertaken by accredited contractors.

A detailed assessment of predicted wetland impacts is provided in Sections 6.2.2 and 6.2.3.

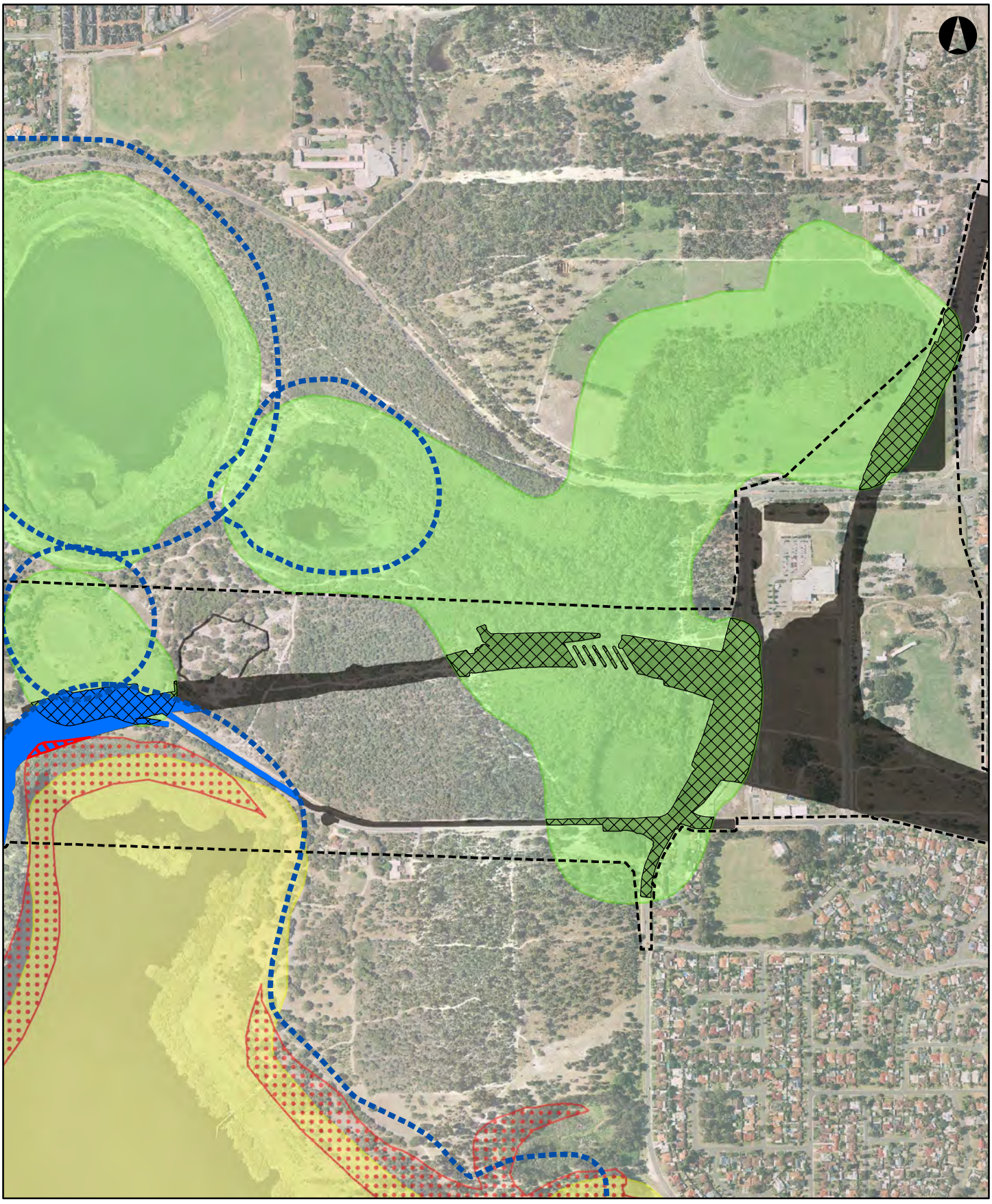
6.2.2. Construction Phase Impacts

The proposed project is predicted to have an impact during the construction phase on the following recognised wetlands within the project area:

- Bibra Lake – mapped within a Lakes EPP boundary;
- Horse Paddock Swamp – mapped within CCW and Lakes EPP boundaries; and
- Roe Swamp – mapped within a CCW boundary.

Whilst the proposed project intersects with the mapped wetland areas of Bibra Lake, Horse Paddock Swamp and Roe Swamp, the degree of intersection and the values associated with the areas intersected vary between the three wetlands (Figure 6.2-1).

The natural composition and wetland values of Lakes EPP and CCW areas intersected by the proposed project are discussed further in Section 6.2.3.



Proposed Project Footprint and Wetland Boundaries

South Metro Connect

Figure 6.2-1

0 100 200 300

Metres

1:10,000 (A4)

- Project Area
- Construction Footprint
- EPP Lakes with 50m buffer

Geomorphic Wetlands

- Conservation Category with 50m buffer
- Resource Enhancement with 50m buffer
- Multiple Use

Wetlands within Construction Footprint

- Conservation Category
- Multiple Use
- EPP Lakes

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The impacted area of mapped EPP wetland has limited ecological value as a functional wetland

The clearing of mature trees between the infrastructure and the lake shore will not be cleared

Horse Paddock Swamp is predominantly void of native vegetation

6.2.2.1. Bibra Lake

Bibra Lake is recognised under the *Environmental Protection (Swan Coastal Plains Lakes) Policy 1992*, and is classified as a Resource Enhancement Wetland (REW) with parts of its fringes mapped as Multiple Use Wetland (MUW) under the Geomorphic Wetlands of the Swan Coastal Plain dataset. The proposed project footprint intersects the mapped MUW and Lakes EPP boundaries; however, does not intersect the mapped Resource Enhancement boundary.

In the context of direct loss of mapped area and values, the intersection between the proposed project and Bibra Lake Lakes EPP wetland is limited. The area of mapped Lakes EPP wetland impacted by the proposed project (approximately 1.0ha) has limited ecological value as a functional wetland. The project footprint impacts on approximately 3.6ha of the 50m Lakes EPP wetland buffer. The intersection of the proposed project and the area with the EPP boundary is generally coincident with existing verges of Hope Road (or immediately adjacent to the south of Hope Road). Vegetation in the area has been assessed as being in 'Completely Degraded' condition (Figure 6.2-2; Appendix K). The proposed project is situated beyond the northern bank of Bibra Lake, approaching no closer than approximately 10m from the lake shoreline. Clearing of mature native trees between the infrastructure's edge and the lake shoreline will not occur.

6.2.2.2. Horse Paddock Swamp

Horse Paddock Swamp is mapped by the Geomorphic Wetlands of the Swan Coastal Plain Dataset with an assigned CCW management category. It is also classed as a Lakes EPP wetland. The proposed project does not intersect the Lakes EPP wetland boundary, but does intersect the geomorphic boundary.

In the context of direct loss of mapped area and values, the intersection between the proposed project and Horse Paddock Swamp is limited. The proposed project will impact 0.2ha of the CCW and 1.3ha of its buffer. The mapped wetland in this area has limited ecological value. Horse Paddock Swamp is predominantly devoid of native vegetation and currently supports vegetation that has been mapped as being 'Completely Degraded' as it is devoid of native understorey (Figure 6.2-2; Appendix K). Although the proposed infrastructure crosses the geomorphic boundary, no native trees will be cleared and there will be no removal of remnant vegetation. There is no anticipated loss or reduction in current wetland function by virtue of the:

- Small area of loss within the mapped boundaries; and
- Lack of intact habitat beneath or adjacent to that project footprint.

6.2.2.3. Roe Swamp

Roe Swamp is mapped as CCW by the Geomorphic Wetlands of the Swan Coastal Plain Dataset. It includes three named wetlands: Lower, Melaleuca and Roe Swamps. The values exhibited by Roe Swamp are commensurate with those of a CCW. The proposed project directly intersects 5.1ha (Figure 6.2-2) of mapped Roe Swamp CCW, of which 0.4ha is non–vegetated, existing road infrastructure. An additional 4.1ha of the Roe Swamp 50m buffer, including 0.8ha of existing road infrastructure, will also be impacted. The buffer within the proposed project footprint on the western side of Roe Swamp comprises vegetation in Good Condition. The buffer on the east side of Roe Swamp is largely non–vegetated, developed or degraded habitat. A temporary (0.5ha) impact on the Roe Swamp CCW will occur as a result of the relocation of Murdoch Drain. Table 6.2-1 quantifies the impacts of the proposed project in the context of the condition of vegetation within the project area.

The proposed project directly intersects with 5.1ha of mapped Roe Swamp CCW and 4.1ha of the Roe Swamp buffer

Table 6.2-1: Clearing Impacts by Vegetation Condition within Roe Swamp CCW Boundary

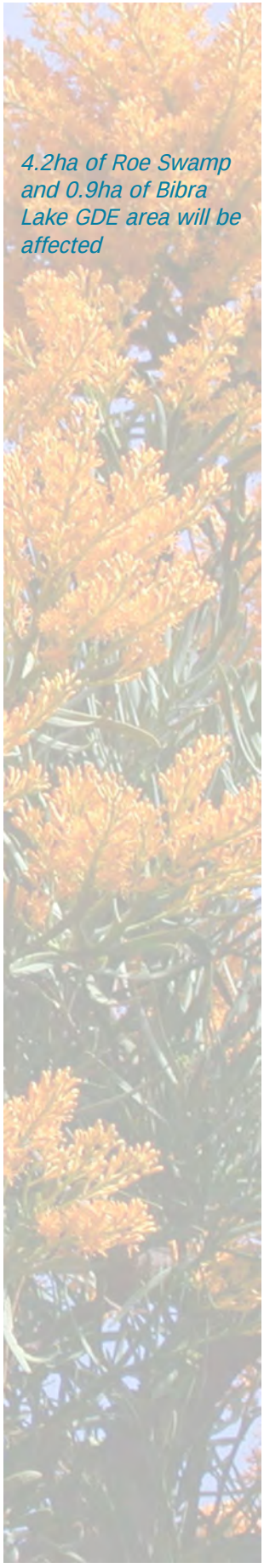
Condition Rating	Area CCW (ha)	Area CCW Buffer (ha)
Completely Degraded	0.3	2.5
Degraded to Completely Degraded	2.0	0.2
Degraded	0.2	0.6
Degraded to Good	0.7	-
Good	0.4	<0.1
Good to Very Good	0.9	-
Very Good	0.2	-
Total Area	4.7*	3.3**

* Excludes 0.4ha of existing road infrastructure

** Excludes 0.8ha of existing road infrastructure

The 'Very Good' condition vegetation, although small in area, is comprised entirely of community type ErCtS beneath the proposed eastern formation embankment. This community type consists of low woodland of *Eucalyptus rudis*, *Banksia attenuata* and *Melaleuca preissiana* over low open shrubland of *Taxandria linearifolia*, *Gastrolobium ebracteolatum* and *Pteridium esculentum* over closed sedgeland of *Cyathochaeta teretifolia* (P3) supporting Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*). The 'Good to Very Good' condition vegetation is comprised of two community types:

- ErMpAfS: Low open forest of *Eucalyptus rudis* and *Melaleuca preissiana* over a tall open shrubland of *Astartea fascicularis* and *Kunzea glabrescens* over an open shrubland of *Pteridium esculentum* over a sedgeland of *Lepidosperma* sp. on brown clayey–loam flats supporting Priority Flora (*Dampiera triloba* (P1), *Aotus cordifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*); and
- ErMpGeS: Low open forest of *Eucalyptus rudis* and *Melaleuca preissiana* with occasional *Banksia attenuata* over a tall shrubland of *Gastrolobium ebracteolatum* and *Kunzea glabrescens* over a low open shrubland of *Taxandria linearifolia* over a sedgeland of *Baumea preissii* subsp. Taxa supporting Priority Flora (*Cyathochaeta teretifolia* (P3), *Aotus cordifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*).



4.2ha of Roe Swamp and 0.9ha of Bibra Lake GDE area will be affected

6.2.2.4. Groundwater Dependent Ecosystem communities within and associated with wetlands

A total of 310ha of GDE sub–communities have been mapped within the GDE study area, which extended beyond the general project area. Approximately 13ha of those GDE sub–communities, of which 7ha (two percent) are intact native vegetation, are within the construction footprint. The direct effects of clearing of GDE communities are detailed in Section 6.6.

Surface cover at Horse Paddock Swamp consists mainly of weeds. There is limited GDE vegetation within this wetland. Within the other mapped wetland areas to be affected by the proposed project, GDE areas are as follows:

- Roe Swamp – 4.2ha*, (within CCW boundary); and
- Bibra Lake – 0.9ha (within EPP boundary).

* Excludes 0.5ha non–GDE vegetation

The occurrence of these mapped GDE areas does not necessarily indicate the presence of viable or valuable vegetation communities (i.e. with condition ratings other than 'Completely Degraded'). The potential impact of the proposed project on the GDEs, as a result of potential changes to the hydrological regime, is discussed in Section 6.6.

The 4.2ha extent of GDE vegetation within the Roe Swamp CCW boundary comprises wetland vegetation ranging from sedgelands to shrublands and woodlands. This area differs from the area reported in Section 6.2.2.3 as it excludes an area of 0.5ha of non–GDE vegetation. A small proportion of the vegetation has been determined to be in 'Very Good' condition. Other vegetation within the Roe Swamp CCW extent has been assessed to be in 'Good to Very Good' condition (Appendix K). Approximately 70 percent of it is degraded, ranging from 'Degraded to Completely Degraded' to 'Good'.

Small non–vegetated areas within the project area, not calculated above, are included in the total area of wetlands impacted. Table 6.2-2 presents a summary of total wetland areas (vegetated and non–vegetated) impacted by the proposed project. The summary illustrates each wetland category and buffer impacted, as well the element of the proposed project responsible.

Table 6.2-2: Summary of Impact on Wetland Areas by Category and Project Element

Section	Roe Highway Extension (ha)				Bibra Drive (ha)		MAC Access (ha)		Total (ha)			
Wetland	CCW	CCW Buffer	EPP	EPP Buffer	CCW	CCW Buffer	CCW	CCW Buffer	CCW	CCW Buffer	EPP	EPP Buffer
Roe Swamp	3.3**	0.3	-	-	2.1	2.0	-	-	5.4**	2.3	-	-
Horse Paddock Swamp	0.2	1.3	<0.1	0.2	-	-	-	-	0.2	1.3	-	0.2
Melaleuca Swamp	-	-	-	-	-	-	0.2	1.8	0.2	1.8	-	-
Bibra Lake	-	-	1.0	3.6*	-	-	-	-	-	-	1.0	3.6*
TOTAL									5.8**	5.4	1.0	3.8*

* Excludes 0.2ha area overlap with Horse Paddock Swamp

** Includes 0.5ha temporary clearing for Murdoch Drain relocation

- n/a

6.2.3. Operation Phase Impacts

Both the road reserve and the selected road alignment intersect directly with mapped wetland boundaries and associated upland and wetland vegetation communities. The direct and indirect impacts on the ecological value of, and linkages between, Bibra Lake, North Lake, Roe Swamp and Horse Paddock Swamp resulting from the construction of the road were recognised by the EPA in Bulletin 1088. These impacts have been considered in the design of the road and, where practical, mitigation options have been developed.

Once constructed and the infrastructure becomes operational, the potential long-term impacts on local wetlands are:

- Fragmentation that over time results in alteration in wetland function: severance by infrastructure that may result in altered interactions between hydrology, hydrochemistry (including wetting cycles and nutrient cycling) and its biological components;
- Reduction in human related wetland values of amenity and aesthetics;
- Indirect loss of vegetation abundance, species diversity and/or vegetation condition; and
- Indirect loss of habitat and habitat function for fauna assemblages.

For further analysis and assessment of human related values in relation to amenity and aesthetics refer to Section 6.12.

With reference to the wetland values described in Section 5.2, the proposed project has the potential to cause loss of values and/or function by virtue of fragmentation and severance. Within the wetlands, this has been further examined in two parts: the Bibra Lake – Horse Paddock Swamp section and the Roe Swamp section.

6.2.3.1. Indirect Impacts from Fragmentation

This section considers the impacts on wetland values that will arise as a result of fragmentation of wetland boundaries. A more detailed discussion of ecological linkages and the impacts of wetland fragmentation is provided in Section 6.8.

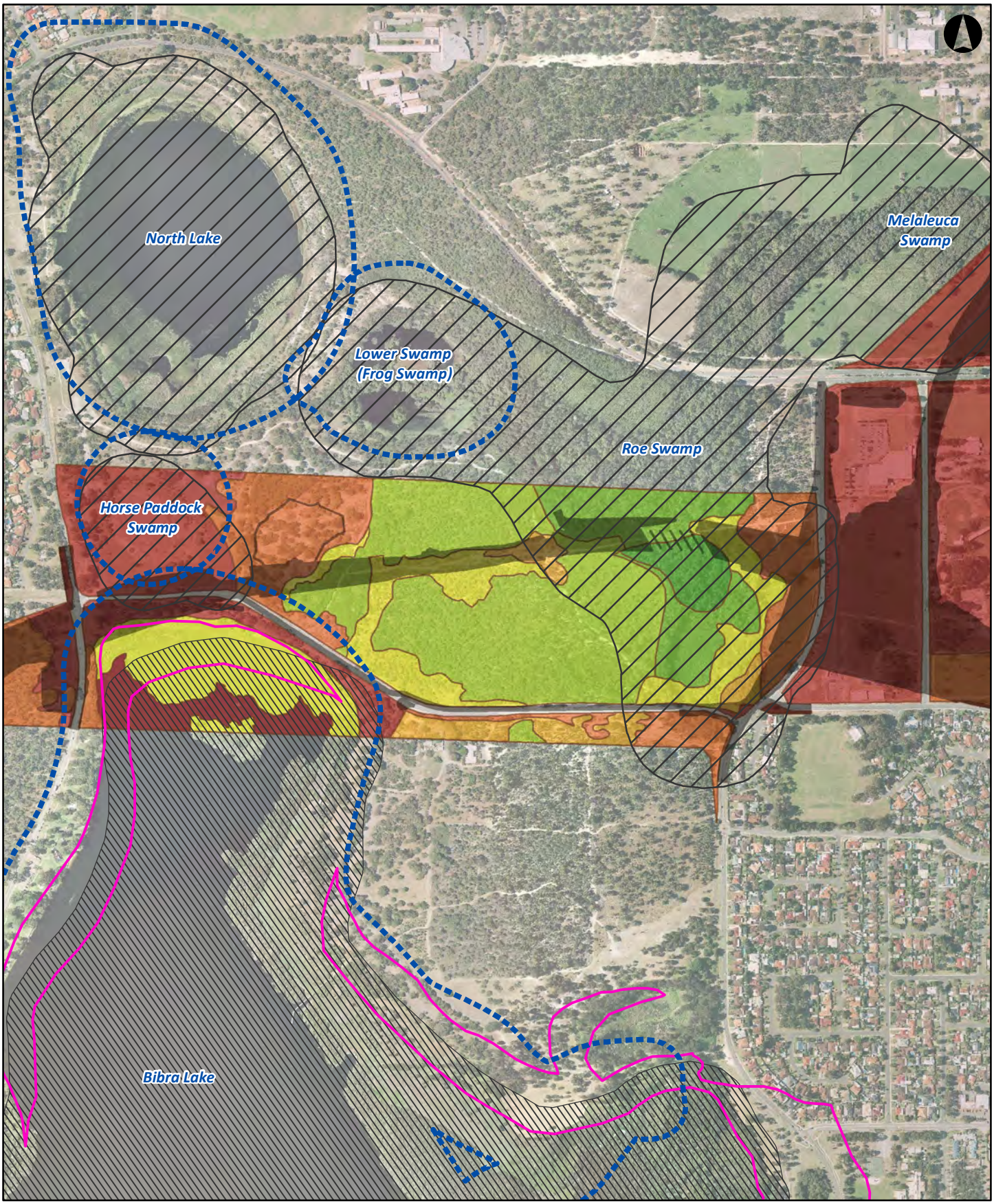
6.2.3.1.1. Bibra Lake, Horse Paddock Swamp and North Lake

The fragmentation associated with a road alignment perpendicular to and between Bibra Lake and Horse Paddock Swamp (and North Lake) is considered to be generally confined to the exacerbation of what is currently limited connectivity between wetlands. This is a result of the presence of Hope Road and degraded vegetation values outwards from that road's margins.

Section 6.8 further describes and analyses statements on the values at risk. As displayed in Figure 6.2-2 and Figure 6.2-3, the proposed project passes between the mapped wetlands. The vegetation condition currently existing between these wetlands is mapped as being Completely Degraded (Figure 6.2-2; Appendix K).

The proposed project also has the potential to continue the existing reduced hydrological exchange between Bibra Lake and the wetlands to the north (Horse Paddock Swamp and North Lake). As described in Section 5.6, surface water exchange or drainage between Bibra Lake and the wetlands to the north is not evident, as Hope Road was constructed on, and most likely contributes to, the topographical high point between the Bibra Lake and Horse Paddock Swamp basins. The topography suggests that the intervening land between the north/south chain of basins was probably seasonally waterlogged, which means that they were, at a time many decades ago, in hydrological connectivity (Appendix D). However, current levels in the inter–basin areas are well above the height of the water table, sufficient to create dry land zones for the majority of the time, in the majority of years.

North and Bibra lakes are probably hydraulically connected by an unconfined superficial groundwater formation. The elevation of the water table on the eastern side of the lakes is higher than that of the lake beds, indicating the dominant regional flow of groundwater into the lakes from the east. Surface drainage does not currently exist, although overland flow may arise during extreme rainfall events. Current connectivity between the basins, if present, would therefore likely be confined to limited groundwater flow and intermittent exchange during 'wet' periods. However, such inter–basin transfer is not sufficiently understood to enable confident commentary on current functionality and, therefore, risk of impact at that localised scale between the lakes. Investigations have been limited by restricted access to wetland areas, in particular, North Lake, Bibra Lake and Horse Paddock Swamp, on account of areas being protected by the *Aboriginal Heritage Act 1972* (Appendix D).



Vegetation Condition within Wetland Boundaries

South Metro Connect

Figure 6.2-2

0 80 160 240 320

Metres
1:10,000 (A4)

Construction Footprint

EPP Lakes with 50m buffer

Geomorphic Wetlands

Conservation Category with 50m buffer

Resource Enhancement with 50m buffer

Multiple Use

Vegetation Condition

CD

D-CD

D

D-G

G

G-VG

VG

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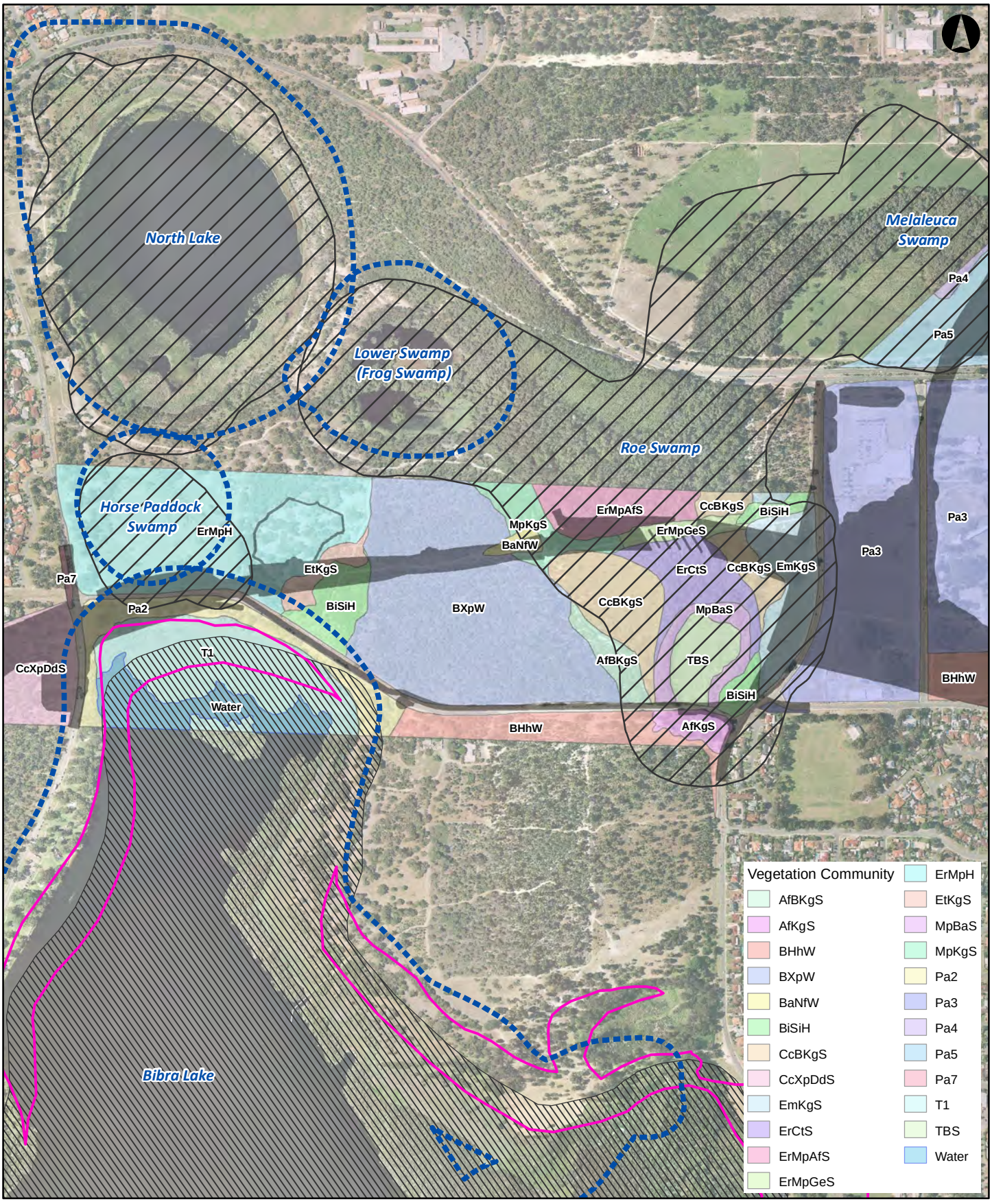

Vegetation Communities within Wetland Boundaries

South Metro Connect

Figure 6.2-3

0 80 160 240 320

Metres
1:10,000 (A4)

EPP Lakes with 50m buffer

Geomorphic Wetlands

Conservation Category with 50m buffer

Resource Enhancement with 50m buffer

Multiple Use

Construction Footprint

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Impact on the hydrological connectivity of the wetlands will be limited

Groundwater can be traced to the wetland margins, but its interaction with the stratified wetland fills cannot be traced. It is unknown whether the groundwater at the margins discharges into the wetland as part of the groundwater system, discharges as part of the water above the ground surface, or whether the groundwater is directed laterally around the wetland fill. Notwithstanding uncertainty, mitigations such as lowered ground surface profile (natural topography to be re–instated) and openings beneath the proposed road structure will promote more natural hydrological conditions in these localised areas between the lakes. Whilst information is limited on the sub–surface exchange of water between Bibra Lake and wetlands located to the north (as described in Section 6.3), the potential for the road to impede groundwater movement will be limited. Therefore, the impact of the proposed project on the hydrological connectivity of these wetlands is considered limited. This impact is discussed further in Section 6.2.3.2.

In summary:

- There is no fragmentation of the Horse Paddock Swamp CCW, as the road aligns to the south. North Lake lies to the north of Horse Paddock Swamp;
- There is no fragmentation of the Bibra Lake Lakes EPP wetland, as the road aligns to the north;
- The design makes use of high topographic relief between the Horse Paddock Swamp CCW and Bibra Lake EPP to avoid interruptions to water conveyance; and
- The design has adopted the use of apertures to aid shallow sub–surface and sheet flow movement when natural flows occur, albeit infrequently.

6.2.3.1.2. Roe Swamp

Roe Swamp has been severed previously and is currently fragmented by Farrington Road, the power transmission line access track and Hope Road. The wetland attributes, functions and values potentially impacted are described in Section 5.2. The proposed project will reduce the connectivity between some of the surface areas of relatively intact vegetation within the Roe Swamp CCW.

The attributes, functions and values of Roe Swamp are considered to be closely linked with the diversity of vegetation communities recorded within it, reflecting interrelationships with geological and associated hydrological expressions and conditions. The spatial heterogeneity of vegetation mosaics through the swamp presents difficulty in the assessment of the potential indirect long–term changes.

As context and an assessment of the extent and consequence of undue effects, it is worth considering the results of previous 'severance' of the Roe Swamp by other roads. Figure 5.8-9 shows that the portion of Roe Swamp to the north (that was fragmented in 1984 by the construction of Farrington Road) and the area of Roe Swamp immediately south of Farrington Road have maintained vegetative diversity on either side of the road. However, the communities present north of Farrington Road differ in the main from those present in the project area (Figure 5.8-9), possibly due to drying of habitat to the south of the existing road formation. There is no evidence that the fragmentation has impacted vegetation condition, with condition being of 'Good to Very Good' condition on either side of Farrington Road (Appendix D). This suggests a degree of maintenance of the local geological and near surface hydrological conditions to support plant diversity over the past 25 years. Additionally, this could be interpreted as evidence of the degree of robustness in the natural system, in terms of hydrological cycles and related biological distributions of plant species and communities. The severance effect of the road (road laid on grade) is more evident at Hope Road with clear truncation in the southern extent of *Typha*–dominated sumpland.

In order to avoid water convergence, connectivity and fragmentation risks, direct on ground footprints should be minimised. Vegetation communities described in Section 5.8 partially represent locally significant vegetation communities that contribute to hydroecological function.

The vegetation within the boundaries of the Roe Swamp CCW, in the proposed footprint predominantly consists of *Eucalyptus* or *Eucalyptusl Banksia* woodland (CcBKgS, ErCtS, EmKgS) with some areas of *Eucalyptusl Melaleuca* (ErMpGeS) or *Melaleuca* woodland (MpKgS). Three of these vegetation communities support populations of Priority Flora: CcBKgS, (*Jacksonia gracillima* (P3)), ErCtS (*Dampiera triloba* (P1) and *Cyathochaeta teretifolia* (P3)), and ErMpGeS (*Cyathochaeta teretifolia* (P3)). Of these communities, the one of highest importance is the habitat for the P1 species, *Dampiera triloba.* This species is supported by community ErCtS and clearing of the majority of this vegetation type will be avoided with the proposed bridge construction.

The inter–related nature of these vegetation communities and their linear alignment has been observed near the proposed Roe Swamp bridge aperture along the existing power line service track. The effect of the remnant service line is evident in the current distribution of vegetation having made small alterations in surface and near surface water conveyance. The proposed project continues the history of disturbance on the same footprint as the current disturbance, along both the service line then to the west over the existing service track, beneath the power lines and between towers. This evidence indicates the importance of created topography and achieving appropriate drainage invert levels in the final design. The current physiography also signifies that wetland form and function is retained, even after installation and operation of infrastructure that was not purpose–built.

In summary:

- The wetlands are currently fragmented due to Farrington Road, Hope Road and the power transmission line corridor;
- There will be partial fragmentation of the wetland within the boundary of the Roe Swamp CCW, because of placement of road infrastructure within its boundary. Direct loss of vegetation and habitat was previously described. Habitat due north and south of the proposed road infrastructure will no longer be closely, linearly connected;
- Apertures installed during construction (bridge and pedestrian and fauna underpasses) will maintain partial habitat connectivity; and
- The dominant water conveyance generally south to north will be maintained by using a bridging aperture and other hydrological openings, as described below.

6.2.3.2. Effects of Hydrology and Hydrogeology on Wetland Function and Values

The direct impacts on hydrology, hydrochemistry and limnology are provided in Section 6.3. This section examines indirect effects on wetland values and function arising from changes to surface and groundwater conveyances.

A case study examining the effect of linear infrastructure on other wetlands within the Beeliar Regional Park is presented in Appendix J. It indicates that, while there has been an overall change in wetland size and vegetation distribution at those target wetlands through time (many decades), it does not appear to be directly related to the installation of transport infrastructure and is more likely a response to changing land use and declining rainfall, combined with the natural progression of wetland morphology over time.

6.2.3.2.1. Roe Swamp

Roe Swamp is an integral part of the linked hydrological, geomorphic and ecological systems within the eastern low hollows of the Bassendean Dunes. Roe Swamp feeds directly to the larger lakes to the west. The conveyance of water in a south–west and then a general westerly direction is evident from the alignment on the south side of the Murdoch Drain and also from the orientation of the vegetation communities. As discussed in Section 6.3, the orientation of the proposed project, being generally east–west, is anticipated to have limited disruption on the regional groundwater flows, which are also generally east–west and occur just below the natural ground level within Roe Swamp. Further to the west, the depth to groundwater gradually increases to tens of metres below ground surface.

With regard to Roe Swamp, the system has demonstrated a degree of robustness to impacts, as evidenced by the ongoing functionality of Roe Swamp, despite the fragmentation caused by Farrington Road, Hope Road and the power transmission line. The proposed project represents a larger footprint on Roe Swamp than other infrastructure and proposes to cross a central section of the wetland.

Local scale potential impacts on the vegetation within Roe Swamp from altered hydrology are discussed in Section 6.6, where a conceptual effects model and an associated indicative estimate of the potential affected zone have been presented. While those estimates are indicative only, they assist in contextual assessment of the risk of adverse impacts from changed hydrology. Further explanation is presented below to substantiate that the estimates on the extent of zones of indirect vegetation effect will not result in compromised wetland functionality.

In relation to predicted indirect groundwater effects on vegetation and GDEs, the following should be noted (Appendix D):

- Investigations show that local groundwater flows are not evenly distributed across the project area, with some geological units conducting groundwater more rapidly than others;
- Horizontal hydraulic gradients in the section between Bibra Drive and Progress Drive are generally very small (as low as 0.0002);
- Transmissive sands are the most common soil medium through the wetlands although, through the region, other variables may influence the movement of groundwater, including the presence of limestone lenses, coffee rock, yellow sands, muddy fills and buried wetland sediments; and
- Paleochannels, coarse sand layers and diagenesis have been identified as potentially contributing to variation within general direction of east–west groundwater flow within the project area.

The groundwater level data for nested bores indicates that over time, lateral and/or vertical flow (leakage) occurs, such that groundwater levels associated with these less permeable materials equilibrates with the regional watertable. That is, perched seasonal (rainfall–fed) aquifers and aquitards at shallow depths are unlikely to be permanently isolated from the region–wide watertable levels and flows. However, there may be small localised (currently undetected) strata that retard transmission rates, leading to localised mounding and wetting of plant shallow root zones. This mounding effect was observed in the groundwater bore network, but only after bore installation in March 2010, just prior to the first seasonal rainfall event and not after the onset of 2010 rains. The intention of ongoing monitoring is to identify the occurrence of differential infiltration or localised mounding effects. During 2010, no large differences in groundwater levels were detected along the bore transect aligned beneath the proposed infrastructure between Bibra and Progress Drives, signifying a relatively uniform depth of the regional groundwater. Therefore, neither a distinct nor extensive indirect effect of altered groundwater on GDE vegetation is anticipated. Deeper regional unconfined aquifer flow from east to west under the project area will continue unimpeded by the presence of the road infrastructure at, or near, the ground surface.

The presence of limited layers of iron cementation and formation of ferricrete (coffee rock) was noted on some bore logs along the proposed project between Bibra Drive and at a site east of Horse Paddock Swamp. However, there was no indication that impervious and/or retarding layers are laterally contiguous. This means that the soils would not vertically retard water infiltration entering the regional groundwater table, nor create seasonally perched watertable(s) above the regional watertable. Hence, the risk of deformation by road formation weight at, or near, the surface and 'piercing', and possibly draining, these layers through piling is very low.

The road infrastructure will not impede regional aquifer flow from east to west

Installation of appropriately sized apertures including a bridge at Roe Swamp avoids the issue of impedance to surface and near–surface water conveyance along the topographic low point of the catchment and will maintain the core water cycle essential to the continued long–term function of the Roe Swamp. This will be achieved by the use of openings beneath the road structure (including culverts and underpasses) and the relocation of a shallow replication of Murdoch Drain.

6.2.3.2.2. Bibra Lake, Horse Paddock Swamp and North Lake

The project area wetlands are a direct expression of hydraulic continuity with the unconfined aquifer of the superficial formations and an expression of the regional groundwater. The surface water in the lakes and sumplands is, under natural conditions, largely exposed groundwater. Wetlands in urban areas also have a more complex set of water balance components, including additional sources of water, such as stormwater drainage, runoff from open parks and sealed catchment areas, and losses through irrigation and bore extraction of groundwater up gradient. The natural sources of the surface water in the lakes and sumplands are the groundwater under the basin, lateral flows from the eastern margins and direct rainfall (Appendix D).

The proposed project will not intersect the groundwater table (by cutting shallow profiles into the natural ground levels) nor impede regional groundwater flow paths. An aperture beneath the road surface centred on the natural topographic low point, south–east of Horse Paddock Swamp, will eliminate the risk of disruption of surface water and groundwater conveyance between lakes in this part of the Beeliar chain.

Sands are the dominant component of the in situ material between Bibra Lake and Horse Paddock Swamp. Sand grain to grain contact provides the soil strength and compressibility: compaction due to the weight of an embankment would be small through the profile at the depths typical of the regional groundwater table. Even where organic matter or clay/silt fines predominate in less permeable material (giving potential to relatively more compressibility), the resultant compression would be isolated essentially to a zone directly beneath or directly adjacent to the embankment in the order of several metres or so devoid of vegetation, because of preceding construction needs. The project will not retard the flow path or volume so will not significantly affect potential for sub–surface inter–basin transfers.

For further explanation of risk of physical changes to hydrogeology, refer to Section 6.3.

6.2.4. Management and Mitigation

6.2.4.1. Direct Loss of Mapped Wetland Areas

The proposed project alignment and footprint area has been significantly altered, when compared with the original Metropolitan Regional Scheme (MRS) road reserve. As illustrated in Figure 6.2-4, the interchange originally proposed for Bibra Drive and Roe Highway occupied a large area of Roe Swamp and would have effectively removed a large percentage of the southern Roe Swamp area. The current design has been altered to limit that initial conceptual impact on Roe Swamp.

Figure 6.2-4: Original MRS Interchange Arrangement at Roe Swamp

The proposed project alignment has been positioned to coincide with an existing Western Power utilities access track that currently crosses Roe Swamp. This minimises clearing requirements and further limits new fragmentation of the wetland area.

The area of Roe Swamp that is contained within the MRS road reserve does not currently form part of the Beeliar Regional Park, is not formally part of the conservation estate and is therefore not managed for conservation purposes. In the event that the proposed project is approved, the portion of Roe Swamp within the MRS road reserve, but not developed as part of the proposed project, would be offered to the State Government for inclusion in the adjoining conservation estate and management by the Department of Environment and Conservation (DEC). This is an area of approximately 9ha and is discussed in more detail as Offset Proposal 3 (Section 10).

9ha of Roe Swamp will be transferred from road reserve to conservation estate

Additionally, Wetland value impacts will be mitigated and / or offset through the:

- Creation of additional wetland values at the Hope Road bioretention basin, with a total area of 1.7ha;
- Restoration of 8.4ha of degraded Horse Paddock Swamp and surrounding uplands, with the objective of re–establishing functional wetland values within, and adjacent to, the CCW and EPP boundaries; and
- Weed control and restoration of about 5ha of degraded wetland fringes of North Lake.

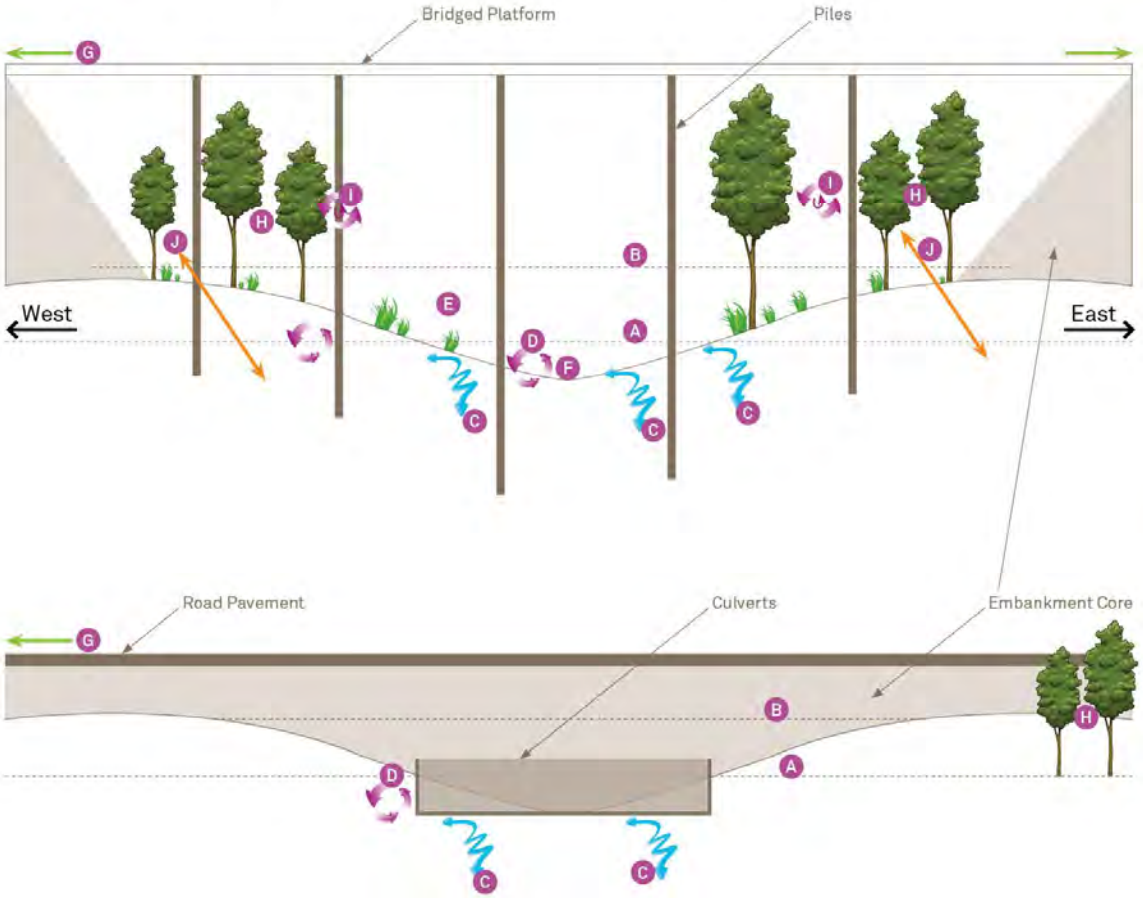
6.2.4.2. Fragmentation of Wetlands and Wetland Associated Vegetation

The location and characteristics of the proposed road alignment was determined on the basis of a multi–criteria assessment, which is described in detail in Section 3 and Appendix C. With the selected alignment intersecting mapped wetland boundaries, the design was developed to limit the extent of the fragmentation that may be caused by the road to wetland areas.

Apertures such as bridge structures and other openings (underpasses and culverts) have been selected as a mechanism to avoid hydrological severance and limit fragmentation of ground mosaics across Roe Swamp and between Bibra Lake and Horse Paddock Swamp. The locations, where bridged structures and embankments are proposed, have been selected due to the importance of vegetation values, maintaining fauna movement and/or sustaining/enhancing hydrological regimes. The selected alignment incorporates siting within areas of existing fragmentation and edge effects associated with the power transmission line, its associated track and the straightened elements of Murdoch Drain.

The road design at Roe Swamp has been developed to permit north–south hydrological, faunal and floristic exchanges, and enable typical connectivity between micro–habitats present within Roe Swamp. Figure 6.2-5 illustrates the anticipated benefits and interactions with the hydrological, flora and fauna values to retain wetland processes and function through Roe Swamp. Specifically, the bridge structure proposed within Roe Swamp is positioned to span the topographical low and the area (within the proposed project) assessed as being most likely to convey water during periods of seasonal high water. This area coincides with vegetation in 'Very Good' condition or vegetation that has been determined to support flora of conservation significance or other importance.

Water management options – Roe Swamp



Factor	Bridge Option	Embankment Option
	Comments on Impedance Level	
A – Typical seasonal surface flow conveyance	Retained beneath structure.	Retained beneath structure. Low
B – Extreme surface flow conveyance	Retained beneath structure. Low	Absent beneath structure. Moderate
C – Below ground hydrological conveyance	Retained beneath structure. Low	Partly retained beneath structure. Moderate – Low
D – Natural wetting drying hydrological processes	Retained beneath structure.	Absent beneath structure. Low – Moderate
E – Catchment flood capacity	Retained beneath structure. Low	Absent beneath structure. Moderate
F – Centred on low topography	Retained beneath structure	Absent beneath structure
G – Runoff capture and treatment from road	Managed with structure	Managed with structure
H – Native vegetation	Retained beneath structure. Low	Cleared beneath; present adjacent to structure. High – Moderate
I – Under canopy moisture and light	Retained beneath structure. Low – Moderate	Absent beneath structure
J – Passage of plants and animals (invertebrates; avifauna; ground dwelling fauna). Dispersal of seeds and pollen.	Retained beneath structure. Low	Absent beneath structure

Figure 6.2-5: Water Management Options – Type Cross–sections for Bridge versus Embankment Options over Roe Swamp

The road design includes apertures of significant width between Bibra Lake and wetlands to the north, in recognition of the potential for surface and sub–surface conveyance between these features. Furthermore, the development of the proposed project would facilitate the partial closure of Hope Road, terminating the road east of Bibra Lake. The closure of road section between Bibra Lake and the wetlands to the north will permit reinstatement of topography. This will be to a level that reinstated the near–surface seasonal water–logging of the soil substrate between the wetlands increasing basin hydrological interaction (although this is not currently evident). Therefore wetland hydrological function will not be affected by road infrastructure severances through this section.

6.2.5. Summary and Conclusions

The following statements summarise key findings related to direct impacts within the wetlands, indirect effects on wetland functions and processes and makes conclusions in relation to matters raised within EPA Bulletin 1088.

6.2.5.1. Residual Impacts

The proposed project will impact on an area of approximately 1.0ha within the Bibra Lake Lakes EPP wetland boundary, although this area has limited ecological value as a functional wetland. The project footprint overlaps approximately 3.8ha of the associated 50m buffer of Lakes EPP wetland boundary. In Horse Paddock Swamp, although the proposed infrastructure crosses the geomorphic CCW boundary, no native vegetation will be cleared. There is no anticipated loss or reduction in current wetland function by virtue of the lack of intact habitat within or adjacent to the project footprint.

The values exhibited by Roe Swamp are commensurate with those of a CCW. The area of direct intersection with the project and mapped wetland area is 5.6ha (temporary and permanent clearing). The 50m buffer around Roe Swamp includes an area of 4.1ha intersecting with the proposal; however, with the exception of the western boundary, this is largely either unvegetated land, degraded habitat or already developed.

In the region of Bibra Lake – Horse Paddock Swamp:

- There will be no fragmentation of the wetland within;
  - Horse Paddock Swamp CCW boundary, as the road aligns to the south
  - North Lake lies to the north of Horse Paddock Swamp
  - Bibra Lake EPP boundary, as the road aligns to the north
- The proposed design makes use of high topographic relief between the Horse Paddock Swamp CCW and Bibra Lake EPP to avoid interruptions to water conveyance; and
- The proposed design will adopt the use of apertures, set at appropriate elevations, to aid return of shallow sub–surface and surface sheet flow movement, when natural flows occur, albeit infrequently.

Roe Swamp has been severed previously and is currently fragmented by Farrington and Hope Roads. Also a power easement/access track for a transmission line runs east to west and the proposed project will adopt disturbance on the same footprint, along both the service line then to the west over the existing service track, beneath the power lines and towers. Evidence there indicates the importance of created topography in altering water conveyance and the need to achieve appropriate drainage invert levels in the final road infrastructure design in order to re–instate near natural flows. The current physiographic form also signifies that wetland function can be retained, even after installation and operation of (small scale) infrastructure that was not purpose–built.

There will be partial additional fragmentation of the wetland within the boundary of the Roe Swamp CCW, because of placement of infrastructure within its boundary. Habitat due north and south of the proposed road infrastructure will no longer be closely, linearly connected. However, the dominant surface water conveyance paths generally south to north will be maintained by using a high level bridging aperture and other openings for hydrological flow paths sympathetic to permit natural rain–fed flows.

Operational effects associated with contaminants in road runoff are addressed by the provision of dedicated constructed wetlands to simulate water cycle processes, temporarily retain waters to remove contaminants from runoff and then passing treated water into the catchment's aquifers. Such treatment areas will be consistent with wetland form and function, providing additional regional wetland areas (1.7ha).

Only small differences in groundwater levels were detected over the winter of 2010 signifying a relatively uniform depth of the regional groundwater. Therefore, neither a distinct nor extensive indirect effect of altered groundwater on GDE vegetation is anticipated because the deeper regional unconfined aquifer flow from east to west under the project area will continue unimpeded by the presence of the road infrastructure at, or near, the ground surface. The localised presence of limited layers of iron cementation and formation of coffee rock was noted on some bore logs in some areas along the proposed alignment. However, there was no indication that impervious and/or retarding layers are laterally contiguous. This means that the soils would not vertically retard water infiltration entering the regional groundwater table, nor create seasonally perched watertable(s) above the regional watertable. Hence, the risk of subsurface deformation by road formation weight at, or near, the surface and 'piercing', and possibly draining, these layers through piling is very low.

A summary of the management, mitigation and residual impacts on the proposed project area wetlands is presented in Table 6.2-3.

Table 6.2-3 Residual Impacts on Wetlands

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Vegetation removal	Loss of fauna habitat function of the wetland resulting in alteration of species composition and abundances Loss of 4.2ha of GDE vegetation within Roe Swamp CCW boundary and 0.4ha within CCW buffer Loss of approximately 2.1ha of intact native vegetation within Roe Swamp CCW boundary and 0.6ha within CCW buffer	Relocate Murdoch Drive Extension Interchange to the east Align road along cleared transmission corridor Rehabilitate secondary disturbed areas, offset loss of vegetation and shallow tilling of compacted materials 'Top down' method to construct bridge at Roe Swamp to minimise clearing required Strict dust management utilising water from outside the project area	Aerial extent of GDE communities within project area reduced by 13.3ha Area of intact native vegetation within Roe Swamp CCW boundary reduced by 2.1ha
Excavation of road cuttings; placement of fill and other earthworks	Temporary and permanent loss of 5.8ha of mapped CCW area and 5.4ha of CCW buffer (Roe, Melaleuca and Horse Paddock swamps) Loss of 1.0ha of mapped EPP area (Bibra Lake) Fragmentation of habitat for fauna utilisation	'Best balance' of road design factors to situate crossing/ apertures at Roe Swamp and through the road formation between Progress and Bibra Drives facilitating water conveyance and ecological connectivity Road alignment to avoid all key areas within Bibra Lake and Horse Paddock Swamp Stormwater treatment basins to remove pollutants, hold runoff and recharge groundwater for conveyance through wetlands Locate construction laydown areas and stockpiles outside wetland boundaries Creation of bioretention basin (1.7ha) between Roe and Horse Paddock Swamp	Transport corridor crossing CCW Reduced connectivity of Roe Swamp

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Localised alterations in groundwater distribution and surface water drainage patterns Temporary loss of 0.50ha of Roe Swamp CCW values with the relocation of Murdoch Drain	Proposed bridges at Roe Swamp and southeast of Horse Paddock Swamp Purposeful placement of culverts and openings through formation between Bibra and Progress Drives during detailed design Undertake detailed geological investigation to confirm ground condition Review design options to minimise load impacts from embankments; where necessary, consider use of novel geotechnical support material	
	Erosion and sedimentation into surface waters Effects on macro invertebrate communities as well as other fauna within the food web due to changes in water quality	Construction management plan including procedures to prevent emissions off project construction footprint	
	Alteration in groundwater distribution (mounding) in response to altered water availability	Bioretention and/or infiltration basins to capture and treat road runoff at slow percolation rates Direct stormwater flows to basins Bioretention and other basins designed to capture and treat road runoff	
	ASS–related impacts resulting from dewatering activities	Complete detailed geological investigation Avoid deep cuts into ASS laden soils where possible Develop and implement ASS management plan including treatment and disposal procedures (Refer Section 6.5 for more detail)	

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Operation Phase			
Physical presence of road	Decline in amenity values and aesthetics	Reduction in total clearing footprint via design measures Vegetation rehabilitation including screen trees and sensitive lighting as required Use texture and colour on abutments, piles and walls to blend with recessive colours into natural landscape	A reduction in amenity and aesthetics
	Solar shading will result in some alteration in species composition of retained vegetation beneath bridge	Supplementary planting with shade tolerant species to maintain vegetated habitat linkage	Alteration in vegetation community species composition in 0.4ha under proposed bridge
	Introduction of pollutants from road runoff or direct spills above existing background	Road design will ensure full containment of road drainage within wetland areas and will direct flows to drainage basins. Bioretention and/or infiltration processes to capture and treat road runoff	Drainage basins improve water quality delivered wetland areas

6.2.5.2. EPA Bulletin 1088

Table 6.2-4 highlights the EPA concerns for wetlands from the proposed project as stated in Bulletin 1088 (EPA 2003).

Table 6.2-4: EPA concerns for Wetlands as Stated in Bulletin 1088

Bulletin 1088 Statement	Proposed Project Concept Response
The construction of the alignment ... would involve the clearing and filling of certain areas that are considered to be of high conservation and environmental significance (i.e. conservation category wetlands and areas protected by an Environmental Protection Policy). In particular, construction .... would directly impact the southern portion of Horse Paddock Swamp, the northern section of Bibra Lake and a sizeable area of Roe Swamp	Clearing of land will occur in Roe Swamp to the extent of 5.6ha (includes 0.5ha of temporary clearing) out of a mapped area of 53.7ha. An additional 4.1ha of Roe Swamp CCW buffer will also be cleared. The majority of the area to be cleared within the CCW boundary contains vegetation in a condition rating of less than 'Good' or better Very small areas of land will be developed within the Bibra Lake (1.0ha) and Horse Paddock Swamp (0.3ha) boundaries and none of these areas have functional wetland values. A combined total of 5.4ha of wetland buffer for these two wetlands will also be impacted
Construction of the Roe Highway extension in this area would indirectly impact other wetland areas located outside the alignment through severance of wetland linkages between North and Bibra lakes, between Roe Swamp and North Lake, and the rest of the wetland complex located further north *This severance would result in significant impacts on the values and functions of the wetlands adjacent to the highway extension, and on the unity of the eastern Beeliar Wetland chain*	There is no evidence of extensive habitat or hydrological linkage between North and Bibra lakes. Notwithstanding, restoration of hydrological connectivity is proposed by installation of apertures through the road formation. To complement that activity, restoration of Horse Paddock Swamp (8.4ha) is proposed as an offset, given its completely degraded vegetation condition rating The risk of severance of wetland linkages between Roe Swamp and North Lake is addressed by the proposal of a bridge spanning the topographic low point from east to west at Roe Swamp. Additional apertures for passage will be installed through the embankment Loading of embankments is predicted not to impact on sub–surface flow mechanisms The retention of hydrological function will avoid significant impacts on the values and functions of the wetlands associated with flows from east to west The unity of the eastern Beeliar chain would benefit from an area of Roe Swamp that is contained within the MRS road reserve and not currently part of the Beeliar Regional Park. That portion, not developed as part of the proposed project (9ha), forms part of the proposed project's environmental offset package and is offered to the State for inclusion in the conservation estate and management by the DEC

6.2.5.3. Offset

An offset is proposed for residual impacts on the proposed projects wetland areas, in particular Roe Swamp. This comprises:

- Commencement of a staged wetland restoration programme for Horse Paddock Swamp;
- Weed control and rehabilitation of degraded wetland fringes of North Lake;
- Contribution of $100,000 to community based rehabilitation funds; and
- Transfer of land over Roe Swamp currently within the MRS to Beeliar Regional Park.

Further details of the proposed wetland offset are provided in Section 10.

6.3. Surface and Groundwater Movement

The EPA's objective for surface and groundwater is:

> *To maintain the quantity of water so that existing and potential environmental values, including ecosystem maintenance, are protected.*

6.3.1. Potential Impacts

A range of potential impacts on surface and groundwater movement were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. Drainage design solutions, which are described in detail in Appendix H, were developed for the following potential impacts:

- Excavation of road cuttings could cause a decline in local groundwater levels – the vertical alignment has been designed to ensure there is no requirement for road cuttings below the water table; and
- Construction of embankments will result in a barrier to the movement of surface water, causing a decline in vegetation health – drainage design includes provision for culverts at topographical low points.

A detailed assessment of predicted surface and groundwater impacts is provided in Sections 6.3.2 and 6.3.3.

6.3.2. Construction Phase Impacts

Construction phase impacts on surface and groundwater flow include:

- Increases in surface water runoff caused by vegetation clearing;
- Altered surface water flow paths by filling with embankments;
- Changes to local groundwater level by drawdown of local aquifers;
- Altered groundwater flow regime by road cuttings; and
- Subsurface compaction by loading from embankments.

6.3.2.1. Altered Surface Water Runoff Volumes and Flow Paths

Clearing of vegetation associated with the construction of the proposed project will change the local water balance, should it rain heavily during construction, depending on the construction section. Removal of vegetation reduces evapotranspiration and increases the surface water runoff. Similarly, where transmissivity of soils is high (i.e. sands) it causes accelerated infiltration. In terms of water balance function, the proposed extent of vegetation loss will have a minimal effect on evapotranspiration and infiltration across the catchment.

When road embankment earthworks fill an area that currently channels or feeds flowing or standing water, the amount of water received down–gradient of the embankment can decline and the amount up–gradient can increase. It can also have the effect of impounding water up gradient, increasing the soil moisture levels. The effect of this process is to cause either drying of the soil profile (down gradient) or inundation (up gradient), both of which can influence the growth and vigour of vegetation within the affected area.

Relatively shallow cut–and–fill earthwork profiles means that drainage and ephemeral flow paths are not largely interrupted. Notably, a portion of Murdoch Drain is proposed to be relocated and the consequence is considered separately in Section 6.3.2.3.

6.3.2.2. Changes to the Local Groundwater Level

The road pavement level of the proposed project will be higher than the maximum recorded groundwater level. However, during construction it may be necessary to undertake temporary groundwater dewatering to facilitate some construction activities. This can lead to a short–term lowering of local groundwater levels and potentially impact water levels in the groundwater dependent ecosystems. However, following completion of construction activities potentially requiring localised lowering, natural groundwater levels will re–establish.

6.3.2.3. Filling and Relocation of Murdoch Drain

The proposed project will affect approximately 150m of the existing Murdoch Drain. The existing drain will be filled and the location of the new alignment will be excavated below groundwater levels. It is likely this will result in an increase in the local water levels where the existing drain is filled and a decrease in the local water levels where the new drain is constructed. Due to the limited area impacted and the small distance between the existing and relocated drain, the consequence is considered negligible. Management of impacts associated with the disturbance of Potential Acid Sulfate Soils (PASS) are discussed in Section 0.

6.3.2.4. Sub–Surface Compaction

There is concern that loading on road infrastructure on the ground may compress the soils, causing them to restrict the passage of groundwater. Finite element modelling (using PLAXIS 2D and 3D) was used to examine the effect of embankment loading on the underlying soils. Figure 6.3-1 illustrates an example of model outputs. On the left had side, the figure shows elevation; and on the right, the colour scale indicates percent volumetric strain. It is representative of the cross section for the proposed project between Horse Paddock Swamp and Bibra Lake and represents a base of 8.5m fill.

Modelling shows that the maximum effect for the thickest embankment cross–section on typical soil profiles is approximately a three percent reduction in porosity. This is related to a small physical reduction in the spaces between sand grains that form the soils. Consequently, it is expected that there will be a very small effect on the porosity of the sandy soils underlying the proposed embankment. Very small reductions in porosity would result in slightly lower values of hydraulic conductivity in affected soil layers. As expected, the results indicate a low proportion of compaction, as sandy soils are typically supported by grain to grain contact. Most of the change in porosity is expected to occur in the top one to two metres of the soil immediately beneath the embankment. Therefore, the proposed infrastructure is expected to have a minimal, if any, discernible impact on groundwater levels beneath and adjacent to the road formation. Generally, groundwater levels or the water table is at least several meters below for the majority of the alignment.

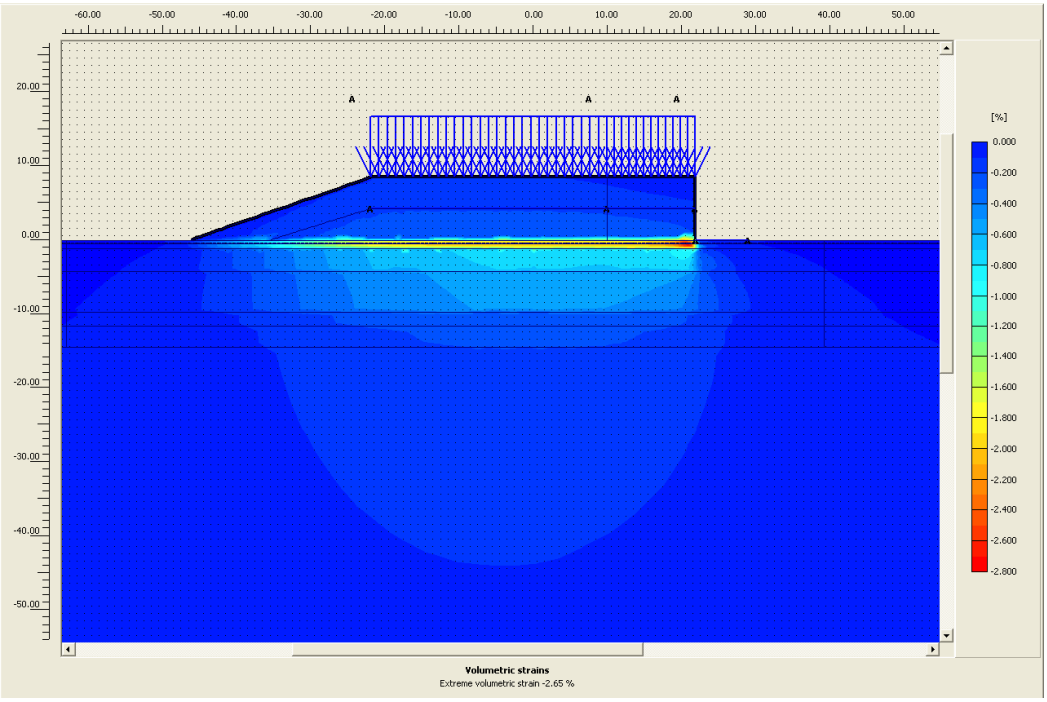


Figure 6.3-1: Conceptual Compression Forces from Embankment Cross-section Constructed at 8.5m above Grade

6.3.3. Operation Phase Impacts

Operational phase impacts on existing surface and groundwater flow relate to the proximity of the impermeable road surface to wetland areas and the consequence of road runoff.

6.3.3.1. Surface Water Runoff Volumes

Road pavement and embankment areas are proposed to be located on existing permeable ground surface and the new surface will have a lower permeability and higher runoff coefficient, compared to the natural ground. This will result in local, negligible modifications to the surface water regime.

6.3.3.2. Changes in Groundwater levels

The concentration of surface water runoff from the road into infiltration basins will result in a localised increase in the groundwater levels beneath the infiltration basin. Drainage basins have been positioned in the landscape to ensure that they will have minimal negative influence on groundwater levels. The proposed bioretention basin east of Horse Paddock Swamp adjacent to Hope Road is intended to increase groundwater supply in this area to provide additional water to Horse Paddock Swamp, which is located down gradient of the basin.

6.3.4. Management and Mitigation

The concept design for the proposed project comprises components that impact existing surface water and require management measures. Many have been largely incorporated into design allowances. The Drainage Design Report (Appendix H) provides additional detail. During the development of the concept design, several management measures were considered essential to the design in accordance with the principles of water resource management:

- Implementation of Surface Water Management Principles;
- Relocation of Murdoch Drain;
- Bridge and culvert openings over and adjacent to Roe Swamp and other locations along the alignment; and
- Basins throughout the project area located outside the wetland boundaries (Figure 3.5-1 to Figure 3.5-6).

6.3.4.1. Water Management Principles in Design – Water Flows

The following principles of water resource management, developed by DoW and detailed in the *Stormwater Management Manual for Western Australia* (2004) and the *Decision Process for Stormwater Management in Western Australia* (2009) were implemented during the development of the concept design for the proposed project.

6.3.4.1.1. Mimic Natural Drainage

It is important to design systems to mimic natural drainage processes as much as possible and support the water requirements of ecosystems. The proposed project coincides with two existing areas of ephemeral surface water ponding at Roe Swamp and north–east of Bibra Lake. At these locations, the alignment was adjusted to find the option with the least impact on surface water, which included: moving the alignment north to avoid the open water body of Roe Swamp; an open structure (bridge) over the lowest point in the terrain; and retaining walls instead of embankments to minimise the width of the formation. Culverts will be used to retain local drainage beneath the formation. The position of the alignment was determined with consideration to several conflicting priorities, including fauna habitat, vegetation quality and social effects.

The concept design does not propose a direct discharge of stormwater into the wetlands.

6.3.4.1.2. Maintain Pre–development Water Regime

The impervious catchment created by the proposed project totals 10.4ha, which equates to approximately 1.4 percent of the overall catchment. Existing road pavement coverage in the catchment is approximately 46ha (6 percent).

Major approaches incorporated in the design include:

- Retain or detain typical rainfall events as close to the source as possible in stormwater treatment basins;
- Replicate peak flow rates to pre–development hydrology; and
- Retain known and potential water conveyance pathways near topographic low points near Horse Paddock Swamp and Roe Swamp.

Surface water runoff from impervious road pavement surfaces will be larger than would occur in the pre–development catchment. To maintain pre–development water regimes, runoff from road pavement surfaces will be collected into bioretention and infiltration basins.

Retaining native vegetation helps to maintain the existing water regime by minimising losses due to evaporation and maintaining the high evapotranspiration rates of mature trees. Vegetation will also aid in soil stabilisation and will limit erosion during larger rainfall–runoff events. Section 6.6 provides a detailed explanation of quality and quantity of vegetation that will be retained to mitigate impacts.

The alignment was adjusted to ensure the least impact on surface water

To maintain pre-development water regimes, runoff will be treated in stormwater basins

6.3.4.1.3. Minimise Cutting and Filling of the Natural Surface

In order to achieve the vertical geometry required for highway design standards sections of cut and fill are unavoidable, particularly within an undulating landscape. Similarly, it is not always feasible to have the road surface at the same level as the existing ground. Vertical profiles take into account mass haulage volumes, in order to minimise the amount of material transported either to or from the site. While cutting and filling along the entire alignment has been necessary, the extent of this has been minimised.

Edge treatments of sections of high fill or low cut were designed as steep sloping embankments or vertical retaining walls, depending on the need for protection of adjacent areas. The following considerations were made during the development of the concept design to minimise cutting and filling:

- A retaining wall is proposed on the south side of the alignment adjacent to Bibra Lake, to protect existing surface water and fringing vegetation (and other values);
- Vertical cutting has been kept above the maximum recorded groundwater levels, to limit the impact on the local groundwater system;
- A retaining wall is proposed at the section adjacent to Murdoch Drain, to reduce the amount of filling into this existing open drain. However, there is still a section of the drain that is expected to be affected by fill and will require relocation; and
- A retaining wall is proposed for the south side of the alignment, where it passes through Roe Swamp, to minimise the extent of filling required.

6.3.4.1.4. Manage Road Vertical Profile

The majority of the road vertical profile is greater than 2m higher than the annual average high groundwater level. By maintaining this vertical distance, waterlogging can be avoided and soil filtration and aerobic microbial action can occur prior to the runoff entering the groundwater. There are two locations where geometrical constraints have governed, and maintenance of this vertical distance was not possible. These are located along Roe Highway, between Murdoch Drive and Bibra Drive, and along Murdoch Drive, for 200m north of Farrington Road.

6.3.4.1.5. Manage Rainfall Events on Altered Catchment

Retaining small rainfall events at the source reduces the amount of runoff and mimics the natural drainage process of the catchment. Consideration of this principle was weighted against directing stormwater away from wetlands and prevention of stormwater pollution of sensitive environments. The need to protect the existing wetland system from accidental spills and road pollutants by controlling the discharge point was considered a higher priority than retaining the small rainfall events at source. Therefore, kerbing of the road is proposed on the alignment between Bibra and Progress Drives, such that road runoff can be managed through pit and pipe systems and discharged at a controlled location to be treated in a proprietary stormwater treatment system before entering a purpose–built bioretention basin. This solution is discussed in more detail in Section 6.4.

The concept design has incorporated the management of large rainfall events in either road reserves or water bodies. This provides adequate protection to infrastructure during flood events and is a principle in the *Stormwater Management Manual of Western Australia* (2004).

6.3.4.2. Relocation of Murdoch Drain

The invert levels of Murdoch Drain vary along its length and it does not exhibit a positive grade in any direction. As such, Murdoch Drain only flows during major storm events when the surface water contribution from the drain's catchment delivers sufficient water and energy to force water in the drain westward. In its current state, Murdoch Drain serves to locally reduce the groundwater levels beneath its bed and adjacent to its batters.

The proposed project will affect a length of approximately 150m of the existing Murdoch Drain and a new 'replicate' alignment will be excavated below groundwater levels. The proposed diversion of Murdoch Drain is intended to replicate its current function, keeping invert levels similar (albeit graded evenly), so that groundwater is expressed under the same situations as in its present form. A indicative concept design for the realignment of Murdoch Drain where it coincides with the proposed project is provided in Figure 6.3-2.

The relocation of a portion of Murdoch Drain is intended to replicate its current function

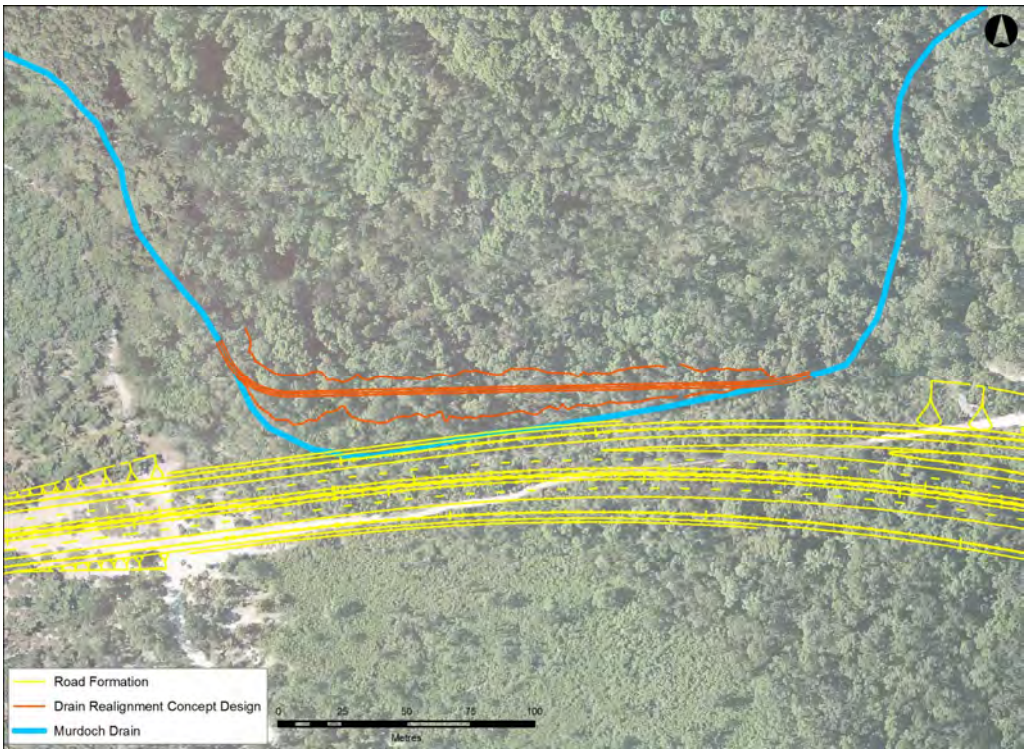


Figure 6.3-2: Concept Realignment of Murdoch Drain

The relocation of a portion of Murdoch Drain is unlikely to have a measurable effect on groundwater levels on a regional or local scale, as groundwater will not be displaced or removed from the area.

An assessment of the presence and concentration of PASS will be required prior to finalisation of the location of the new drain alignment. Any PASS burden present can and will be managed in determining depth and alignment of the drain, and the treatment and handling requirement of the sediment (Section 0).

The concept for re–instatement is currently shown in Figure 6.3-2 as 'straight and engineered'. During detailed design, consideration will be given to:

- Protection of existing vegetation and other values when developing the alignment and profile; and
- Appropriate bed elevation for the relocated drain.

The realignment does not impact potential Carnaby's Black–Cockatoo habitat trees and is within the low value category of Carnaby's Black–Cockatoo foraging trees.

6.3.4.3. Bridges and Culverts adjacent to Roe Swamp and Horse Paddock Swamp

The proposed project includes a bridge at Roe Swamp. An assessment of the surface water flows has been made and additional openings, in the form of culverts, are also proposed to allow for unimpeded surface water movement at this location for environmental flows, as well as larger storm events. An opening is also proposed beneath the road to promote the re–instatement of potential surface level connectivity between Horse Paddock Swamp and Bibra Lake.

6.3.4.4. Stormwater Basins

A mixture of bioretention and infiltration basins will be used throughout the project area. Where the basins are located close to wetlands, the basins incorporate a bioretention section within the infiltration basins. The location of the basins is detailed in Appendix H.

A large bioretention basin is proposed east of Horse Paddock Swamp at Hope Road. This basin has been designed to attain the best management practice targets outlined above. In addition to helping achieve water quality objectives, the basin will also help reach water quantity objectives. The Hope Road bioretention basin will hold a 1 in 5 year Average Recurrence Interval (ARI) storm within its bunds. Storm events larger than this will sheet flow at low velocities to the adjacent water body. This is in accordance with principles set out in both the *Stormwater Management Manual for Western Australia* (2004) and the *Decision Process for Stormwater Management in Western Australia* (2009). The concept plans of the proposed bioretention basins are shown in Figure 6.4-2 to Figure 6.4-4.

Further basis to the situation, function, design and operation of the basins is given in Section 6.4. Localised groundwater mounding will result beneath the basins as a result of the planned retention function, but this will only be evident after large and/or prolonged runoff events into the basins.

6.3.5. Summary and Conclusions

The following statements summarise key findings related to direct and indirect impacts on surface and groundwater movement and makes conclusions in relation to key matters within EPA Bulletin 1088.

6.3.5.1. Residual Impacts

It is predicted that the proposed project will result in minor residual impacts including:

- Temporary localised alteration in groundwater distribution and surface water drainage patterns;
- Minor localised alteration to ephemeral surface water flows; and
- Localised groundwater mounding.

The proposed project has been designed to ensure planned alterations to surface water flows are minimal. Bridges will be constructed at major existing and potential flow paths at Roe Swamp and between Bibra Lake and Horse Paddock Swamp. Minor drainage lines and localised surface flow paths will be managed through use of culverts or other openings beneath the road formation. Murdoch Drain will be relocated and replicated to maintain existing values.

The risk of long term impact on groundwater movement has been demonstrated to be minimal and highly localised (in times after heavy rains). Bridges will be installed at Roe Swamp and Horse Paddock Swamp to assist in maintaining the largest components of existing surface and groundwater flow regimes. Further to this, the strategic placement of culverts and openings will enable localised surface water flow and surface and groundwater interactions.

Bioretention and infiltration basins will be installed and operated throughout the project area to manage surface water runoff and poor water quality created by impervious road surfaces. This measure will also mimic the natural water cycle, where percolation and infiltration to groundwater accounts for a significant portion of the catchment's water. Localised groundwater mounding will be evident as a residual effect beneath these basins, particularly after wet years leading to enhanced recharge.

The risk of subsurface deformation by road formation weight at, or near, the surface and 'piercing', and possibly draining, these layers through piling is very low. Excavations through cuttings will not penetrate below the annual average groundwater level, so groundwater will not be intersected and regional groundwater will flow unimpeded and maintain its typical levels. During aperture construction, localised temporary draw–down of shallow groundwater may be required (for installation of infrastructure) but this will return to natural levels in the next wet season after construction. Construction water will be taken from outside the project area.

These strategies, in conjunction with construction management practices, will ensure the quantity of water is maintained to protect existing and potential environmental values, including wetland function.

Key water conveyance and function will be maintained in the important wetland regions of Bibra Lake – Horse Paddock Swamp and Roe Swamp, such as:

- The proposed design makes use of high topographic relief between the Horse Paddock Swamp CCW and Bibra Lake EPP to avoid interruptions to the core wetland water conveyance;
- To date, a relatively uniform depth of the regional groundwater has been measured. Neither a distinct nor extensive indirect effect of altered groundwater (on GDE vegetation) or flow through (as lake standing water) is anticipated, because the deeper regional unconfined aquifer flows under the project area and this will continue unimpeded by the presence of the road infrastructure at, or near, the ground surface; and
- Furthermore, the proposed design will adopt the use of variously–sized apertures, set at appropriate elevations, to aid return of shallow sub–surface and surface sheet flow movement, when natural flows occur (albeit infrequently). This will aid ephemeral wetting and drying patterns of adjacent GDE according to natural rain events and seasons. In time, small scale residual changes in localised areas of water movement adjacent to the road embankments may express as changes to vegetation.

A summary of the management, mitigation and residual impacts on surface and groundwater movement is presented in Table 6.3-1.

Table 6.3-1: Residual Impacts on Surface and Groundwater Flow Paths and Quantities

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Vegetation removal	Increase in surface runoff generation from a cleared catchment	Localised stormwater management and practices. Infiltration and bioretention basins will be utilised to retain stormwater	Nil
Excavation of road cuttings and piling	Groundwater dewatering will lower the local water table	Construction activities will be undertaken above the seasonally high groundwater table	Nil
	Localised alterations in groundwater distribution and surface water drainage patterns	Protection of existing surface water and fringing vegetation at the northern end of Bibra Lake Retaining walls have been proposed to minimise filling Vertical cutting to a depth above the maximum recorded groundwater levels Retaining wall is proposed at the section adjacent to Murdoch Drain to reduce the extent of filling into	Temporary localised alteration in groundwater distribution and surface water drainage patterns

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
		the drain Retaining wall proposed on south side of alignment through Roe Swamp, to reduce filling of wetland.	
Placement of fill, compaction of embankment foundations and other earthworks	The road embankment will result in compaction of the existing soil profile, reducing the hydraulic conductivity below the structure and alter the net groundwater flows (ongoing into the Operations phase)	PLAXIS modelling indicates that the compression will be localised (under the road), shallow in its effect (1–2m) and insignificant change in porosity (<3%)	Nil
	The road embankment will be a barrier to surface water flow (ongoing into the Operations phase)	Adjustment of alignment to implement the option with the least impact on surface water flows Openings will be provided to maintain surface water flow paths Install largest apertures at two points: Roe Swamp and south–east of Horse Paddock Swamp Purposeful placement of culverts and other openings beneath embankments along the Progress – Bibra Drive section during detailed design	Minor localised alteration to ephemeral surface water flows
Operation Phase			
Physical presence of road	Increased surface water runoff from road surface and corridor	Infiltration and bioretention basins will be utilised to mimic the pre–development water regime Design to direct flows to central basins. Bioretention and/or infiltration processes to capture and treat road runoff	Localised groundwater mounding

6.3.5.2. EPA Bulletin Matters

These extracts from Bulletin 1088 (EPA 2003) are similar to those presented in Wetlands section because of the relationship between wetland function and water flows.

Bulletin 1088 Statement	Proposed Project Concept Response
The construction of the alignment…would involve the clearing and filling of certain areas that are considered to be of high conservation and environmental significance (i.e. conservation category wetlands and areas protected by an Environmental Protection Policy). In particular, construction …. would directly impact the southern portion of Horse Paddock Swamp, the northern section of Bibra Lake and a sizeable area of Roe Swamp	Filling is an essential part of road formation and embankment construction, but effects can be minimised by reducing loads (to managed compressional forces), using piles (to limit infrastructure footprints) and using apertures (to maintain water flow paths) Bridges will be installed at the areas of highest significance (the north–south connection between Bibra Lake and Horse Paddock Swamp; and over Roe Swamp)
Construction of the Roe Highway extension in this area would indirectly impact other wetland areas located outside the alignment through severance of wetland linkages between North and Bibra lakes, between Roe Swamp and North Lake, and the rest of the wetland complex located further north *This severance would result in significant impacts on the values and functions of the wetlands adjacent to the highway extension, and on the unity of the eastern Beeliar Wetland chain*	Restoration of hydrologic connectivity is proposed by installation of apertures through the road formation between Bibra Lake and Horse Paddock Swamp The risk of severance of wetland linkages, in the part associated with altered water conveyance between Roe Swamp and North Lake, is addressed by a number of design mitigations: • A bridge spanning the topographic low point from east to west over Roe Swamp • Additional apertures for water passage will be installed through the embankment for local water flows • Murdoch Drain is proposed to be relocated north from its current location and replicated in function to promote flow of waters from east to west towards North Lake • No earthworks cutting or excavation will occur beneath the water table (average annual maximum level) • Loading of embankments is predicted not to impact on sub–surface flow mechanisms Constructed retention basins will recharge treated catchment water captured from stormwater (in direct proportion to its rainfall occurrence) into the regional aquifer

6.4. Water Quality

The EPA's objective for water quality is:

> *To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.*

Such emissions may arise as spills or runoff during the infrastructure construction phase and/or road operations phase. The project area and catchment surrounds have been modified from a landscape dominated by agriculture, vegetated surfaces and other undeveloped areas in the mid–1970s to mainly residential developments prevalent today. As a result of past and current land use practices, the wetlands and surrounding vegetated areas are not pristine and the water quality flowing through ephemeral paths and infiltrating ground water contain high levels of contaminants from human activities. As indicated in Section 5.7, elevated concentrations of elements, metals, hydrocarbons and nutrients have been recorded in the groundwater, stormwater inflows, surface waters and bed sediments in the lakes and sumplands within the study area.

The Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality (2000) stipulate a framework for assessment, monitoring and management of values of ambient background water quality within natural Australian waterways. In this context, respective receiving waters will be subject to inflows from an entire contributing catchment which in natural waterways will largely be non–urbanised with limited impervious surfaces. In the case of Bibra Lake, North Lake, Horse Paddock Swamp and Roe Swamp the inflows are primarily via groundwater ingress from an extensive catchment that has been significantly modified through urban development.

As part of the National Water Quality Management Strategy (NWQMS), Chapter 3 of the series specifically addresses typical characteristics of wetland and freshwater lake conditions and water quality. The NWQMS recognises the wide range of geographic, climatic, physical and biological factors that influence particular aquatic ecosystems, making it essential that ecosystem management incorporates site–specific information. The following tables (Table 6.4-1, Table 6.4-2 and Table 6.4-3) contrast site–specific monitoring data for the study area (refer to Section 5.7 for further details) against the benchmarks established by the NWQMS.

The ANZECC trigger values are intended to be applied to ambient in stream water quality and have not been developed for event based runoff such as stormwater inflows. Inflows from stormwater assets are not consistent with the pre development hydrology, which makes assessment against ANZECC targets difficult. Whilst these point source discharges invariably contribute to the overall water quality in the receiving environment they are not comparable to trigger values for receiving wetlands or catchment freshwater stream values. The stormwater inflow sampling results are included for comparison with the receiving waters and to demonstrate the highly contaminated characteristics of these.

Variations in physical and chemical water quality variables can occur naturally through periods of drought and flood, and climatic change and can have important consequences for aquatic and riparian biota. Variations in climate and consequent distinct variations in rainfall, runoff and river flow are known to occur as was the case in the most recent year of baseline monitoring, 2010.

It is evident that enrichment of pollutants and nutrients has occurred and this is consistent with the understanding of catchment activities and uses, past and current. Table 6.4-1 contains default trigger values for physical and chemical stressors for south–west Australia for slightly disturbed wetlands and freshwater lakes. These are contrasted to recent lake and stormwater quality monitoring data for the study area. Shading is used for where there was a clear exceedance of the ANZECC guideline level.

Table 6.4-1: Default Trigger Values

Surface Water Analytes	Chlorophyll–*a*	Total Phosphorus	Dissolved or Reactive Phosphorus	Total Nitrogen	Nitrates	Dissolved Oxygen	pH
Unit	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
ANZECC level	30	0.06	0.03	1.5	0.1	>5	7.5–8.5
Bibra Lake Mean (Range)	35 (2.9–150)	0.57 (0.26–0.87)	0.2 (0.04–0.4)	4.6 (2.1–13)	0.12 (<0.01–0.23)	8.3 (7.2–11.6)	8.4 (8.2–8.8)
North Lake Mean (Range)	76 (7–190)	0.26 (0.08–0.41)	0.08 (0.07–0.08)	1.8 (1.1–2.6)	0.02 (0.01–0.03)	8.2 (6.2–17.7)	6.8 (4.9–7.0)
Stormwater Mean (Range)	-	0.2 (0.03–1.1)	-	2.7 (0.2–19)	0.5 (0.01–5.6)	-	-

Table 6.4-2 contains trigger values for water quality toxicants at 95% species protection level in natural water bodies. These are contrasted to recent lake and stormwater quality monitoring data for the study area. Shading is used where there was a clear exceedance of the ANZECC guideline level.

Table 6.4-2: Trigger Values for Toxicants

Analyte	Units	ANZECC (2000)	Mean (Range) Bibra Lake	Mean (Range) North Lake	Mean (Range) Stormwater Runoff
Al	µg/L	55	190 (46–430)	98 (19–150)	260 (51–710)
As**	µg/L	24 (As III) and 13 (As V)	6.7 (4.3–11)	3.1 (3–3.1)	17 (2.5–25)
Cr**	µg/L	1 (Cr VI)	1.4 (1.2–1.9)	1.3 (1.3)	2.4 (1.1–6)
Cd	µg/L	0.2	<0.2	<0.2	<0.2
Cu	µg/L	1.4	1.9 (1–4.5)	1 (1)	7.9 (1.1–34)
Fe	µg/L	300*	1000 (360–1800)	9600 (9500–9700)	300 (50–840)
Pb	µg/L	3.4	3.2 (1.5–5.4)	4.6 (3.6–5.1)	5.7 (1.1–19)
Ni	µg/L	11	1.6 (1–2.7)	1.4 (1.2–1.4)	-
Se	µg/L	5	1 (1)	<1	-
Zn	µg/L	8	15 (7–35)	21 (6.9–35)	56 (26–180)
TPH C_6-C_9	µg/L	-	<25	<25	54(54)
TPH C_{10}-C_{14}	µg/L	-	83 (77–87)	54 (54)	110 (61–330)
TPH C_{15}-C_{28}	µg/L	-	380 (170–1300)	230 (190–260)	510 (100–1700)
TPH C_{29}-C_{36}	µg/L	-	250 (130–560)	130 (120–150)	320 (100–760)
BTEX	µg/L	-	-	-	38 (38)

*DEC 2010a, Assessment levels for soil, sediment and water

**total of both valence states
- indicates that the particular analyte was not tested

TPH – total petroleum hydrocarbons

BTEX – benzene toluene ethylbenzene and xylenes

Table 6.4-3 contains trigger values for pollutants in aquatic sediments. These are contrasted to recent wetland sediment quality monitoring data for the study area.

Table 6.4-3: Trigger Values for Pollutants in Sediments

Analyte	Unit	ISQG–High	Mean (Range) Bibra Lake	Mean (Range) North Lake
As	mg/kg	70	3.7 (<0.4–12)	3.5 (<0.4–10)
Cr	mg/kg	370	18 (0.9–65)	11 (1.4–21)
Cd	mg/kg	10	0.08 (<0.1–0.28)	0.08 (<0.1–0.46)
Cu	mg/kg	270	5.7 (0.3–21)	4.9 (<0.1–15)
Fe	mg/kg	-	2900 (340–11000)	3700 (800–14000)
Pb	mg/kg	220	23 (1.3–66)	32 (0.8–110)
Ni	mg/kg	52	3.4 (0.35–9.1)	2.3 (0.2–4.6)
Se	mg/kg	-	1.0 (<0.5–2.7)	1.0 (<0.5–2.7)
Zn	mg/kg	410	27 (1.5–90)	21 (<0.5–93)
TPH C_6-C_9	mg/kg	100*	<10	<10
TPH C_{10}-C_{14}	mg/kg	500*	21 (<10–130)	11 (<10–37)
TPH C_{15}-C_{28}	mg/kg	1000*	190 (<50–890)	170 (<50–450)
PAH (total)[#]	µg/kg	45000	7.9 (<LOR–34)	12 (<LOR–64)
trans-Chlordane	µg/kg	-	-	0.8(0.2–1.3)
p,p'-DDE	µg/kg	27	-	0.3(0.2–0.4)

[#]PAHs concentrations were normalised to 1%TOC (Total Organic Carbon)
*Ecological Investigation Level (EIL), DEC 2010, Assessment levels for soil, sediment and water

DDE – dichlorodiphenyldichloroethylene

ISQG – Interim Sediment Quality Guidelines
LOR: Limit of Reporting

PAH – polycyclic aromatic hydrocarbons

TPH – total petroleum hydrocarbons

Algal blooms were recorded in the lakes during the recent study period and previous studies have reported frequent blooms dominating large areas of the lakes (Appendix I). The macroinvertebrate study also collected species indicating eutrophic conditions in the wetlands of the study area (Appendix Q).

South Metro Connect (SMC) has adopted an objective that there will be no net increase in the load of pollutants entering regional wetlands as a result of the proposed project. Accordingly, road drainage design gives consideration to the existing modified condition of the wetlands to ensure that additional contaminants and nutrients do not enter the natural systems, either in runoff or through infiltration to groundwater (Appendix H). Project contribution to wetland water quality will be assessed against the established water and sediment quality baseline.

6.4.1. Potential Impacts

A range of potential impacts on water quality were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. Design solutions were developed for the following potential impacts:

- Excavations could result in the release of groundwater to surface flow paths – the vertical alignment has been designed to ensure there is no requirement for road cuttings below the water table;
- Washdown practices could result in the release of contaminants to the wetlands via surface runoff and percolation to groundwater – washdown and maintenance areas will be established in contained areas away from the wetland boundaries;
- An accidental spill during surfacing and asphalt laying could contaminate wetlands – the activity will occur during dry conditions, which, combined with the rapid drying of material, will ensure it is unlikely that spillages will reach the wetlands; and
- Poorly stored hazardous materials and chemicals may result in contaminants reaching the wetlands – all chemical and hazardous materials will be stored in fully contained designated areas located away from the wetlands.

A detailed assessment of predicted water quality impacts is provided in Sections 6.4.2 and 6.4.3.

6.4.2. Construction Phase Impacts

The short–term impacts on water quality are related to the period of construction activities. Water quality effects could arise from:

- Sediments liberated (blown, dropped, spread or washed) from ground disturbing activities;
- Gross, suspended or dissolved contaminants in stormwater runoff from construction activities; and
- Acid sulfate drainage leaching and/or washing into surface and ground waters. This impact is discussed in detail in Section 0 and is therefore not considered further within this section.

For example, water quality can be affected by:

- Vehicle transport of soil and fill;
- Placement and storage of materials;
- Erosion and sedimentation;
- Litter, waste and washing–down practices; and
- Spills and accidental releases of chemicals.

The majority of these activities risk impacting surface water quality through loss of sediment and chemicals to surface flow paths. For dissolvable chemicals and ASS leachate, groundwater quality may also be adversely affected. The control of sediment and soils on the construction site will determine the actual risk of impact, so greatest attention will be given to site clearing and management of sediment and erosion.

Construction activities require the disturbance of the soil surfaces, after the initial removal of existing vegetation, which predisposes the site to erosion. This potentially leads to sediment loss in surface runoff into preferential flow paths, ultimately reaching the wetlands. Also, improper storage can lead to litter and other materials being blown by wind or washed away by rainfall, and washing–down practices can contaminate receiving water bodies. Site based management can eliminate the risk of such events resulting in contamination. In addition, there are various other potential risks to water quality in the area, due to inherent risks from construction circumstances. These risks can be well controlled by the implementation of appropriate management plans.

6.4.3. Operation Phase Impacts

The proposed project will have the following operational phase impacts on the existing water quality conditions:

- Road runoff polluting ephemeral flow paths that lead to existing surface water bodies and wetlands;
- Road runoff polluting soils adjacent to roads connecting to natural groundwater;
- Road maintenance activities that may cause spills and loss of chemicals; and
- Spills of hazardous chemicals entering the wetlands as a result of vehicles and hazardous freight transport.

6.4.3.1. Runoff Quality

Urban road surfaces accumulate contaminants, which are typically washed away during large storm events. Typical non–point source contaminants from roads include gross litter and particulates, nutrients, heavy metals and elemental compounds (i.e. nickel, copper, zinc, cadmium and lead), oxygen demanding materials (e.g. organic compounds), hydrocarbons (asphalt, diesel and petrol), as well as polycyclic aromatic hydrocarbons (PAHs), which are generally created as combustion by–products from fuels or accidental chemical spills. After rainfall, these contaminants flow from the road surface and potentially accumulate or migrate through surrounding soils in verges, and into flow paths or, given the transmissive nature of sands beneath the project site, the groundwater. Given the known long–term tendency for road surfaces to 'generate' low level poor quality stormwater, it is important that measures be adopted and incorporated into the proposal, that are integral to its design and its functionality.

The majority of road based contaminants are bound to fine particulates. Therefore, the fate of those particulates will determine the fate of the majority of contaminants suspended in runoff from roads or infrastructure maintenance areas. Rainfall can create shallow sheet flows over the road surface which typically provides the energy to mobilise and wash particulates (and other dissolved contaminants) into adjacent drains. It is the capture and treatment of the runoff from the road surface during the most frequent events that is most effective in controlling the load of pollutants in runoff. If road runoff volumes are captured entirely, it is possible to account for all potential contaminants into a closed treatment train, which then uses physical, chemical and biological processes to meet required water quality objectives (Appendix H).

The locations of the various elements of a treatment train are important considerations in ensuring sustained effectiveness. Generally, the adoption of best management practices within the treatment train should consider the hydrology of the contributing sub–catchments and ability of the chosen intervention to adequately remove the target pollutants within the available constraints. The ongoing maintenance and servicing of elements must also be a key consideration to ensure that appropriate technologies are positioned where they can be best accessed by relevant asset managers. For example, pre–screening devices such as gross pollutant, sediment and oil traps can be located prior to discharge of stormwater to downstream treatment systems in areas where ongoing monitoring and maintenance can be readily accommodated without disruption to either the function of the road or ancillary uses. A downstream system can include vegetated treatment elements (such as bioretention basins) which are less prone to clogging from sediment and litter and can be incorporated into the overall landscape design to enhance aesthetics. Treated stormwater can then be discharged to the receiving environment whether it be through percolation to the underlying groundwater or discharge to surface water. Usually, where site conditions permit, designers are encouraged to infiltrate at–source as many rainfall runoff events as possible. The overall stormwater management approach can therefore address issues relating to peak runoff through large capacity attenuation and water quality through vegetated treatment elements.

Potential impacts on groundwater and wetland water quality will be minimised through the implementation of stormwater design principles, the details of which are provided in Appendix H. The result will be that during road operations there will be no net impact on the existing quality of surface waters or groundwater within wetlands adjacent to the project area from road runoff.

6.4.3.2. Spills

While considered extremely unlikely, the consequences of an accident involving a dangerous goods truck that results in a spillage to the wetlands are considered significant enough to warrant detailed consideration.

A preliminary risk assessment was conducted to determine the likelihood of spilling dangerous goods on the proposed extension of Roe Highway, from Kwinana Freeway to Stock Road. Since the proposed project does not currently exist, vehicle crash statistics from the existing Roe Highway were used to determine the risk. The proposed project would have similar characteristics (design standards, speed limits, and road users) to the existing Roe Highway. The statistics were also compared to other major roads in the area, including Kwinana Freeway, Leach Highway and South Street.

Main Roads statistics for Kwinana Freeway, Leach Highway, Roe Highway and South Street for the period 1 January 2005 to 31 December 2009 are shown as the number of crashes per kilometre of road per annum involving trucks and trucks carrying dangerous goods. Based on its proposed length, adjustments were made for Roe Highway Stage 7 from South Street to Kwinana Freeway. Figure 6.4-1 shows the number of crashes per kilometre per annum on the various roads.

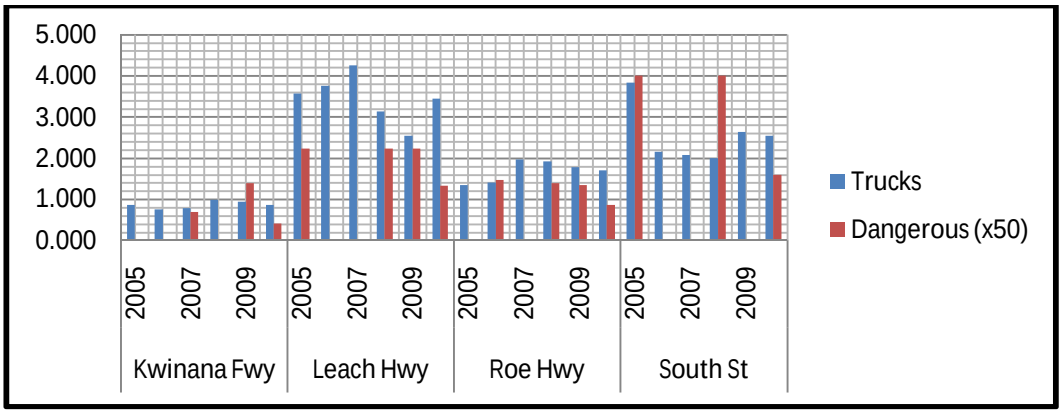


Figure 6.4-1: Number of Truck Crashes per Kilometre per Annum

As indicated by Figure 6.4-1, Roe Highway had an average of 1.734 truck crashes and 0.0178 truck crashes involving trucks with dangerous goods per kilometre per annum during the period 2005 – 2009. These figures are generally higher than that for Kwinana Freeway and are generally lower than that for Leach Highway and South Street. From Figure 6.4-1 it can also be seen that there was an increase in the rate of crashes from 2005 to 2007, with a decrease since. If the average number of crashes on Roe Highway is used as an indication of risk (evidently at a rate slightly higher than Kwinana Freeway), as long as the characteristics of Roe Highway will remain reasonably constant, then it can be assumed that:

- 1 truck will crash, on any given kilometre of Roe Highway, every 0.58 years; and
- 1 truck carrying dangerous goods will crash, on any given kilometre of Roe Highway, approximately every 56 years.

Approximately 1.2km of the proposed road surface passes directly over or adjacent to wetland environments (i.e. between Bibra Drive and Progress Drive) and is also above grade (the 'wetland section'). Assuming this section will have a similar risk profile to the existing Roe Highway then it can be predicted that:

- 2 trucks might crash within the 'wetland section' per annum; and
- 1 truck carrying dangerous goods might crash within the 'wetland section' every 47 years.

The risk of a dangerous goods truck crashing within the wetland section of the highway is calculated as 1-in-47 years

The consequences of a spillage outside of the wetland area are greatly reduced, as the road is generally through shallow excavations and the adjacent receiving environments less sensitive (than surface waters or wetlands). However, by way of comparison, for the entire 5.18km length of the proposed project, it can be expected that:

- 9 trucks will crash on the road through the proposed project per annum; and
- 1 truck carrying dangerous goods will crash on the road through the proposed project every 11 years.

A dangerous goods truck will only potentially harm the environment if its load is spilt during a crash. In the absence of evidence of spillages from the crash statistics, it can be assumed that a very small proportion of dangerous goods trucks involved in crashes will spill their loads. The 1-in-47 year possibility of a chemical tanker crashing on a stretch of the proposed project adjacent to a wetland environment is considered very unlikely as the risk of loss of significant quantities of dangerous goods becomes diminishingly small. Notwithstanding, risk management measures to reduce the risk of harm to the environment should a spillage occur are discussed below.

6.4.4. Management and Mitigation Principles

Impacts on water quality are preventable with the implementation of appropriate management practices: this section focuses on the management measures to be applied during construction and operation of the proposed project.

To best manage and mitigate against detrimental effects on the quality of water, a set of guiding principles has been developed through consultation with various authorities. These planning and design principles include:

- Avoid directing drains to natural waterways and wetlands;
- Provide buffers to sensitive water resources;
- Retain or re–establish perennial native vegetation buffers that reduce the immediate contamination risk by acting as stormwater contaminant filters and allow time for effective remedial action, in the event of a chemical spill;
- Protect vegetation, as these fringing buffers provide significant water quality benefits through their ability to sustain aquatic ecosystems and filter pollutants in stormwater runoff;
- Position the roads and the associated engineered drainage system outside the bounds of waterways and associated fringing vegetation, other than essential waterway crossings;
- Where possible retain a minimum vertical separation distance of two metres from the road sub–base to the high (wet–season) water table;
- Incorporate geometric and road safety design measures to limit the risks and effects of potential transport accidents, especially where traffic densities may be high;
- Consider location–specific management plans to cope with accidental fuel or other chemical spills. The design of the road should include measures for interim spillage control and containment; and
- Develop site–specific erosion and sediment control plans, to minimise uncontrolled stormwater runoff during construction activities.

6.4.4.1. Construction Management Practices and Procedures

Detailed preparation and adoption of site based management practices will ensure avoidance or prevention of sediment, erosion and spill risks to water quality of the adjacent wetlands. The risk of accidental discharge during construction activities will be managed by adhering to strict procedures that will be outlined in a Construction Environmental Management Plan (CEMP). Management measures will include, as a minimum:

- Staging of works by scheduling and sequencing to minimise the risk of sediment mobilisation as a result of mechanical disturbance during high rainfall events;
- Develop construction management plans with water quality management controls, such as: water supply, waste disposal, chemical use and management, material handling and storage, vehicle movement, servicing and storage, workforce awareness;
- Sediment containment and erosion management measures will be applied to limit sediment mobilisation and transport during rainfall, such as bunding, filter strips and stockpile stabilisation;
- Appropriate temporary fencing, bunding and hoarding will be installed to limit the ingress of litter and gross pollutants to flow paths and wetlands;
- Servicing and refuelling of plant and equipment within designated maintenance areas situated at least 50m from wetland boundaries;
- Spill response, cleanup and reporting procedures;

- Appropriate procedures for corrective actions and remediation requirements for salvage of chemical spills; and
- Maintenance regime for high risk items, such as hydraulic lines, with particular focus on plant and machinery being used between Progress Drive and Bibra Drive.

6.4.4.2. Water Management Principles in Design – Water Quality

The following key elements were incorporated into the working design to entrain mitigations to provide for environmental management.

6.4.4.2.1. Waterway and Wetland Buffer Vegetation

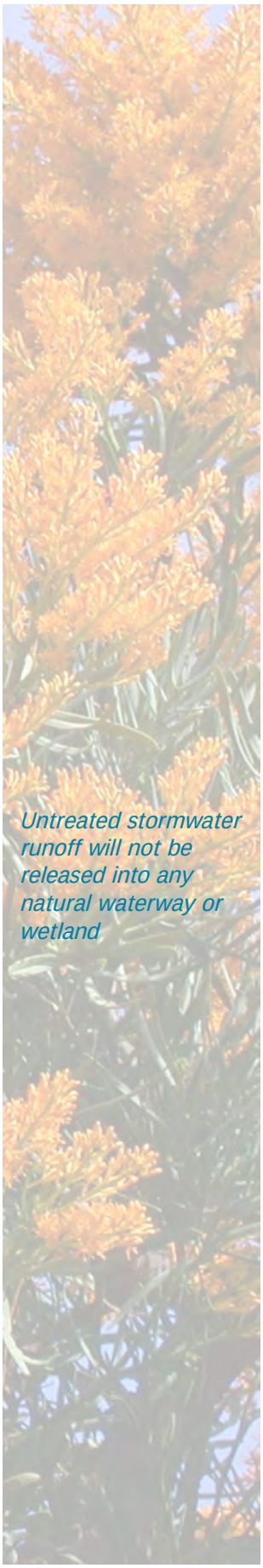
Sensitive water resources (and associated buffers) are located within or adjacent to the proposed project. The following principles were applied during the development of the concept design and consideration was given to placement of road and associated drainage infrastructure to optimise the design:

- Minimise encroachment into the buffer by considering alignment options;
- Minimise the project footprint, where practical, by using retaining walls in locations that coincide with a wetland or its buffer;
- Retain native vegetation between the toe of the alignment's formation and the edge of the current buffer; and
- Ensure the proposed treatment train provides enhancement opportunities (i.e. wetland creation) and harmonises with the area setting, where runoff discharge locations are close to or within a wetland or associated buffer.

The footprint of the proposed project (i.e. road and associated infrastructure) was minimised through the introduction of bridge openings and retaining walls through waterways and wetland vegetation, where practical. This was undertaken in order to reduce the amount of clearing required and to protect waterway and wetland vegetation, refer to Section 6.6 for more detail. Vegetation is an essential aspect of the water quality treatment chain. Every effort will be made to retain and protect existing waterway vegetation, to ensure that water quality objectives are met.

6.4.4.2.2. Engineered Drainage Systems

Engineered drainage systems for the proposed project are designed with the aim to capture, handle and treat road runoff. These have been situated outside the geomorphic wetland boundaries wetlands and associated buffers, refer to Appendix H. Buffers are considered to be a dedicated area of 50m width adjoining the wetland to be protected, as stated in the EPA Guidance Statement No. 33 *Environmental Guidance for Planning and Development* (EPA 2008b).



Untreated stormwater runoff will not be released into any natural waterway or wetland

The proposed engineered drainage systems will include:

- Pit and pipe networks adjacent to the kerb line in the new road formation;
- Proprietary systems for the removal of gross pollutants, solids that settle, oils and floatables, to be located under the road embankment/verge and upstream of discharge points;
- Headwall and outlet protection, to reduce the energy and velocity of road runoff prior to entering the bioretention basin. This will be located as close to the road embankment as practicable, and will be designed to blend into the natural environment. It may include rock protection, vegetation debris and other energy diffusing vegetation to reduce velocities, where required; and
- Bioretention basins, to provide additional water quality treatment, will be located in areas that have been identified as currently degraded or cleared of vegetation. Although the basins will be engineered systems, they are expected to provide enhancement of degraded areas by introducing native wetland vegetation to support aesthetic, ecological, social and environmental aspects, as well as water quality and quantity management objectives. The proposed basins are discussed in Section 6.3.

Engineered drainage systems proposed directly within the wetland include:

- Bridge, arch and culvert structures located at Roe Swamp; and
- Bridge and culvert structures located south of Horse Paddock Swamp.

6.4.4.3. Management of Roadway Stormwater Runoff

Untreated stormwater runoff will not be released into natural waterways or wetlands because:

- It is not a significant natural pathway of water ingress to Beeliar Chain wetlands (this is more typically groundwater); and
- It is likely to be polluted with chemicals and other potential contaminants.

As the road is situated adjacent to wetlands (including Conservation Category Wetlands (CCWs) and associated buffers), the direct runoff will be kept on the road corridor or within a purpose–built drainage system situated mostly within the Metropolitan Region Scheme (MRS). The collected runoff will then be released at controlled locations. This will be achieved by the implementation of kerbing and pit/pipe networks in the project design, to convey road runoff to suitable discharge point(s) for treatment. Appendix H provides more information on the drainage design infrastructure to be used.

Pollutants from road runoff are proposed to be managed through the following methods:

- No uncontrolled road runoff entering the CCWs or surrounding standing water environment;
- Controlled discharge of road runoff into a purpose–built treatment train;
- Treatment train comprising proprietary stormwater pre–treatment system, vegetated bioretention systems then overland flow path;
- Proprietary stormwater treatment shall provide high removal efficiencies of solids that settle and associated pollutants, oil and floatables for a chosen flow event;
- Bioretention basin to target removal of total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) to 85, 65 and 45 percent, respectively, and provide sufficient detention storage for a 5–year Average Recurrence Interval (ARI) event; and
- Overland flow path for events greater than 5–year ARI will be in the form of sheet flow facilitated by a broad crested weir downstream of the bioretention basin. Flow velocities will be sufficiently low to ensure no scour occurs (Appendix H).

6.4.4.3.1. Stormwater – modelling capture and treatment requirements

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) has been used to verify the water quality performance of the proposed bioretention system and to size it accordingly. MUSIC is a continuous time series computational model whereby historical gauged rainfall data are used to estimate both the quantity and quality of site generated runoff. These data are then used to design treatment elements which remove contaminants and report on the expected mean annual load reductions of total suspended solids (TSS) total phosphorous (TP) and total nitrogen (TN). The design of a stormwater management response which receives runoff from an entirely impervious catchment (road carriageway) negates the concern often raised with the application of continuous time series rainfall–runoff models on sandy coastal plain soils. Without the inclusion of significant pervious land cover there is high confidence in the rainfall runoff relationship and the subsequent stochastic pollutant concentrations generated. The algorithms behind the MUSIC model and pollutant inputs are described in detail in Appendix H.

Vegetated bioretention basins primarily operate by directing stormwater through surface vegetation and then runoff is allowed to filter and percolate through a prescribed filter media layer. Pollutants are retained through fine filtration, adsorption and some biological uptake. The most important functioning element in a bioretention basin is the vegetation, which enhances the function of the substrate for biological activity, facilitating gaseous exchange to the soil. It aids microbial communities in biodegradation and assimilation of contaminants collected at the treatment site.

A bioretention basin will be constructed to treat road drainage collected within the wetland section

The base of the bioretention basins will not be artificially lined and therefore free draining to the underlying groundwater. Based on the treatment processes described, outflows from the base of the system are predicted to have concentrations of total phosphorus at approximately 0.1 mg/L and total nitrogen at approximately 1.0 mg/L. In comparison with the sampled stormwater characteristics presented in Table 6.4-1 these outflow concentrations represent a significant improvement in water quality compared to existing unmitigated discharges and are predicted better than the mean water quality measured within the surface water bodies. The treated concentrations from the MUSIC modelling are considered to represent the capability of current technology. Further assessment of these outflows needs to consider dilution with groundwater from other undeveloped areas of the total catchment.

6.4.4.3.2. Bioretention and Infiltration Basins

The management of stormwater will be achieved through a combination of bioretention and infiltration basins, which will be co–located. Where the basins are located close to wetlands, the basins will incorporate a vegetated bioretention system embedded within the footprint of the overall infiltration basins. Stormwater will preferentially engage the bioretention area until the 350mm extended detention depth is reached. This typically equates to approximately the 3 month ARI event. Larger infrequent events will effectively overtop the bioretention element and engage the wider infiltration basin area. This water will subsequently percolate through the in situ sandy soils to the groundwater. The location of the basins throughout the proposed footprint is illustrated in Appendix H and Figure 3.5-1 to Figure 3.5-6.

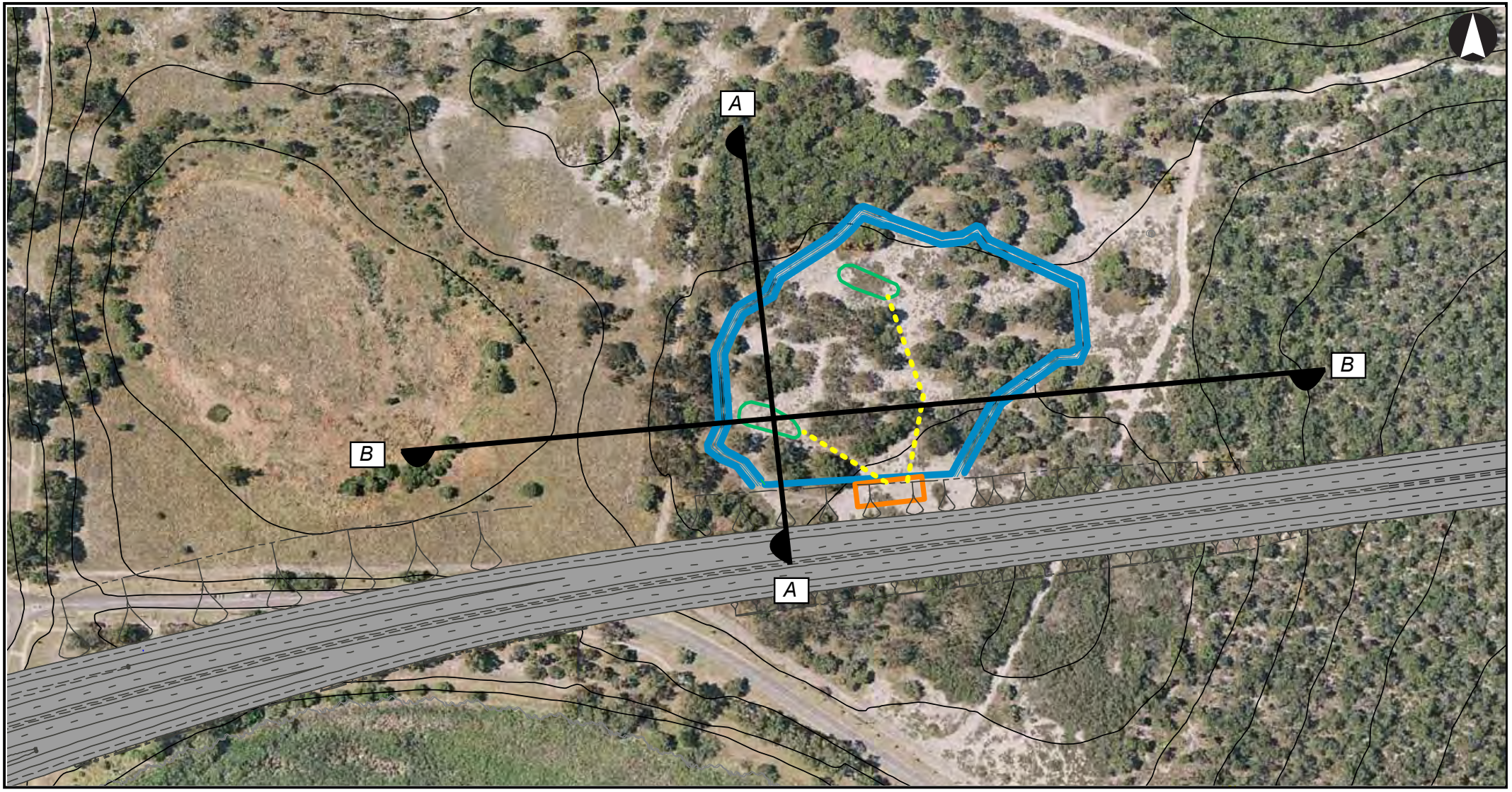
The infiltration basins have generally been sized for a 20–year ARI event unless there is an overflow route available, in which case the basins have been sized for a 1 in 5 year storm. Vegetation clearing was an important criterion in the design of stormwater basins for the project. Care has been taken to limit clearing and excavation to areas of less significant vegetation community and condition. Significant trees and other vegetation have also been avoided, wherever possible. The detailed design of the bioretention basins will include specific inundation frequency analysis to inform the selection and planting of vegetation suited to the local climate and post construction hydrology.

A large bioretention basin is proposed in an area east of Horse Paddock Swamp (Hope Road Bioretention Basin) as illustrated in Figure 6.4-2. The conceptual sketches of sectional elevations of the proposed bioretention basin are presented in Figure 6.4-3 and Figure 6.4-4. These sketches indicate the proposed areas of excavation within the infiltration basins that will be developed as dedicated bioretention elements.

The filter medium is proposed to have a saturated hydraulic conductivity of 180 millimetres per hour whereas the existing soil hydraulic conductivity is approximately 625 millimetres per hour (equivalent to 15 metres per day). This reduction of hydraulic conductivity, in addition to the biological processes attributable to the vegetation, allows TSS, TP and TN to reach reduction targets of 85, 65 and 45 percent, respectively. The bioretention systems have been designed using MUSIC software and have been designed to reach these best management practice targets of pollutant removal. This water treatment will help attain water quality requirements and goals of the project and will protect nearby environments.

In order to properly assess that the stormwater treatment basins do not adversely affect groundwater quality, monitoring will be conducted both upstream and downstream of the basin locations. In areas identified as necessary locations, consideration will be given to the development of required boreholes and accompanying monitoring and maintenance plans.

The Hope Road bioretention basin will be constructed to ensure that water quality is treated to an acceptable standard and, as such, no residual impact on water quality is predicted (Appendix H).



Hope Road Bioretention Basin Concept Plan

South Metro Connect

Figure 6.4- 2

Legend

- New bund wall
- Pipe
- Bioretention areas
- Gross Pollutant Trap/oil separator manifold combined with flow splitter and energy dissipation structure
- Proposed road
- Contour Line
- Earthworks

A — A

B — B

Sectional Elevation illustrated in *Figure 6.4- 3*

Sectional Elevation illustrated in *Figure 6.4- 4*

***Final location of piping subject to existing vegetation and to be confirmed during detail design**

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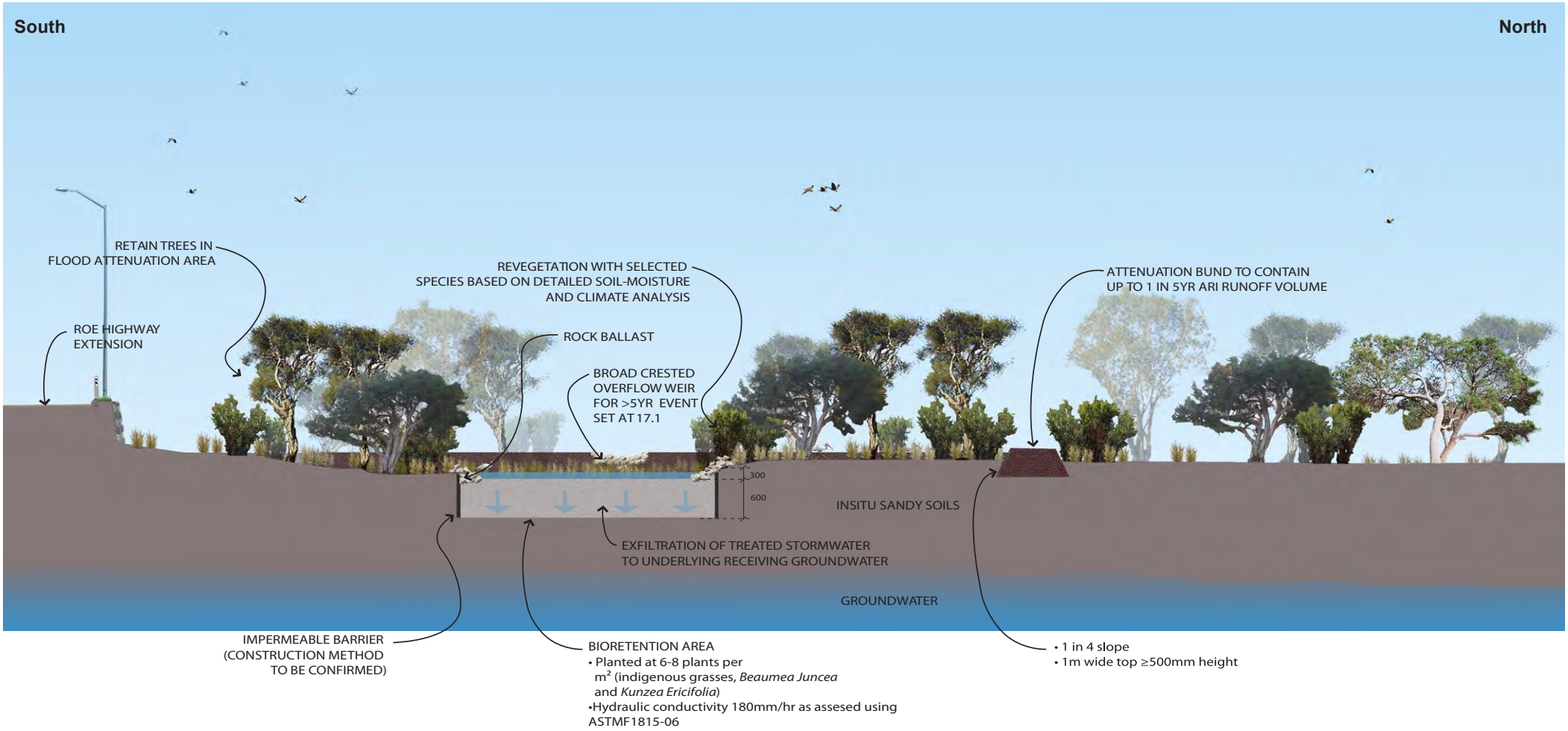

Hope Road
Bioretention Basin
Sectional Elevation A-A
South Metro Connect
Figure 6.4- 3

A — A

Sectional Elevation reference line illustrated in *Figure 6.4- 2*

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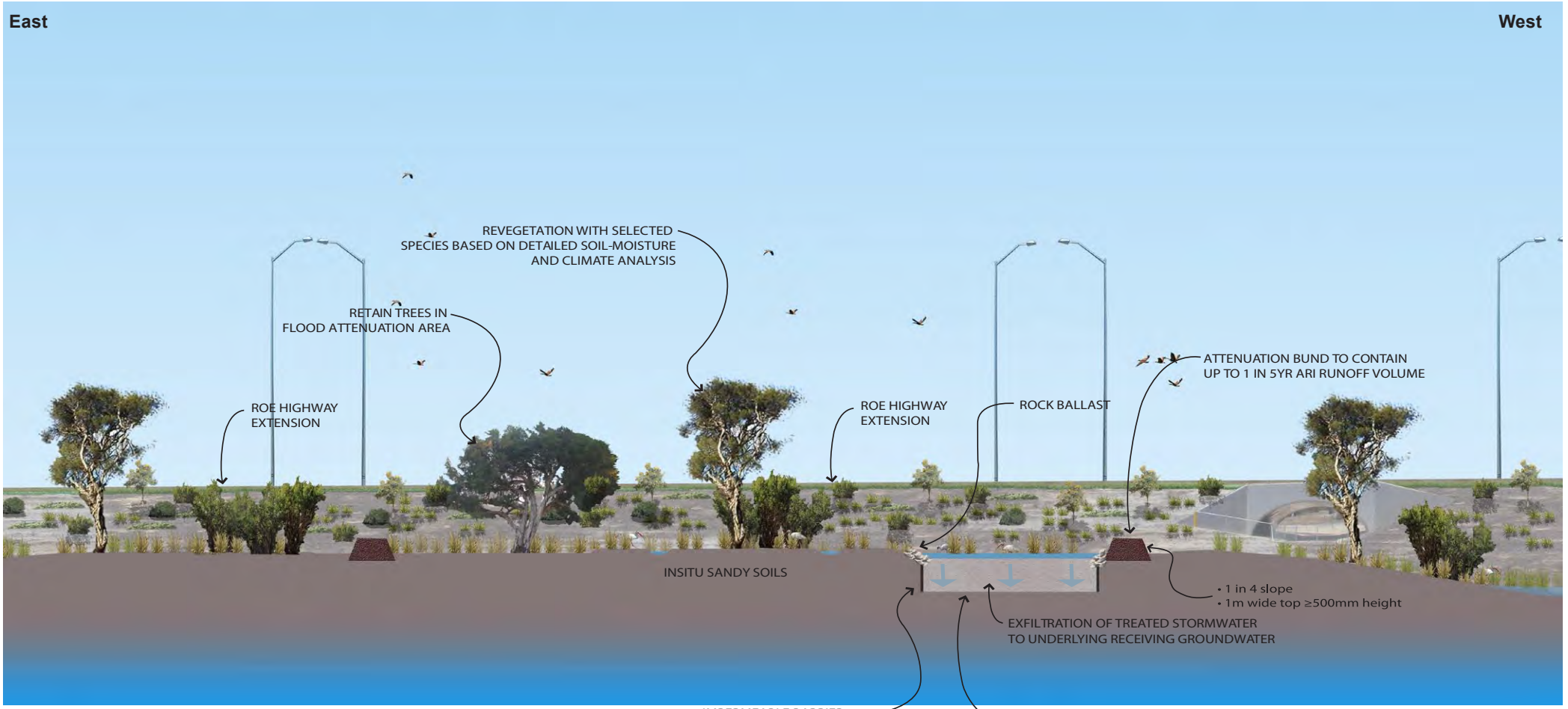
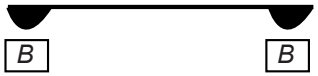


Hope Road
Bioretention Basin
Sectional Elevation B-B
South Metro Connect
Figure 6.4- 4



Sectional Elevation reference line illustrated in *Figure 6.4- 2*

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6.4.4.4. Transport Accidents causing Spills and Contamination

The design, which conforms to safety standards aimed at minimising the risk of accidents during operation, includes the installation of concrete barriers where retaining walls and bridges are proposed, including the section through Roe Swamp CCW and the south side of the bridge between Horse Paddock Swamp and Bibra Lake. In addition, a concrete barrier will be installed above the embankment adjacent to Horse Paddock Swamp to a point at least as far as the eastern edge of the proposed bioretention basin. Furthermore, the curvature of the road ensures that the majority of incidents will be either in the direction of the centre of the road (west bound traffic) or away from Roe Swamp (east bound traffic). These measures ensure that the majority of incidents will be fully contained within the road area.

The stormwater management system has also been designed to contain spills by incorporation of:

- Kerbing of the road between Bibra and Progress Drives, such that road runoff is managed through a pit and pipe network and discharged at controlled locations to be treated in a proprietary stormwater treatment system before entering a purpose–built bioretention basin;
- Inclusion of oil/water separators in the stormwater drainage system, and the capacity to isolate their discharge points; and
- Collection of all road pavement runoff into either bioretention or infiltration treatment basins.

For the very rare event that an incident results in a chemical spill within the wetland area, emergency response plans will be developed in coordination with the Department of Environment and Conservation to ensure that spillages are contained as much as practicable.

Concrete barriers and kerbing will be installed in sensitive areas to contain potential spills

6.4.5. Summary and Conclusions

The following statements summarise key findings related to direct impacts on surface and groundwater quality, additional indirect effects and makes conclusions in relation to the stated key matters within EPA Bulletin 1088.

6.4.6. Residual Impacts

Extensive investigations of the study area wetlands indicate that both surface and groundwater quality within and adjacent to the project area currently contain elevated levels of pollutants and contaminants. While detectable in their presence, none of these (tested) pollutants lead to concern for ecological or human health. These measured levels of contaminants such as metals (and other elements), pesticides, hydrocarbons and nutrients in water and lake sediments provide:

- Evidence of historical catchment disturbance, modifying processes and effects caused by past activities and ongoing catchment processes; and
- A baseline for assessing the performance of future development activity, including the construction and operation of the Roe Highway.

Construction activities required for the proposed project will be undertaken in accordance with strict management protocols that are designed to limit the risk of sedimentation (from ground disturbance and clearing) and contaminants (from equipment) entering adjacent protected wetland systems or infiltrating to groundwater.

The proposed project has been designed for its operations so that road drainage is contained within a stormwater drainage system and directed to appropriately–sized infiltration and/or bioretention basins for treatment, before release. Purpose–designed elements will include pervious filter media for the basin beds and provenance native vegetation for biologically enhanced activity within certain basins. Down–gradient water quality performance monitoring will be undertaken for the Hope Road bioretention basin.

Road safety requirements will ensure that the risk of accidental spillage from traffic incidents is minimised and contained within proprietary systems for extraction.

Management of water quality in road runoff (including from all sealed surfaces) will capture and direct a small proportion of total annual volume of water that would otherwise percolate into local soils away to treatment basins. This may cause a slight reduction in runoff water to vegetation down–gradient to the road formation. After treatment, those waters percolate to the groundwater. This will result in localised mounding but importantly those treated waters will return to regional water cycle pathways.

A summary of the management, mitigation and residual impacts associated with water quality is presented in Table 6.4-4.

Table 6.4-4: Residual Impacts on Water Quality

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Earthworks causing sediment movement or chemical loss from construction area to flow paths and wetlands	Construction traffic and disturbance of vegetation will expose soils to erosion and sediment movement during and after heavy rainfall events Stockpiling of imported materials may result in loss to drainage paths and adjacent waterways	Adopt site based management practices for sediment containment. Avoid winter works between Bibra Drive and Progress Drive. Site preparedness against erosion prior to onset of winter rains	Low levels of sediments liberated into adjoining flow paths where site containment temporarily fails after heavy or unseasonal rains

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Oxidation of PASS with leachate into surface and ground waters The project area has the potential for ASS to occur within three metres of natural surface. If disturbed, sulphide minerals in the soil may oxidise to create acidity, potentially liberating metals into surface and ground waters	Investigations confirmed that the spatial distribution of ASS will require appropriate management, including handling, treatment and disposal	Nil
Operation and maintenance of plant and machinery	An accidental spill of harmful substances that enters the ground or surface water is predicted to cause some degree of environmental harm, particularly to wetland ecosystems	Strict protocols regarding the location of and requirements for the maintenance, servicing and refuelling of construction machinery Development of an Emergency Response Plan (ERP) that incorporates management measures or processes aimed at reducing potential impacts from accidental release of contaminants Development of a CEMP to prevent spills during construction as well as to specify procedures for remediation in the event of contamination	Nil The CEMP, ERP and maintenance and servicing protocols during construction are sufficient to provide adequate management of these predicted impacts
Operation Phase			
Non hazardous vehicles and Hazardous freight transport spillage	In the rare event that a bulk chemical tanker accident results in discharge into the wetland areas, there is the potential for a decline in ecosystem function	Medium performance concrete barriers with top rail will be installed at bridge locations and full height retaining walls with wire rope barriers installed at remaining sections along the alignment Development of an Emergency Response Plan in consultation with DEC	Nil There is less than a 1-in-47 year chance that a crash involves a bulk chemical tanker will result in the discharge of hazardous chemicals and this will be captured by the closed reticulated drainage prior to reaching wetland

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Stormwater runoff from road surface and infrastructure	Road runoff will contain pollutants from vehicles that had accumulated on pavements, potentially draining to existing surface water bodies and/or road verges into groundwater Many pollutants are already detectable in regional wetlands surface waters and sediments and stormwater elsewhere in the catchment and SMC would increase the pollutant load	Integrated stormwater design, management and treatment systems (including bioretention basin) to collect and restore water quality prior to return to the water cycle and the regional environment Performance monitoring to substantiate quality criteria	Nil
	Bioretention basins	Basins will provide the distal part of closed treatment train with release of captured treated waters into groundwater	Local groundwater mounding at site of percolation

6.4.6.1. EPA Bulletin Matters

These EPA Bulletin does not specifically identify pollution or contamination of waterways or wetlands as an impact risk from aspects such as the Roe Highway construction or road traffic. However the following responses are made.

Bulletin 1088 Statement	Proposed Project Concept Response
"...dense wetland vegetation associated with Roe Swamp potentially plays a role in moderating the chemistry of groundwater inputs from the east. Therefore, the protection of this vegetation is considered to be a high priority"	The risk to groundwater chemistry, in the part associated with reduced vegetation coverage in Roe Swamp and with runoff, is addressed by a number of design mitigations: • A reticulated stormwater drainage system • Spill control and interception devices from hazardous road crash materials (fuels, hazardous materials, wastes, chemicals) • Constructed retention basins with rehabilitated vegetation will be used to recharge treated catchment water captured from stormwater (in direct proportion to its rainfall occurrence) into the regional aquifer • Implementation of Environmental Management Plans for the disturbance footprint / construction areas The design response to vegetation loss is described elsewhere. Dense native and/or high quality vegetation is largely avoided and rehabilitation of degraded vegetation is proposed to enhance the functions such as water chemistry, eco–hydrology and habitat availability

6.5. Acid Sulfate Soils and Existing Ground Contamination

The EPA does not have a specific objective for acid sulfate soils (ASS); however, the objective of the *Acid Sulfate Soils Planning Guidelines* (WAPC 2008) jointly prepared by the Western Australian Planning Commission (WAPC) and DEC is:

> *To ensure that the subdivision and development of land containing acid sulfate soils is planned and managed to avoid potential adverse effects on the natural and built environment*.

In relation to pollution management, the EPA states the following objective:

> *To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.*

General EPA objectives relevant to potential impacts associated with ASS and management of existing contaminated sites include the following:

> *To maintain integrity, ecological functions and environmental values of wetlands, soil and landform* (EPA 2009d); and

> *To ensure that remediation of site contamination achieves an acceptable standard that protects the environment, is compatible with the intended land use, and is consistent with appropriate criteria* (EPA 2008b).

6.5.1. Potential Impacts

Potential acid sulfate soils (PASS) exist throughout the Swan Coastal Plain. Left undisturbed and under anaerobic conditions, they generally do not pose a risk to the environment. However, activities that cause PASS to become oxygenated will result in the formation of actual acid sulfate soils (AASS), which can cause significant environmental impacts without proper management.

With respect to potential sources of contaminants, the preliminary site investigation conducted for the proposed project (Appendix E) determined that there is a relatively low likelihood of encountering contaminated sites within the project area. Nevertheless, historical practices of using wetlands for both formal and informal waste disposal mean that the potential for encountering unrecorded contaminated sites exists in the following ways:

- Inadequate management of ASS has the potential to result in a range of environmental impacts. Design solutions have been developed to avoid or minimise the risk of several of these: Groundwater drawdown may arise from abstraction of construction water, which has the potential to result in oxidation of ASS – construction water will be sourced from outside the project area;

- Construction of bridge supports could result in the exposure of ASS, resulting in the acidification of receiving waters – the Roe Swamp piles will be driven, avoiding the need to bring drill spoil to the surface. The bridge at Horse Paddock Swamp will be constructed on spread footings, which are unlikely to require excavation beneath maximum groundwater levels;
- There is a risk that excavation for road construction will disturb historically contaminated sites – with the exception of an historical landfill, most potential sources of contamination resulting from historical land use are avoided by the proposed alignment; and
- Once in place, the road formation may exert sufficient downward pressure to reduce maximum groundwater levels adjacent to the road, resulting in oxidation of ASS – ground compression is assessed as unlikely to result in a significant change in maximum groundwater levels (See Section 6.3), which already fluctuate significantly both seasonally and over the long term.

6.5.2. Construction Phase Impacts

ASS have the potential to form where excavations or dewatering result in the oxidation of PASS. The majority of the proposed project that passes through high risk ASS will not be disturbed other than by removing up to a 300mm depth of topsoil and adding fill material. It is unlikely that this excavation will disturb PASS, as the topsoil to be removed currently undergoes seasonal wetting and drying. There is a short cutting to a depth of about 2m in a sandy rise to the west of Roe Swamp that will not intersect the water table.

Murdoch Drain currently sits within an area of high risk ASS. Since construction, Murdoch Drain has developed its own ecological function and is now considered a functioning component of the Roe Swamp system. The proposed project requires that a section of Murdoch Drain is filled. It is proposed that the drain be realigned by excavating a channel immediately north of the proposed road in order to maintain connectivity and the ecological function served by the drain. Excavation required for the realignment of the drain is likely to disturb PASS.

The impacts of oxidation of PASS as a result of excavation or dewatering can be serious, as sulphuric acid and metals can potentially be released into the sensitive wetland environment. Corrosion of concrete foundations and structures in the long–term can also occur as a result of ASS being disturbed during construction.

As with other construction projects involving excavation within an urbanised area, there is a risk of encountering previously unrecorded contaminants within the project area. Historical land use suggests that the likelihood of this occurring is low. However, wetlands have been historically used for both formal and informal sanitary landfill and the risk that there are unknown landfills within the project area warrants further consideration.

There is a potential that excavation activities may also result in the disturbance of potentially contaminated ground that currently has no pathways to sensitive receptors. Furthermore, the use of this material as fill in other areas of the proposed project, particularly areas with transport pathways to sensitive receptors (such as near wetland areas) could result in contamination. The likelihood of this occurring is greatest where material excavated from the area between Progress Drive and Stock Road is used for fill between Progress Drive and Kwinana Freeway.

The sections below contain a brief assessment of landfills, other sites; as well as rubbish and other contaminants within the project area.

6.5.2.1. Landfills

Historical landfills are known to exist within 2km of the project area (Figure 5.4-2). Owing to their locations in relation to the project area and the generally westerly direction of groundwater flow, these abandoned sanitary landfills will not have an impact on the proposed project.

From examination of historical aerial photographs, an area that (prior to 1970) was subject to land filling and is located adjacent to the southern boundary of the project area, south–east of the intersection of Bibra Drive and Hope Road. This area has been occupied by a residential development since before 1989 and is not listed in the Department of Environment and Conservation (DEC) contaminated sites database (CSD).

Interpretation of historical aerial photography indicates that there is possibly an unrecorded landfill site adjacent to Bibra Drive. The preliminary site investigation (PSI) indicates that this area does not encroach into the construction area; however, the accuracy of the record is unknown and there is a minor risk that construction works will result in the unplanned release of contaminants, resulting in environmental harm (refer to Appendix E).

6.5.2.2. Rubbish and Other Contaminants

It was evident during visual inspections of the project area that rubbish, including fragments of asbestos, had been dumped in various locations. It is also known that some fence sheeting in the area contains asbestos. Management of such materials is required.

6.5.3. Management and Mitigation

Giving due consideration to the proposed cut and fill design profile, the results of investigations to date indicate that treatment of minor quantities of ASS will be required. However, further investigations will be required to assess and quantify high risk areas, where access has been restricted to date (i.e. Aboriginal sites), and along the proposed realignment of part of Murdoch Drain.

Treatment of minor quantities of ASS will be required

Detailed sampling of high ASS risk areas will be undertaken prior to construction

A detailed study of a suspected landfill east of Roe Swamp will be undertaken

Practices and procedures for the management and treatment of ASS in Western Australia have been developed over the last 10 years through both industry and Government initiatives. These are documented as draft guidelines (DEC 2009b).

The primary approach for the management of ASS during the construction phase of the proposed project is avoiding its disturbance. Avoidance will be achieved in high ASS risk areas located in the vicinity of Hope Road by removing the topsoil to a depth of up to 300mm prior to the placement of clean non–acid sulfate soil (NASS) fill material.

Avoiding the disturbance of ASS material will also be achieved by staging construction works such that excavation within high risk areas occurs during drier months of the year, to limit the need for dewatering. This will be essential for the construction of Murdoch Drain.

Topsoil excavated during the construction phase of the proposed project will be field tested for ASS. If results of field tests are negative, no treatment (addition of lime) will be required. However, if field test results are positive, Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) testing will be undertaken to determine the appropriate liming rates required to neutralise the soil.

The results of the field and laboratory testing obtained in this study could be used as a basis for the initial assessment of ASS; however, a comprehensive assessment is contingent on the results of further detailed investigations. Based on the current level of detail available, it is expected that the requirement for lime dosing will be minimal, other than possibly for the realignment of part of the Murdoch Drain. Lime dosing requirements will be determined in accordance with DEC guidelines (DEC 2009b).

To prevent long–term damage to concrete foundations and structures, construction mitigations will be implemented in areas where PASS are to be disturbed. In such areas, piled foundations will be surrounded by a steel liner filled with concrete to prevent corrosion of the pile. For pre–cast foundations, a corrosion prevention additive will be used in the concrete. Bore hole investigations will be initiated prior to ground disturbance to identify the extent of PASS disturbance and consequent mitigation requirements.

Main Roads commits to the detailed sampling of high ASS risk areas within the project area prior to the construction phase. This will be accomplished to determine accurate lime dosing requirements and to provide information for the development of a detailed ASS Management Plan (ASSMP), in accordance with DEC guidelines. Main Roads also commits to ensuring that construction activities do not result in the release of existing contaminants.

With respect to sources of potential contamination, Main Roads will undertake a detailed study of the suspected landfill located approximately 300m east of Roe Swamp. This study will be conducted to gain a better understanding of historical land use and its potential impact on soil and/or groundwater in the project area.

If the study concludes that project construction will result in the disturbance of contaminated material from this potential source, a detailed investigation and remediation programme will be undertaken in accordance with DEC guidelines. A Construction Environmental Management Plan (CEMP) will be prepared to address circumstances where construction activities result in:

- Unexpected excavation of contaminated areas;
- Unearthing of rubbish and other contaminants dumped within the project area; and
- Handling of asbestos sheeting, mainly from fences.

The CEMP will specify:

- Procedures to be implemented if unexpected contaminants are disturbed;
- Appropriate licensed landfill locations for the disposal of contaminated material; and
- General construction practices to minimise the risk of disturbing in situ contaminated material.

6.5.4. Summary and Conclusions

Following implementation of management and mitigation measures, no residual impacts associated with ASS and other sources of contamination will remain. A summary of the mitigation and management proposed for these factors is presented in Table 6.5-1.

Table 6.5-1: Residual Impacts Associated with ASS and Sources of Potential Contamination

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Creation of storage areas for lime for ASS treatment	Improper storage of lime will result in contaminated runoff from the storage area entering the project area waterways. Substantial contamination of waterways will cause changes in pH and subsequent adverse impacts on aquatic life	CEMP will include requirements for containment of site drainage within laydown and storage areas Development and implementation of an ASSMP that details requirements for lime storage	Implementation of the proposed ASSMP and CEMP will ensure adequate management of this impact

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Excavation of road cuttings and other earthworks, including construction of bioretention and drainage basins	If inappropriately managed, PASS oxidised during dewatering will release metals and sulphuric acid, which will cause deterioration of water quality and ecosystems in a sensitive wetland area	Development of an ASSMP that specifies that dewatering is minimised Schedule excavation works that require dewatering when the groundwater table is near its seasonal low level Implement an appropriate management strategy, consistent with the principal of avoidance	Implementation of the proposed ASSMP as well as minimisation of dewatering and appropriate timing of excavation works, will ensure adequate management of this impact
	If inappropriately managed, PASS disturbed during construction will cause corrosion of foundations and structures	Undertake detailed sampling and SPOCAS testing to accurately determine extent of PASS to be disturbed Development of an ASSMP Utilisation of steel liners or concrete additives in areas of PASS disturbance	Implementation of the proposed ASSMP and protective coatings/additives, where necessary, will ensure adequate management of this impact
	If excavation disturbs previously dumped rubbish containing contaminants, such as asbestos, exposure to such items will lead to contamination of soil and/or groundwater and adverse human health effects for workers handling the contaminated material	Development and implementation of a CEMP As part of the CEMP, development of appropriate identification, removal and disposal methods in accordance with DEC and Department of Health *Guidelines for Assessment, Remediation and Management of Asbestos–Contaminated Sites in Western Australia* (2009) prior to commencement of earthworks and in conjunction with land clearing activities	Proposed management and mitigation measures will ensure adequate management of this impact

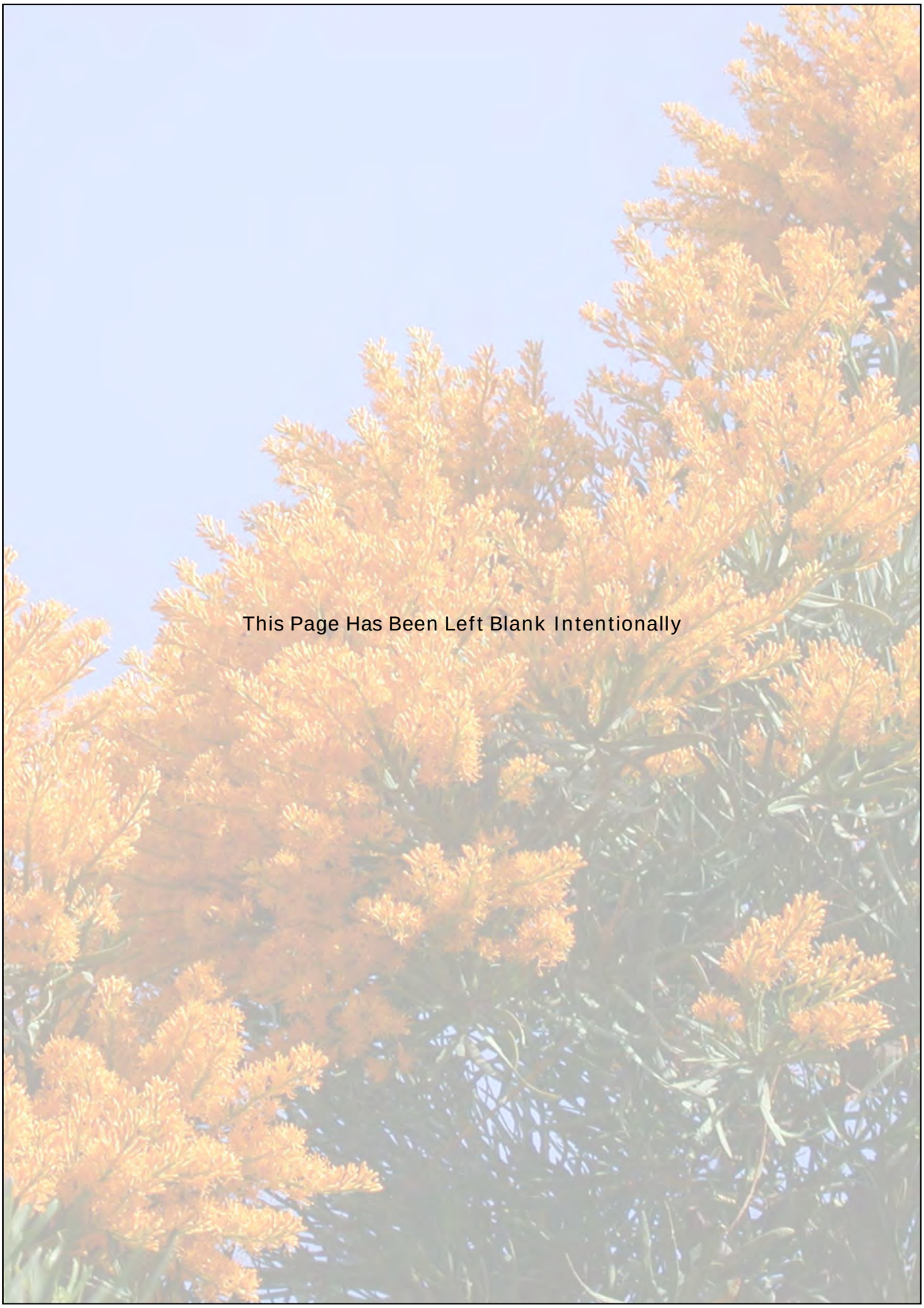
Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	If contaminated soil is transferred from one part of the project area for use as fill elsewhere, it will cause contamination of previously uncontaminated areas	Development and implementation of a CEMP	Proposed management and mitigation measures will ensure adequate management of this impact
Excavation and placement of fill, including Murdoch Drain re–alignment	Exposure and oxidation of PASS will release sulphuric acid and metals, and cause deterioration of water quality and ecosystems in a sensitive wetland area	Undertake detailed sampling and SPOCAS testing to accurately determine necessary liming rates Development of an ASSMP Schedule excavation works that require dewatering when groundwater levels are at their lowest levels Implement an appropriate management strategy, consistent with the principal of avoidance	Implementation of the proposed ASSMP as well as minimisation of dewatering and appropriate timing of excavation works, will ensure adequate management of this impact
	Importation and use of contaminated fill during construction of the road will introduce contaminants into the project area	Development and implementation of CEMP outlining procedures to manage screening of imported fill	Proposed management and mitigation measures will ensure adequate management of this impact

CEMP – Construction Environmental Management Plan

ASSMP – ASS Management Plan

Minimisation of dewatering and avoiding the disturbance of PASS; as well as preparation and implementation of an ASSMP will ensure optimal management of ASS. The WAPC, DEC and EPA objectives regarding ASS and protection of wetlands and landforms will therefore be satisfied in relation to this factor.

The development and implementation of a comprehensive CEMP will ensure that the EPA objective regarding release of potential pollutants or contaminants from historically contaminated sites is satisfied and that contaminants and rubbish are properly disposed of. Although records indicate that there are no known contaminated sites within the project area, the CEMP will ensure that procedures are in place to prevent the release of contaminants from previously unrecorded sites that are inadvertently disturbed by construction activities.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6.6. Flora and Vegetation

The EPA objective in relation to flora and vegetation is:

> *To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.*

EPA Bulletin 1088 (EPA 2003) expresses the following key concerns relating to potential impacts of the extension of Roe Highway on flora and vegetation values:

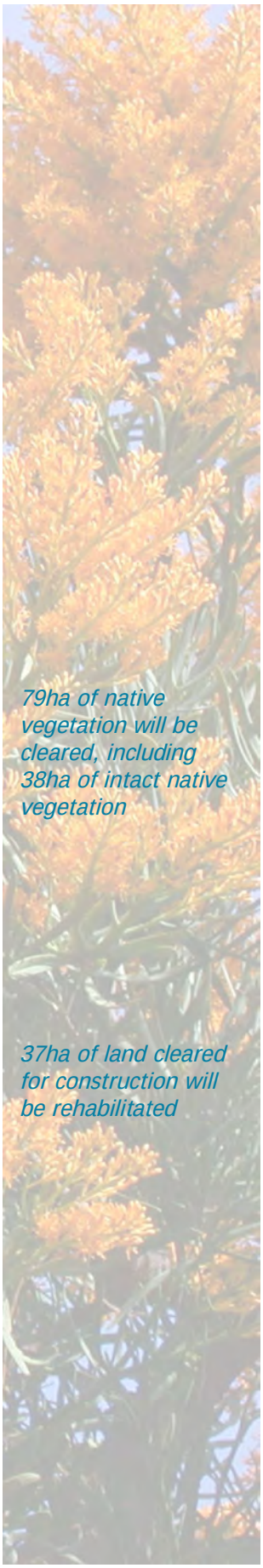
- Construction of the Roe Highway extension would involve clearing of remnant native vegetation within Bush Forever Site 244;
- Construction of the highway extension would also result in off–site impacts on vegetation of the Karrakatta Complex – Central and South, situated south of the alignment and within Bush Forever Site 244;
- Construction of the highway extension would impact vegetation located to the west of Progress Drive (identified as Karrakatta Complex – Central and South) and to the east of Bibra Drive (identified as Bassendean Complex – Central and South);
- The highway extension would cause a loss of gradation from wetland to upland vegetation. It would also result in the loss of regionally significant vegetation which is not well represented within the Eastern Chain of the Beeliar Wetlands;
- Clearing of vegetation within the Roe Swamp complex would lead to significant impacts on the functions, values and fauna habitats of this wetland, as well as on the ecological linkages it currently maintains with North Lake and the wetland complex to the north; and
- Viability and long–term management of the vegetation within the area will be reduced as a result of the area being further fragmented by the highway extension.

The EPA considers protection of the dense wetland vegetation occurring in Roe Swamp in particular to be a high priority given its potential role in moderating chemistry of groundwater arriving from the east (EPA 2003).

6.6.1. Potential Impacts

A range of potential impacts on flora and vegetation were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. The following potential impacts are either not considered to be significant or have been addressed through design solutions:

- Vegetation removal could result in a loss of State listed Declared Rare Flora (DRF) or Commonwealth listed threatened flora – there are no historical or current records of DRF from within the project area so listed species will not be impacted;
- Vegetation removal could result in the loss of Threatened Ecological Communities (TECs) or Priority Ecological Communities (PECs) – there will be no clearing of TECs or PECs as there are no historical or current records within the project area;



79ha of native vegetation will be cleared, including 38ha of intact native vegetation

37ha of land cleared for construction will be rehabilitated

- During construction, inappropriate disposal of construction waste (including litter of personal consumer waste or construction waste) could smother vegetation and impede its growth – standard construction procedures require that construction and personal waste is appropriately contained and disposed off site;
- Operation of the road may result in an increased occurrence of fire – it is unlikely that the road will result in an increased occurrence of fire given the separation between vehicles and vegetation. In addition, the road itself will function as a firebreak, reducing the consequence of fires caused by external influences; and
- The presence of the road could cause an alteration in vegetation composition and distribution in response to altered water availability – the project design incorporates creation of a bioretention basins in the form of a constructed wetland area to contain and treat stormwater collected from the alignment where it passes through the wetlands. Alteration in vegetation composition will be confined to locations immediately adjacent to retention/infiltration basins.

A detailed assessment of predicted flora and vegetation impacts is provided in Sections 6.6.2and 6.6.3.

6.6.2. Construction Phase Impacts

6.6.2.1. Removal of Vegetation

The project footprint is currently represented by vegetation in a range of conditions, as described in Section 5.8. More than 54 percent of the project area has been mapped to be in 'Degraded' condition or worse ('Completely Degraded'), and 27 percent has been mapped to be in 'Good' condition or better. No areas of 'Excellent' condition were recorded within the project footprint. Table 6.6-1 presents the area of impact for each vegetation condition rating.

Table 6.6-1 shows that the total clearing for the project will require the removal of 79.3 hectares of native vegetation, of which 41.8 hectares will be permanently cleared. The remaining 37.5 hectares includes embankments, temporary storage and laydown areas and traffic bypasses (side tracks) and will be available for rehabilitation upon completion of construction. The area of vegetation to be retained under the proposed bridge structures has not been included in the value of vegetation to be cleared. Of the total area to be cleared, 37.5 hectares (47 percent of the cleared area) is native vegetation rated as 'Degraded to Good' condition or better, hereafter referred to as intact native vegetation. The remaining 41.8 hectares consists of areas that have been cleared or are devoid (or almost so) of native vegetation (rated 'Degraded' or poorer).

Table 6.6-1: Clearing Impacts by Vegetation Condition Rating

Condition Rating	Extent within Project Area (ha)	Approximate Construction Footprint (ha) (Permanent and Temporary Clearing)	Approximate Project Footprint Area (ha) (Permanent Clearing Only)
Excellent	0	0	0
Very Good	3.5	0.2	0.1
Good to Very Good	20.3	6.4	3.4
Good	45.1	13.2	7.0
Degraded to Good	46.4	17.7	8.9
Degraded	24.4	11.2	6.0
Degraded to Completely Degraded	58.1	24.3	13.2
Completely Degraded	55.9	6.3	2.9
TOTAL	253.7	79.3	41.5

Table 6.6-2 presents the area of each intact native vegetation community impacted by clearing (not degraded variants) for the proposed project. The conservation significance for each vegetation communities (for a range of reasons) are also identified. The final column shows the percentage of the area of each mapped community within the project area that would be retained. Refer to Table 5.8-5 for vegetation community descriptions and Figure 5.8-3 and Figure 5.8-4 for community distribution.

Table 6.6-2: Clearing Impacts by Vegetation Community

Vegetation Community	Approximate Extent within Study Area (ha)	Approximate Extent within Total Construction Footprint (ha)	Approximate Extent within Permanent Footprint (ha)	Community Significance	% Mapped Community Retained
BahS	2.1	2.1	1.1	Limited local representation (locally significant)	0
BHhW	15.5	11.6	6.5	Supports Priority Flora (*Cyathochaeta teretifolia* (P3), *Dampiera triloba* (P1) and *Jacksonia gracillima* (P3)) and PMR significant flora species (*Chamelaucium uncinatum, Conostephium minus*)	25.2
BXpW	15.2	1.2	0.7	None identified	92.4
BaNfW	0.4	0.3	0.2	Limited local representation (locally significant)	27.1
BaTs	23.1	10.6	5.0	Supports PMR significant flora species (*Chamelaucium uncinatum, Conostephium minus*)	54.4
BiSiH	2.6	0.6	0.4	Supports Priority Flora (*Jacksonia gracillima* (P3)) Limited local representation (locally significant)	75.2
CcAf	<0.1	<0.1	<0.1	None identified	0
CcBKgS	4.5	0.5	0.4	Supports Priority Flora (*Jacksonia gracillima* (P3), *Cyathochaeta teretifolia* (P3) and *Dampiera triloba* (P1) and a PMR significant flora species (*Conostephium minus*)	88.2
CcXpDdS	9.3	6.8	2.9	None identified	26.7
CcXpMrS	29.9	19.5	10.7	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3), *Tetraria* sp. Chandala (P2)) and a PMR significant flora species (*Chamelaucium uncinatum*)	35.0

Vegetation Community	Approximate Extent within Study Area (ha)	Approximate Extent within Total Construction Footprint (ha)	Approximate Extent within Permanent Footprint (ha)	Community Significance	% Mapped Community Retained
EgXpS	23.6	10.1	5.5	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3)) and *Jacksonia gracillima* (P3)), a Priority listed and PMR significant flora species(*Dodonaea hackettiana* (P4)) and PMR significant species (*Lechenaultia linarioides*)	57.1
EmApS	7.9	2.7	1.6	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3))	66.0
EmBaS	1.8	0.6	0.1	None identified	65.4
EmKgS	3.2	2.5	1.1	Supports a PMR significant flora species Region (*Hibbertia cuneiformis*)	22.6
EmXpS	6.9	3.7	2.0	Supports Priority Flora (*Eryngium pinnatifidum* subsp. *palustre* (P3) and a PMR significant species (*Chamelaucium uncinatum*)	46.1
ErCtS	2.5	0.2	0.1	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	92.1
ErMpAfS	2.5	0.7	0.5	Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3) and *Jacksonia gracillima* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	71.4
ErMpGeS	0.8	0.4	0.2	Limited local representation (locally significant) Supports Priority Flora (*Cyathochaeta teretifolia* (P3), *Cyathochaeta teretifolia* (P3) and *Jacksonia gracillima* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	48.4
ErMpH	12.8	1.5	0.5	Supports a PMR significant flora species (*Hibbertia cuneiformis*)	88.0

Vegetation Community	Approximate Extent within Study Area (ha)	Approximate Extent within Total Construction Footprint (ha)	Approximate Extent within Permanent Footprint (ha)	Community Significance	% Mapped Community Retained
EtKgS	0.8	0.4	0.2	Limited local representation (locally significant) Supports a PMR significant flora species (*Hibbertia cuneiformis*)	54.1
MpBaS	5.0	<0.1	<0.1	None identified	99.4
MpKgS	1.5	0.5	0.4	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1) and a regionally significant flora species (*Ixiolaena viscosa*)	64.6
T1	6.5	0.3	0.1	None identified	95.9
TBS	1.7	<0.1	<0.1	None identified	98.6

PMR – Perth metropolitan region

The community significance column in Table 6.6-2 shows that 12 species of significance have been recorded within the vegetation communities that will be affected by the proposed project. These species include Priority Flora, species that require taxonomic (identification) review, regionally significant flora and significant flora of the Perth metropolitan region. Of these classifications, Priority Flora are of higher importance for conservation purposes.

Poor representation is a typical characteristic of communities of significance. Loss of these community types from clearing will reduce this representation in the local and regional context.

The final column of Table 6.6-2 presents the percentage area of each of the communities that were mapped within the 258 hectare study area that will be retained (i.e. area outside the proposed project footprint). A number of these communities will have their extent within the project area reduced, with BahS and CcAf in particular being completely removed from the project area.

BahS and CcAf will be completely removed from the project area

The species composition of the intact vegetation communities recorded within the project area were analysed and compared to the Gibson *et al.* (1994) dataset to infer Floristic Community Types (FCTs) present in the project area. A number of vegetation communities, including CcAf, were found to be too degraded or lacked sufficient native species for statistical comparison with this dataset.

All of the FCTs supported by the project area are documented to be 'Well Reserved' and at 'Low Risk' of extinction (Appendix K). Based on this information, and consultation with the DEC, it was determined that none of the vegetation communities within the project area is considered to be equivalent to PECs or TECs under either State or Commonwealth listings.

The EPA holds an objective of retaining at least 30 percent of pre–European extent of vegetation types (EPA 2000). The proposed project will result in removal of vegetation from four vegetation complexes, two of which are already below this threshold (

, shown in Figure 5.8-2). However, none of these reductions will result in a significant change to their current extent, with the extent of Bassendean Complex – Central and South falling by 0.3% of its current extent (<0.1% of its original extent) and the Karrakatta Complex – Central and South being reduced by 0.3% (<0.1% of its original extent). Following implementation of the proposed project, the extents of the Herdsman Complex and Cottesloe Complex – Central and South will remain above 30 percent of their pre–European extent, thereby meeting the EPA objective for these complexes.

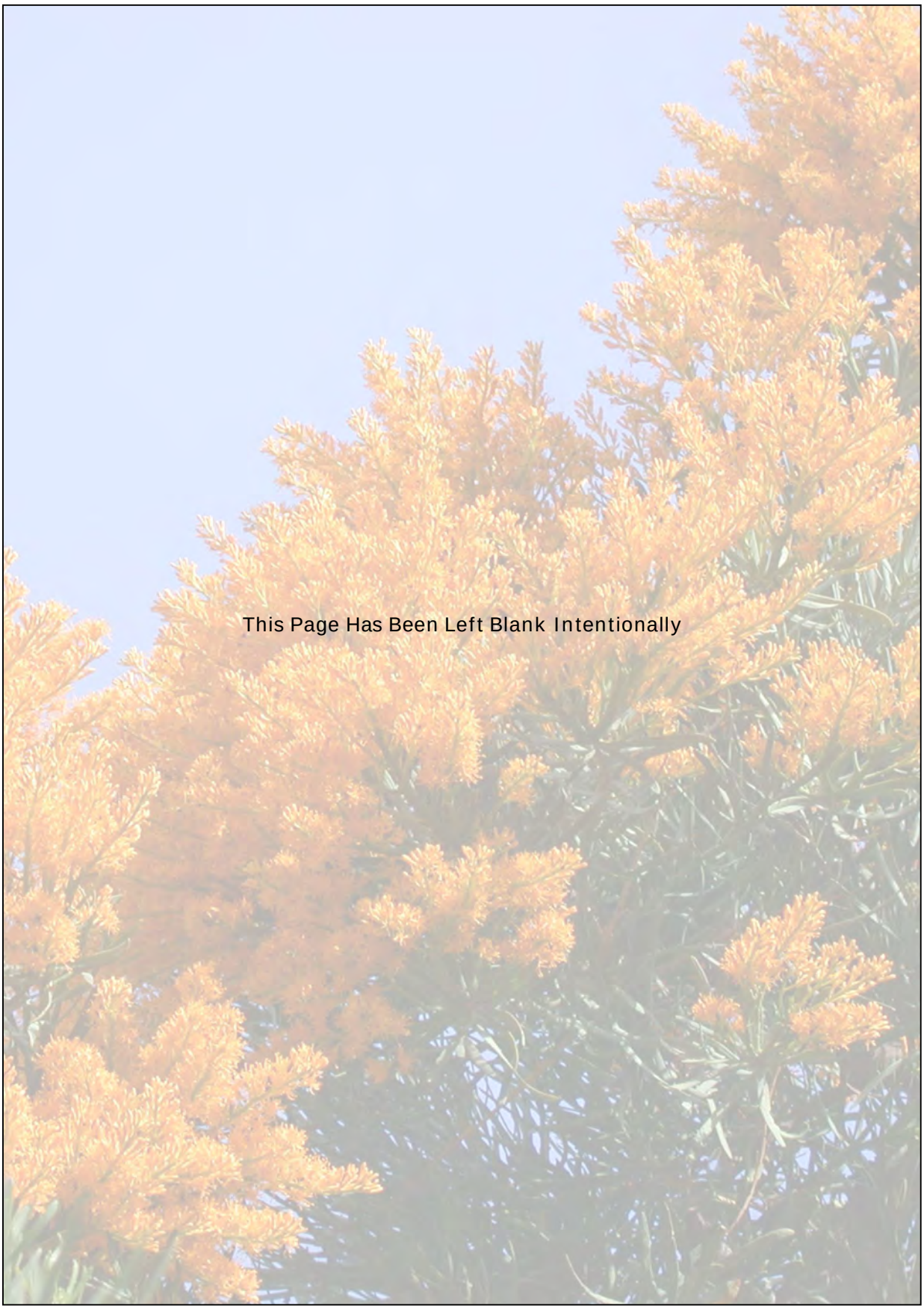

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Table 6.6-3: Impacts on Vegetation Complexes

Heddle Vegetation Complex[1]	Pre–European Extent (ha)[2]	Current Remaining Area (ha) (2000)[2]	% of Pre–European Extent Remaining (2000)	Area of Native Vegetation Cleared for Construction (ha)	Pre–European Extent Remaining Following Construction[3]	% Reduction in Current Extent Remaining
Bassendean Complex – Central and South	46,220	10,919	23.6	35.9	10,883ha 23.5%	0.3
Herdsman Complex	6,509	2,017	31.0	3.0	2,014ha 30.9%	0.2
Karrakatta Complex – Central and South	34,532	6,275	18.2	21.2	6,254ha 18.1%	0.3
Cottesloe Complex – Central and South	34,439	12,362	35.9	19.1	12,343ha 35.8%	0.2

[1]Heddle *et al*. 1980

[2]WAPC 2000a

[3]These values are based on most recent (i.e. 2000) current remaining extent values. It is noted that values of current remaining extent are likely to be lower than those presented

Given the minimal reductions in remaining extent of vegetation complexes, as well as that all of the FCTs supported by the project area are 'Well Reserved' and at 'Low Risk' of extinction, it is considered that the removal of vegetation communities BahS and CcAf from the project area does not constitute a significant impact at a regional scale.

6.6.2.1.1. Clearing of Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are ecosystems reliant on the use of groundwater at some stage of their life cycle. These ecosystems are therefore significantly altered if groundwater availability is modified beyond its normal range of fluctuation (Colvin *et al.* 2003).

A total of 310ha of GDE sub–communities have been mapped within the GDE study area, which extended beyond the general project area. Of the 79 hectares of remnant native vegetation proposed to be cleared, a total of 13ha of GDE sub–communities will be cleared for the construction footprint. Of this area, 7 ha are considered to be intact native vegetation. This represents 2 percent of all GDE sub–communities within the study area. The clearing directly impacts 28 GDE sub–communities, representing 41 percent of GDE sub–communities present, none of which will be removed completely. Table 6.6-4 summarises the extent of clearing of each of the defined and mapped GDEs.

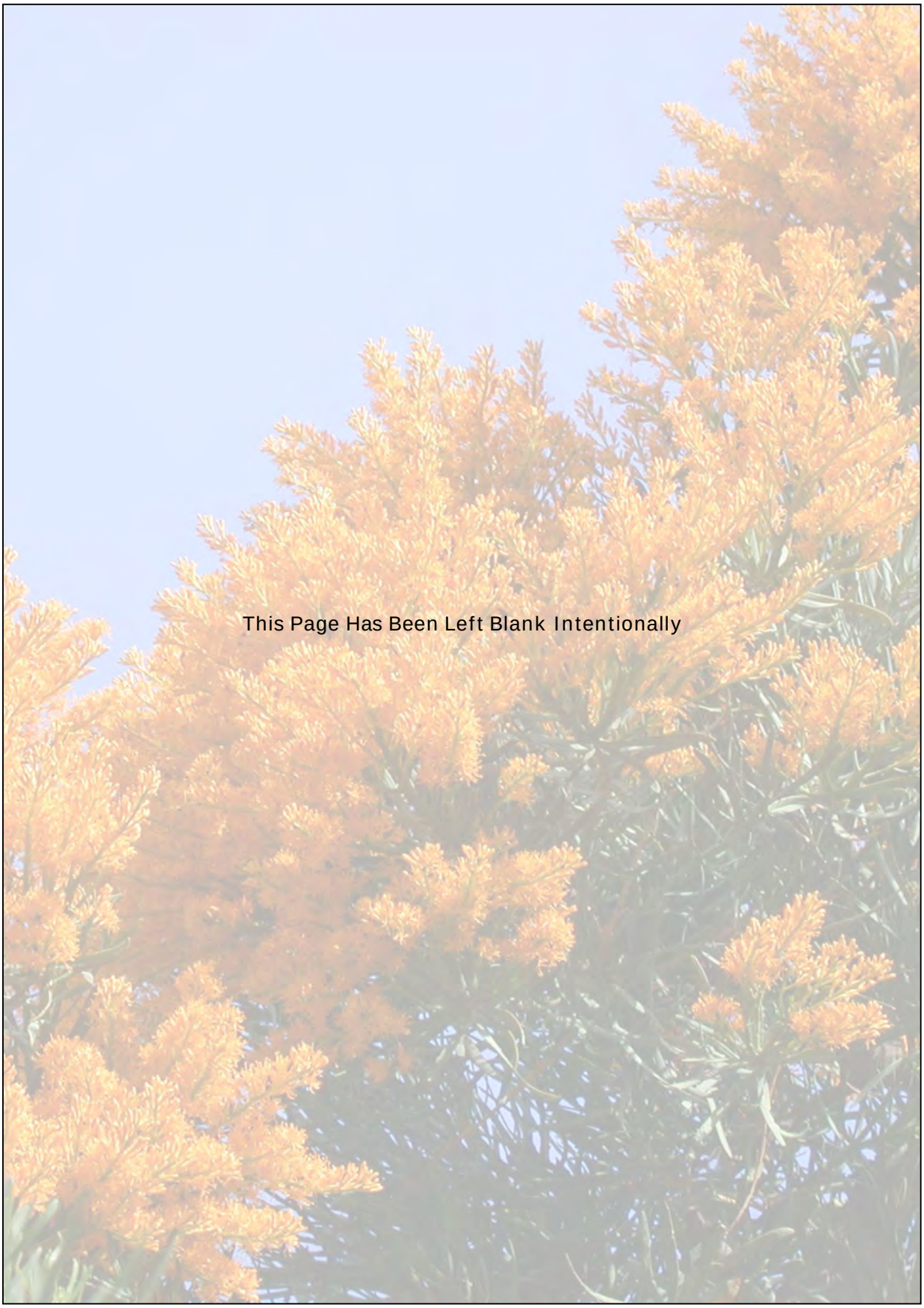
13ha of cleared vegetation is classed as GDE

Table 6.6-4: GDE Communities Impacted by the Construction Footprint

Broader Community	GDE Sub–Communities	Approximate Area (ha) Within Study Area	Total Area (ha) of Broader Community Within Study Area	Area Cleared for Construction Footprint (ha)	% of Sub–community Cleared for Construction Footprint	% of Broader Community Cleared for Construction Footprint
Banksia Woodland	2. Mixed *Banksia* woodland SubComm 1	3.3	64.5	<0.1	0.9	2.8
	4. *Banksia ilicifolia* open woodland SubComm 4	4.4		<0.1	<0.1	
	17. *Banksia attenuata/Banksia menziesii* open forest SubComm 8	6.0		0.3	5.5	
	21. *Banksia attenuata/Banksia menziesii* woodland SubComm 9	7.5		1.4	18.6	
	22. Mixed *Banksia* woodland SubComm 2	7.7		<0.1	0.7	
Corymbia calophylla tall open woodland over *Banksia menziesii* and *Banksia attenuata* woodland	37. *Corymbia calophylla* tall woodland over *Banksia menziesii and Banksia attenuata* woodland SubComm 1	3.8	19.9	0.1	3.1	16.0
	41. *Corymbia calophylla* tall open woodland over *Banksia menziesii* and *Banksia attenuata* woodland SubComm 2	16.0		3.1	19.1	
Corymbia calophylla tall woodland	16. *Corymbia calophylla* tall open woodland SubComm 1	0.25	12.6	<0.1	1.7	16.2
	42. *Corymbia calophylla* tall open woodland over *Banksia attenuata* woodland SubComm 3	11.0		2.0	18.1	
	53. *Corymbia calophylla* open woodland SubComm 4	0.1		<0.1	28.8	

Broader Community	GDE Sub–Communities	Approximate Area (ha) Within Study Area	Total Area (ha) of Broader Community Within Study Area	Area Cleared for Construction Footprint (ha)	% of Sub–community Cleared for Construction Footprint	% of Broader Community Cleared for Construction Footprint
Eucalyptus rudis tall closed forest and *Melaleuca preissiana* closed forest	23. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* open woodland SubComm 2	1.2	5.3	0.8	68.6	27.0
	24. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* woodland SubComm 3	2.7		0.6	22.7	
Eucalyptus rudis tall closed forest and *Melaleuca rhaphiophylla* closed forest	9. *Eucalyptus rudis* tall open woodland over *Melaleuca rhaphiophylla* open woodland SubComm 1	9.1	23.3	1.2	13.0	5.1
Eucalyptus rudis tall closed forest over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* closed forest	20. *Eucalyptus rudis /Melaleuca preissiana/Melaleuca rhaphiophylla* open woodland SubComm 4	8.6	19.5	1.0	11.2	4.9
Eucalyptus rudis tall woodland over mixed woodlands	38. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 6	1.1	18.7	0.6	52.9	3.5
	58. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 7	1.0		<0.1	5.5	
Melaleuca rhaphiophylla closed forest	14. *Melaleuca rhaphiophylla* closed forest SubComm 2	6.9	14.7	0.2	2.3	1.1
Melaleuca preissiana closed forest	13. *Melaleuca preissiana* closed forest SubComm 1	1.5	1.7	<0.1	1.8	1.6
Melaleuca teretifolia closed tall scrub	11. *Melaleuca teretifolia* closed tall scrub	30.0	30.0	<0.1	0.1	0.1

Broader Community	GDE Sub–Communities	Approximate Area (ha) Within Study Area	Total Area (ha) of Broader Community Within Study Area	Area Cleared for Construction Footprint (ha)	% of Sub–community Cleared for Construction Footprint	% of Broader Community Cleared for Construction Footprint
Scattered	7. Scattered *Corymbia calophylla* and *Eucalyptus todtiana*	1.1	46.2	0.3	27.4	1.3
	8. Scattered *Eucalyptus rudis*	38.7		0.2	0.6	
	18. Scattered *Eucalyptus todtiana*	0.3		<0.1	28.1	
Typha orientalis closed sedgeland	43. *Typha orientalis* closed sedgeland SubComm 2	17.3	19.4	0.2	0.9	0.8
Baumea rubiginosa sedgeland	57. *Baumea rubiginosa* sedgeland	0.2	0.2	<0.1	24.7	24.7
Corymbia calophylla and *Eucalyptus rudis* closed forest	55. *Corymbia calophylla* and *Eucalyptus rudis* closed forest	1.8	1.8	<0.1	2.3	2.3
Eucalyptus gomphocephala closed forest	70. *Eucalyptus gomphocephala* closed forest	0.2	0.2	<0.1	1.4	1.4
Kunzea glabrescens closed tall scrub	1. *Kunzea glabrescens* tall closed scrub SubComm 1	7.4	7.5	1.0	13.0	12.9
Revegetation	62. Revegetation	9.5	9.5	<0.1	0.1	0.1
Total area of GDE communities impacted by construction footprint (ha)				13.3		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15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants, will be removed

6.6.2.1.2. Fragmentation

Vegetation fragmentation is defined as the emergence or increase of patches of vegetation or habitat in a previously contiguous area. Fragmentation and its associated effects include a reduction in the area of vegetation, an increase in the edge to area ratio, community or habitat isolation and a reduction in the size of contiguous vegetation, resulting in a reduction in vegetation integrity. The fragmentation of plant communities can affect the dispersal of the seeds of various native plant species and genetic flow between patches (Saunders and Hobbs 1991). It is important to note that the project area is already heavily fragmented by the existing road network, as well as formal and informal pathways and access tracks throughout the project area.

Over the longer term, the ability of areas that have been reduced in size due to fragmentation to overcome (outcompete) the impacts from edge effects (e.g. weed invasion) is affected. As the effects of disturbance on bushland edges migrate further into native communities, a reduction in floral diversity and cover can occur. Edge effects are discussed as an operation phase impact in Section 6.6.3.2. Impacts of fragmentation are further discussed in Section 6.8.

6.6.2.1.3. State Priority Flora

Proposed clearing is predicted to impact some individuals and populations of Priority Flora. Table 6.6-5 summarises the significance of the proposed clearing impacts on Priority Flora, in the context of the known numbers of plants and populations of each species in the local vicinity and in the region.

Table 6.6-5: Priority Flora Impacts in a Local and Regional Context

Species	Conservation Code	Total Number of Known Populations	Number of Populations Known Within the Study Area	Number of Populations to be Impacted Within Project Footprint	Percentage of Populations to be Impacted	Total Minimum Number of Known Individuals	Number of Individuals Within Study Area	Number of Known Individuals to be Impacted Within Project Footprint	Percentage of Known Individuals Within Study Area to be Impacted
Dampiera triloba	P1	21	14	4	19.1	7,132	66,17	5,404	75. 8
Tetraria sp. Chandala (G.J. Keighery 17055)	P2	3	1	1	0	3	1	1	0.0
Cyathochaeta teretifolia	P3	56	5	3	5.4	582	482+	38	6.5
Jacksonia gracillima	P3	20	3	2	10.0	200	173	15	7.5
Eryngium pinnatifidum subsp. *palustre*	P3	20	4	4	20.0	63	45	16	25.4
Dodonaea hackettiana	P3	56	1	1	1.8	205	1	1	0.5
Calothamnus rupestris	P4	48	2	0	0.0	8,394	2	0	0.0
Eucalyptus caesia	P4	42	1	0	0.0	741	1	0	0.0

Table 6.6-5 shows a proportionately low impact to individuals and populations to be impacted for all recorded Priority Flora species, besides *Dampiera triloba* (P1) and *Eryngium pinnatifidum* subsp. *palustre* (P3). Due to the fact that in accordance with DEC definitions P1 Flora require further survey and that results of such survey may determine that the species is eligible to be listed as DRF, conservation of P1 species and their habitat is important. Therefore, the predicted impact on the population of *Dampiera triloba* (P1) as a result of the proposed project may be significant.

Dampiera triloba (P1) and *Eryngium pinnatifidum* subsp. *palustre* (P3) are both small, inconspicuous herbs; therefore it is likely that the WA Herbarium records underestimate their actual extent. The numbers of 'known' populations and individual plants is based on WA Herbarium (DEC) records, which for some species are limited and the distribution and extent of species is poorly known, in particular small and inconspicuous species. For this reason, the significance of the impacts summarised in Table 6.6-5 is a conservative estimate and therefore represents the maximum possible impact in all cases.

7ha of Bush Forever Site 244 will be cleared, including 4ha of intact native vegetation

6.6.2.1.4. Bush Forever

Bush Forever Site 244 is 402.4ha in size and, of this, 7ha (<2%) occurs within the construction footprint of the proposed project (Figure 6.6-1). Clearing of this area will include the removal of 4ha of intact native vegetation within the Bush Forever Site.

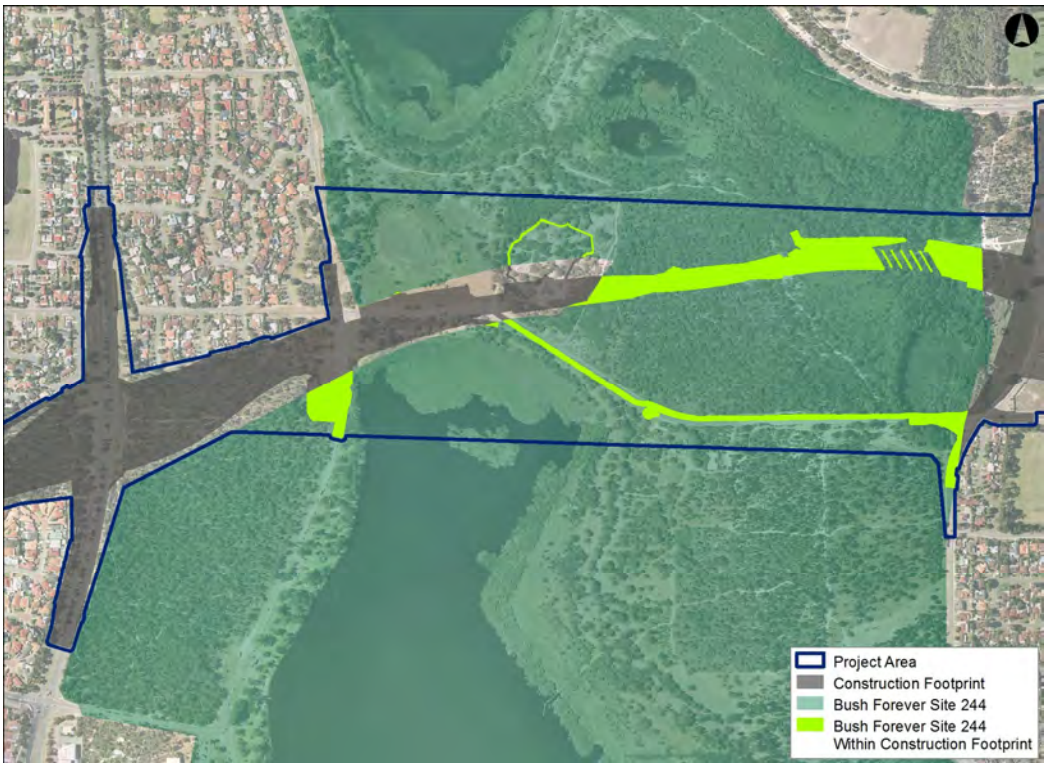


Figure 6.6-1: Impacts on Bush Forever

State Planning Policy 2.8: Bushland Policy for the Perth Metropolitan Region (WAPC 2010) and *Bush Forever* (WAPC 2000a; 2000b) recognise a target of at least 10 percent retention of the original extent of each vegetation complex for the Swan Coastal Plain portion of the Perth metropolitan region, which is recognised as a constrained area.

Bush Forever Site 244 lies on the Bassendean Complex – Central and South, which is currently represented by 24% of its original extent. Implementation of the proposed project will reduce this area by 36ha (

), which represents 0.3% of the currently remaining extent, thereby ensuring that the remaining extent of this complex within the Swan Coastal Plain remains above the 10% threshold.

6.6.2.1.5. Accidental Over–clearing

Accidental over–clearing may occur as a result of construction activities. This is most likely to occur during initial vegetation clearing works; however, general plant and machinery operation during all construction activities could result in some clearing outside of the nominated construction footprint, particularly as a result of operator error.

If over–clearing takes place, the actual area of clearing will be exceeded, which may result in the loss of conservation significant species (DRF or Priority species), additional GDE or significant vegetation communities. For this reason, it will be important to remain within the extent of clearing according to the design and the allotted construction footprint.

6.6.2.2. Spread of Weeds

Weeds and weed seed can be introduced to the project area from other sites by plant and machinery that has not been properly washed down following previous jobs. This could result in the introduction of more vigorous, previously unrecorded weed species to the project area.

The movement of vehicles within the project area may result in the dispersal of weeds from degraded to less degraded areas. Similarly, the movement of soil, particularly weed infested topsoil, could result in the dispersal of weeds throughout the project area.

The edges of cleared vegetation are at greatest risk of weed invasion, due to the lack of competition and extra water from runoff. It is important for ongoing management to ensure that the spread of weeds into areas of disturbance is prevented. The increased competition can hinder the establishment of regenerating native flora.

It is unlikely that any significant change to hydrological conveyance will occur

6.6.2.3. Dust

Following the removal of vegetation, the construction footprint will be devoid of vegetation, exposing loose and friable soil. During dry and windy conditions, the mobilisation of dust has the potential to impact retained native vegetation by settling on leaf surfaces, blocking stomata and preventing the uptake of sunlight necessary for photosynthesis. Dust on leaf surfaces and cuticles can also result in abrasion that can cause sufficient damage to kill the plant. Prolonged dusty conditions can cause eventual death of flora and, in extreme cases, reduce the extent of vegetation communities.

6.6.2.4. Altered Surface Hydrology and Groundwater

The construction of the proposed project could potentially impact surface hydrology and groundwater by:

1) Reducing soil porosity and permeability to groundwater flows as a result of site compaction;
2) Damaging the integrity of aquatards by drilling and piling activities, resulting in the draining of perched aquifers; and
3) Interrupting natural surface water flow paths, resulting in drainage shadowing and ponding.

The first two hydrological impacts above have the potential to affect groundwater dependent vegetation over the long–term. The third impact has the potential to affect vegetation that relies on surface moisture for survival.

GDEs are an association of vegetation and therefore all impacts discussed as relevant to flora and vegetation also apply to GDEs. The assessment of impacts on GDEs, as a result of changes to groundwater conditions, is considered below.

It is considered unlikely that significant physical changes to hydrological conveyance will occur as a result of the proposed project. However, as it has often been raised as a potential impact and the available data do not provide sufficient scale to conclusively discount this potential impact, an estimation of the types and areas of effect is warranted to examine potential consequences of altered hydrology, should it occur.

Groundwater dependent species occur throughout the study area in a complex mosaic of species distribution and density, reflecting changes in soil types and depth to groundwater, as well as more complex stratigraphical and hydrological patterns. The study of GDEs for the project (Appendix D) identified and mapped vegetation with respect to water dependence. Therefore, distribution of GDEs and communities with other water dependencies (e.g. surface water dependent) has been established (Figure 5.8-9).

The characteristics, dependence and sensitivity of GDEs has been determined, based on a combination of the presence of GDE indicator species (known as groundwater dependent flora) and the known depth to groundwater that was determined from both regional and project specific data. It follows, therefore, that assessing potential impacts on GDEs relies on a quantified measure of the predicted impact on groundwater levels. It also follows that it is appropriate to assess impacts on indicator GDE flora species, as well as GDE types.

The importance of groundwater as a water source for individuals of a species and their response to changes in its availability are not necessarily consistent, but may be site–specific and dependent on groundwater depth and seasonal duration (Zencich *et al*. 2002). The assessment of impact has a complexity that relates to the spatial and temporal mosaic formed by GDE distribution and groundwater occurrence. Furthermore, within each community type, a number of species with varying dependencies on groundwater, surface water and vadose zone moisture occur. It is therefore often not possible to characterise GDE, as a whole, in terms of their water dependency.

Impacts on GDEs and water dependent vegetation will be both local (direct) and distal (indirect) from the point of disturbance, with the extent of impact dictated by the underlying geomorphology and hydrogeology.

The ecological water requirement (EWR) of the vegetation and, more specifically, the GDEs of the project area, are determined by the surface water and groundwater regimes of the area and may be considered to be that which the local GDEs require for ongoing survival and function.

The groundwater requirements of the GDEs of the project area are dependent on the levels (depth to groundwater), seasonal wetting and direction of flow. These characteristics have been described in detail in Section 5.8.5.

Distribution and assessment of impacts on GDEs and vegetation as a result of alteration of groundwater have been determined using:

1) A conceptual effects model; and
2) Estimates of potential zones of effect.

These are both described in more detail as follows.

1. Conceptual Effects Model

- The conceptual model of altered flow characteristics in the wetland zone of the project area has been developed, as shown in Figure 6.6-2.
- There is evidence of a deep unconfined aquifer generally flowing from east to west, generally parallel to the proposed road alignment on a regional scale. The deep aquifer is very unlikely to be deformed or altered by the presence of surface–based infrastructure, given that the proposed infrastructure will not intersect known groundwater tables.
- There is no evidence of small–scale, perched aquifers or lenses, although they may exist on small localised scales. These seasonal aquifers may be prone to deformation or alteration.

- The conceptual model is based on the premise that small seasonal perched aquifers typically flow from east to west, but with a slight north–west tendency.
- The conceptual model is not intended to propose flow directions or the existence of perched aquifers beneath the road.
- The conceptual model assumes that wetting and drying may occur equally along the alignment, as a result of the potential 'loading' of the proposed infrastructure on the sediments. This may alter groundwater flows. However, the spatial and temporal distribution of the potential loading is unknown. Conceptual locations of this potential effect are shown in Figure 6.6-2.

2. Zone of Effect Estimates

- The conceptual model developed is shown to hypothesise a mechanism for indirect effects on distal vegetation, as a result of the road installation over the chosen alignment.
- Nominal zones of effect were connected to enable estimations of potential zones of impact on vegetation distal to the road and associated with the potential altered wetting/drying regimes.
- Estimations were made at 5m, 20m and 50m, in order to estimate the types and areas of GDE at risk from potential hydrological alteration. It appears unlikely that, if groundwater influence was to occur, it would occur beyond 50m without initially occurring within the 50m zone. Should groundwater alterations actually occur, a broader zone of influence may occur further than the nominal 50m buffer, but it may not be measurable as an effect.
- Summary outputs show the types of adjacent and distal vegetation situated north and south of the alignment, enabling the interpretation of potential successional vegetation changes in the zones of effect.

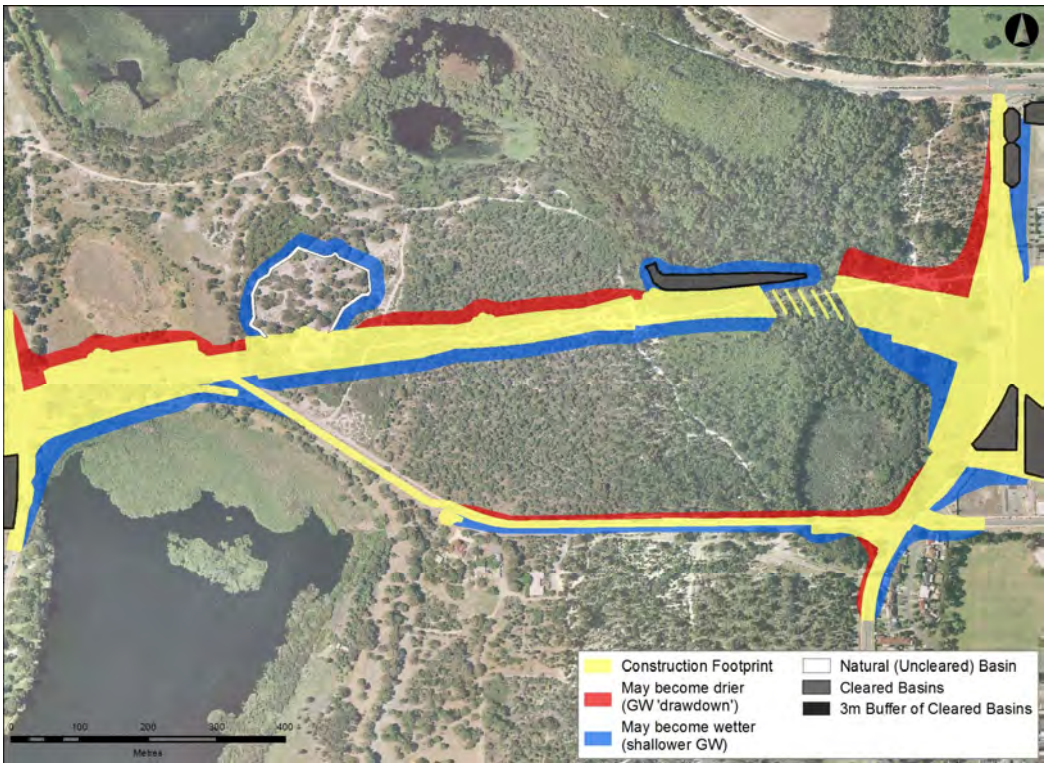


Figure 6.6-2: Conceptual Effect Model of Potential Alterations in Surface Water and Groundwater in the Wetland Zone

The conceptual effects model depicts a hypothetical situation that there is the potential for some areas to become generally drier (groundwater may deepen) and some areas to become generally wetter (groundwater becomes shallower). Since both the spatial location and the magnitude of such effects (if any) have not been confirmed, the assessment presented below considers such potential effects within the 50m zone of impact. Depending on actual presence, areal extent, perching depth and gradient, the actual effect would differ from the conceptual model, but the GDEs potentially at risk and areas in nominated zones of effect would be in the order of those given in the following discussions.

The extent and proportion of each GDE that has been determined to occur within this 50m zone of impact are listed in Table 6.6-6. A colour coding has been applied to represent the scale of impact on each affected GDE, highlighting in yellow those GDE communities with between 10 and 30 percent of their total extent affected by the zone of impact, while those with between 30 and 70 percent of their extent affected coloured orange, and those with more than 70 percent coloured red.

Table 6.6-6: Proportionate Extent of GDEs Represented Within 50m Zone of Potential Effect from Alterations in Surface Water and Groundwater

GDE Sub–communities	Total Project Area (ha)	Approximate Area That Lies Within the Hydrological Zones of Effect (ha)			Approximate % of GDE Sub–communities Potentially Distally Impacted by Hydrological Changes for Each Zone of Effect		
		5m	20m	50m	5m	20m	50m
1. *Kunzea glabrescens* closed tall scrub SubComm 1	7.4	0.2	0.6	1.7	2.0%	7.9%	22.7%
2. Mixed Banksia woodland SubComm 1	3.3	<0.1	0.3	0.7	1.9%	8.3%	21.1%
3. *Eucalyptus rudis* closed forest over *Melaleuca preissiana/Banksia littoralis* low open woodland SubComm 5	0.2	<0.1	<0.1	0.2	4.5%	54.5%	100.0%
4. *Banksia ilicifolia* open woodland SubComm 4	4.4	<0.1	0.2	1.1	0.4%	5.1%	24.7%
6. Scattered *Banksia littoralis*	0.3	–	–	<0.1	0%	0%	15.6%
7. Scattered *Corymbia calophylla and Eucalyptus todtiana* SubComm 4	1.1	<0.1	<0.1	<0.1	2.1%	3.8%	3.8%
8. Scattered *Eucalyptus rudis*	37.1	<0.1	0.2	0.4	0.3%	0.6%	1.1%
9. *Eucalyptus rudis* tall open woodland over *Melaleuca rhaphiophylla* open woodland SubComm 1	9.1	0.2	0.7	0.8	2.4%	7.5%	9.2%
11. *Melaleuca teretifolia* closed tall scrub	30.0	<0.1	0.3	0.7	<0.1%	0.9%	2.5%
13. *Melaleuca preissiana* closed forest SubComm 1	1.5	<0.1	0.3	1.0	3.5%	19.3%	65.3%
14. *Melaleuca rhaphiophylla* closed forest SubComm 2	6.9	<0.1	0.5	0.9	1.1%	6.6%	13.5%
16. *Corymbia calophylla* tall open woodland SubComm 1	0.3	<0.1	<0.1	<0.1	2.0%	8.7%	17.7%
17. *Banksia attenuata/Banksia menziesii* open forest SubComm 8	6.0	0.2	0.7	1.7	2.6%	10.8%	28.1%
18. Scattered *Eucalyptus todtiana*	0.3	<0.1	0.2	0.2	16.1%	67.6%	72.0%
19. *Melaleuca rhaphiophylla* and *Eucalyptus rudis* woodland SubComm 6	2.3	–	–	<0.1	0%	0%	0.1%
20. *Eucalyptus rudis–Melaleuca preissiana–Melaleuca rhaphiophylla* open woodland SubComm 4	8.6	0.4	1.6	2.6	5.0%	18.1%	29.9%
21. *Banksia attenuata–Banksia menziesii* woodland SubComm 9	7.5	0.3	1.2	2.9	3.7%	16.4%	39.1%

GDE Sub–communities	Total Project Area (ha)	Approximate Area That Lies Within the Hydrological Zones of Effect (ha)			Approximate % of GDE Sub–communities Potentially Distally Impacted by Hydrological Changes for Each Zone of Effect		
		5m	20m	50m	5m	20m	50m
22. Mixed *Banksia* woodland SubComm 2	8.1	<0.1	0.3	0.9	0.7%	3.1%	11.5%
23. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* open woodland SubComm 2	1.2	0.2	0.4	0.4	17.1%	30.2%	31.4%
24. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* woodland SubComm 3	2.7	0.3	0.7	1.4	10.2%	26.7%	53.1%
30. *Eucalyptus rudis* tall closed forest over *melaleuca rhaphiophylla* closed forest SubComm 2	1.3	–	–	<0.1	0%	0%	4.7%
33. *Eucalyptus rudis* tall closed forest over *Melaleuca preissiana* and *Melaleuca rhaphiophylla* closed forest SubComm 2	4.5	<0.1	0.2	0.6	0.4%	4.3%	14.1%
35. *Eucalyptus rudis* tall woodland over *Banksia ilicifolia* and *Melaleuca preissiana* open woodland SubComm 1	0.9	–	<0.1	0.1	0%	0.6%	13.3%
37. *Corymbia calophylla* tall woodland over *Banksia menziesii* and *Banksia attenuata* woodland SubComm 1	3.8	0.2	0.8	2.0	4.4%	20.6%	50.8%
38. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 6	1.1	0.2	0.4	0.5	12.9%	36.6%	47.1%
39. *Kunzea glabrescens* closed tall scrub SubComm 2	<0.1	–	<0.1	<0.1	0%	25.0%	100.0%
40. *Eucalyptus rudis* tall closed forest over *Melaleuca rhaphiophylla* closed forest SubComm 4	1.8	–	<0.1	0.4	0%	1.6%	19.4%
41. *Corymbia calophylla* tall open woodland over *Banksia menziesii* and *Banksia attenuata* woodland SubComm 2	16.0	0.3	0.9	2.1	1.6%	5.6%	12.9%
42. *Corymbia calophylla* tall open woodland over *Banksia attenuata* woodland SubComm 3	11.0	0.2	0.8	2.5	1.7%	7.2%	22.2%
43. *Typha orientalis* closed sedgeland SubComm 2	17.3	<0.1	0.4	1.9	0.4%	2.3%	11.1%
46. *Eucalyptus rudis* tall open forest SubComm 1	1.4	–	–	<0.1	0%	0%	2.7%
50. *Melaleuca preissiana Banksia littoralis* closed forest	2.1	–	<0.1	0.4	0%	1.4%	18.9%
53. *Corymbia calophylla* open woodland SubComm 4	0.1	<0.1	<0.1	<0.1	26.8%	71.3%	71.3%

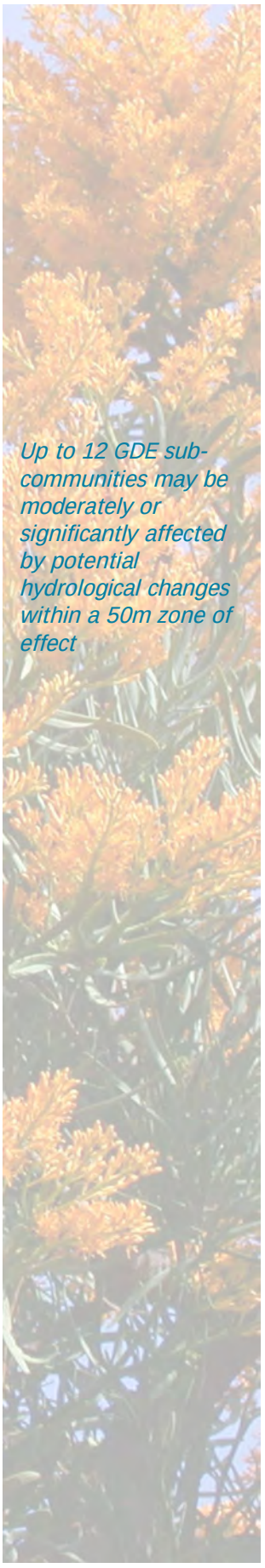
GDE Sub–communities	Total Project Area (ha)	Approximate Area That Lies Within the Hydrological Zones of Effect (ha)			Approximate % of GDE Sub–communities Potentially Distally Impacted by Hydrological Changes for Each Zone of Effect		
		5m	20m	50m	5m	20m	50m
55. *Corymbia calophylla* and *Eucalyptus rudis* closed forest	1.8	<0.1	0.2	0.5	2.1%	9.5%	25.8%
57. *Baumea rubiginosa* sedgeland	0.2	<0.1	<0.1	<0.1	25.4%	28.4%	28.4%
58. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 7	1.00	<0.1	0.2	0.4	5.8%	20.4%	39.1%
59. *Banksia attenuata* and *Banksia menziesii* open woodland SubComm 6	8.8	–	0.2	0.8	0%	2.3%	9.5%
60. *Baumea articulata* closed sedgeland	<0.1	<0.1	<0.1	<0.1	5.4%	16.7%	16.7%
62. Revegetation	9.5	<0.1	0.3	0.9	0.2%	2.6%	9.2%
70. *Eucalyptus gomphocephala* closed forest	0.2	<0.1	<0.1	0.2	6.9%	49.2%	98.6%

Table 6.6-6 indicates that, within a 50m zone of effect, a significant proportion (i.e. greater than 70 percent) of four of 70 mapped GDE sub–communities may potentially be affected by changes in hydrological conditions. A further eight GDE sub–communities will have a moderate proportion (i.e. greater than 30 percent) of their extent potentially affected by changes in hydrological conditions. It is expected that such an effect could result in a successional shift from the current GDE association of species to a different community type, in response to altered water availability. For example, if a location supporting a particular GDE experiences a wetting effect over time (i.e. shallower groundwater or extended inundation periods); the vegetation association may shift to support a different suite of species that preferentially utilise shallower groundwater. Table 6.6-7 lists those twelve GDE sub–communities where this potential effect has been predicted.

For each vegetation community, its corresponding spatial extent was mapped, as well as known flora and/or significant vegetation (Appendix K). Table 6.6-7 presents predictions about possible changes that might occur within each GDE sub–community and vegetation type in response to altered hydrological conditions. This includes consideration of risks to Priority Flora species. The statements made in Table 6.6-7, with regards to predicted possible successional effects, are primarily based on the susceptibility of the dominant and significant flora species to changes in groundwater levels. These susceptibility ratings are in reference to Froend *et al.* (2004) and have been determined by examining rooting depth and typical depth to groundwater in the locations where these species have been recorded in the project area (Appendix D).

A risk rating has been assigned to each vegetation type within GDE sub–communities based on the interpretation of risk to the dominant community species from potentially altered hydrological conveyance. The assessment has determined that many vegetation types in the vicinity of the proposed project (including Priority species) would benefit from the resultant 'wetting' effect and that some would sustain various alterations in hydrology within their current species compositions, resulting in 'wetting' and 'drying' effects. Vegetation communities such as BXpW, EtKgS and ErMpH currently support species that preferentially utilise shallow groundwater or surface water and would benefit from a 'wetting' scenario. Four of the 15 vegetation communities (identified in Table 6.6-7) are at risk of being adversely affected by predicted alterations to hydrology. These vegetation communities occur within six of the 12 GDE communities within the zone of impact and may exhibit successional change (i.e. succession to a different community type that includes a threat to significant flora species) as a result of the proposed project.

The possible effects summarised in Table 6.6-7 and discussed above can broadly be described as 'succession'. Succession of vegetation communities occurs in response to natural effects (such as a drying climate and frequency of fire) and also as a result of indirect impacts of development. Succession is not necessarily an adverse effect and may result in improved vegetation condition ratings (particularly in the case of degraded vegetation that may have responded to previous negative impacts or effects). This can benefit ecosystem values and wetland function. The conclusion made in the final column of Table 6.6-7 determines which effect is considered to be relevant to areas of each community listed.



Up to 12 GDE sub-communities may be moderately or significantly affected by potential hydrological changes within a 50m zone of effect

Table 6.6-7: GDE Sub–communities that May be Affected by Alterations in Surface Water and Groundwater, Their Significance in Relation to Flora and Fauna Values and Predicted Succession Communities and/or GDE Sub–communities

GDE Community Type	% Total Mapped Area of Vegetation Community Type Within 5–50m Zone of Effect	Corresponding Vegetation Community	Significance of Vegetation Community and/or Supported Flora	Predicted Potential Succession Effects and/or Impacts on Significant Flora*		Inferred Net Hydrological Alteration
				Wetter (Shallower Groundwater)	Drier (Deeper Groundwater)	
3. *Eucalyptus rudis* closed forest over *Melaleuca preissiana/Banksia littoralis* low open woodland SubComm 5	5m: 4.5% 50m: 100.0%	AfKgS	No significance. Degraded community	Improvement of degraded community	Negligible degradation or no change	No net change
13. *Melaleuca preissiana* closed forest SubComm 1	5m: 3.5% 50m: 65.3%	ErMpH	Supports a PMR^ significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Some areas no net change Some areas marginally wetter
18. Scattered *Eucalyptus todtiana*	5m: 16.1% 50m: 72.0%	BiSiH	Limited local representation (locally significant)	Increase in *B. ilicifolia.* Possible increase in Pigface (weed) cover	No significant change for reduction up to 0.75m at 0.1m/year. Loss of *B. ilicifolia* for greater reduction	Moderately drier
		BXpW	None identified	Positive effect on dominant species that utilise deep and shallow groundwater	No significant change for reduction up to 1m at 0.1m/year	Moderately drier
		ErMpH	Supports a PMR significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Some areas no net change Some areas marginally wetter

GDE Community Type	% Total Mapped Area of Vegetation Community Type Within 5–50m Zone of Effect	Corresponding Vegetation Community	Significance of Vegetation Community and/or Supported Flora	Predicted Potential Succession Effects and/or Impacts on Significant Flora*		Inferred Net Hydrological Alteration
				Wetter (Shallower Groundwater)	Drier (Deeper Groundwater)	
		EtKgS	Limited local representation (locally significant) Supports a PMR significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Some areas drier Some areas wetter
21. *Banksia attenuata–Banksia menziesii* woodland SubComm 9	5m: 3.7% 50m: 39.1%	BXpW	None identified	Positive effect on dominant species that utilise deep and shallow groundwater	No significant change for reduction up to 1m at 0.1m/year	Moderately drier
		CcBKgS	Supports Priority Flora (*Jacksonia gracillima* (P3)) and a PMR significant flora species (*Conostephium minus*)	Increase in *B. ilicifolia* and *Kunzea glabrescens.* Little or positive impact on significant flora	Negative impact on significant flora present	Some areas moderately wetter Some areas no net change
		EmKgS	Supports a PMR significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Drier
23. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* open woodland SubComm 2	5m: 17.1% 50m: 31.4%	CcBKgS	Supports Priority Flora (*Jacksonia gracillima* (P3)) and a PMR significant flora species (*Conostephium minus*)	Increase in *B. ilicifolia* and *Kunzea glabrescens.* Little or positive impact on significant flora	Negative impact on significant flora present	Wetter
		ErCtS	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	No net change

GDE Community Type	% Total Mapped Area of Vegetation Community Type Within 5–50m Zone of Effect	Corresponding Vegetation Community	Significance of Vegetation Community and/or Supported Flora	Predicted Potential Succession Effects and/or Impacts on Significant Flora*		Inferred Net Hydrological Alteration
				Wetter (Shallower Groundwater)	Drier (Deeper Groundwater)	
		ErMpAfS	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Some areas no net change Small proportion of areas drier
		ErMpGeS	Limited local representation (locally significant) Supports Priority Flora (*Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Mostly no net change Small proportion of areas drier
		MpKgS	Limited local representation (locally significant) Supports a regionally significant flora species (*Ixiolaena viscosa*)	Positive effect on dominant species including Arum Lily (weed)	Reduction in Arum Lily (weed) cover. No significant change for reduction up to 1m at 0.1m/year	Wetter
24. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* woodland SubComm 3	5m: 10.2% 50m: 53.1%	CcBKgS	Supports Priority Flora (*Jacksonia gracillima* (P3)) and a PMR significant flora species (*Conostephium minus*)	Increase in *B. ilicifolia* and *Kunzea glabrescens.* Little or positive effect on significant flora	Negative impact on significant flora present	Mostly wetter Some areas no net change Small proportion of areas drier
		ErCtS	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1), *Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Mostly no net change Some areas wetter

GDE Community Type	% Total Mapped Area of Vegetation Community Type Within 5–50m Zone of Effect	Corresponding Vegetation Community	Significance of Vegetation Community and/or Supported Flora	Predicted Potential Succession Effects and/or Impacts on Significant Flora*		Inferred Net Hydrological Alteration
				Wetter (Shallower Groundwater)	Drier (Deeper Groundwater)	
		MpBaS	Supports Priority Flora (*Cyathochaeta teretifolia* (P3), *Dampiera triloba* (P1) and *Jacksonia gracillima* (P3))	Positive effect on Priority Flora	Negative impact on significant flora present	Very small area potentially drier but mostly no net change
		MpKgS	Limited local representation (locally significant) Supports a regionally significant flora species (*Ixiolaena viscosa*)	Positive effect on dominant species including Arum Lily (weed)	Reduction in Arum Lily (weed) cover. No significant change for reduction up to 1m at 0.1m/year	Wetter
37. *Corymbia calophylla* tall woodland over *Banksia menziesii* and *Banksia attenuata* woodland SubComm 1	5m: 4.4% 50m: 50.8%	BiSiH	Limited local representation (locally significant)	Increase in *B. ilicifolia*. Possible increase in Pigface (weed) cover	No significant change for reduction up to 0.75m at 0.1m/year. Loss of *B. ilicifolia* for greater reduction	Mostly no net change Small proportion of areas drier
		CcBKgS	Supports Priority Flora (*Jacksonia gracillima* (P3)) and a PMR significant (*Conostephium minus*)	Increase in *B. ilicifolia* and *Kunzea glabrescens*. Little or positive effect on significant flora	Negative impact on significant flora present	Mostly no net change Small proportion of areas drier
		EmKgS	Supports a PMR significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Some areas no net change Some areas drier
		ErMpGeS	Limited local representation (locally significant) Supports Priority Flora (*Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Mostly drier Some areas no net change

GDE Community Type	% Total Mapped Area of Vegetation Community Type Within 5–50m Zone of Effect	Corresponding Vegetation Community	Significance of Vegetation Community and/or Supported Flora	Predicted Potential Succession Effects and/or Impacts on Significant Flora*		Inferred Net Hydrological Alteration
				Wetter (Shallower Groundwater)	Drier (Deeper Groundwater)	
38. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 6	5m: 12.9% 50m: 47.1%	CcBKgS	Supports Priority Flora (*Jacksonia gracillima* (P3)) and a PMR significant flora species (*Conostephium minus*)	Increase in *B. ilicifolia* and *Kunzea glabrescens.* Little or positive effect on significant flora	Negative impact on significant flora present	No net change
		ErMpAfS	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Mostly no net change Some areas drier
		ErMpGeS	Limited local representation (locally significant) Supports Priority Flora (*Cyathochaeta teretifolia* (P3)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Mostly drier Some areas no net change
39. *Kunzea glabrescens* closed tall scrub SubComm 2	5m: 0% 50m: 100%	ErMpAfS	Limited local representation (locally significant) Supports Priority Flora (*Dampiera triloba* (P1)) and a regionally significant flora species (*Gastrolobium ebracteolatum*)	Positive effect on Priority Flora and all dominant species	Negative impact on significant flora present	Mostly no net change Some areas drier
		MpKgS	Limited local representation (locally significant) Supports a regionally significant flora species (*Ixiolaena viscosa*)	Positive effect on dominant species including Arum Lily (weed)	Reduction in Arum Lily (weed) cover. No significant change for reduction up to 1m at 0.1m/year	Wetter

GDE Community Type	% Total Mapped Area of Vegetation Community Type Within 5–50m Zone of Effect	Corresponding Vegetation Community	Significance of Vegetation Community and/or Supported Flora	Predicted Potential Succession Effects and/or Impacts on Significant Flora*		Inferred Net Hydrological Alteration
				Wetter (Shallower Groundwater)	Drier (Deeper Groundwater)	
53. *Corymbia calophylla* open woodland SubComm 4	5m: 26.8% 50m: 71.3%	ErMpH	Supports a PMR significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Mostly no net change Some areas drier
58. *Eucalyptus rudis* tall open woodland over *Melaleuca preissiana* and *Banksia littoralis* open woodland SubComm 7	5m: 5.8% 50m: 39.1%	AfKgS	No significance. Degraded community	Improvement of degraded community	Negligible degradation or no change	No net change
		BHhW	Supports PMR significant flora species (*Chamelaucium uncinatum, Conostephium minus*)	Positive effect on dominant species	Negligible degradation or no change	Marginal areas may become wetter
		MpBaS	Supports Priority Flora (*Cyathochaeta teretifolia* (P3), *Dampiera triloba* (P1) and *Jacksonia gracillima* (P3))	Positive effect on Priority Flora	Negative impact on significant flora present	Very small area potentially drier but mostly no net change
70. *Eucalyptus gomphocephala* closed forest	5m: 6.9% 50m: 98.6%	ErMpH	Supports a PMR significant flora species (*Hibbertia cuneiformis*)	Positive effect on dominant species	Reduction in Pigface (weed) cover	Mostly no net change Some areas drier

^PMR – Perth metropolitan region

*Legend

Negative impact
Neutral impact
Positive impact

6.6.2.5. Chemical Spills

Accidental spills or leaks of hazardous materials can occur during construction, as a result of ruptured hydraulic lines or spills during refuelling. A spill of fuel, oil or other hazardous material can have adverse impacts on flora at the point of discharge or indirectly as a result of degradation of water quality upon which certain plant species depend. Impacts that would result from a chemical spill or leak would primarily be death of affected plants. In the case of particularly large volumes, loss of large areas of vegetation may result. If soil becomes contaminated, vegetation may not be able to regrow in the contaminated zone and, if a spill reaches the groundwater, contaminating the aquifer, it could lead to wide scale impacts on groundwater dependent species and ecosystems.

6.6.2.6. Fire

Whilst fire is considered to be a natural component of the ecology of the project area, when it occurs at unnatural frequencies or intensity, there is a risk that it will lead to a decline in flora species, changes to vegetation community composition and increased occurrence of weeds.

Fires may be accidentally started through careless behaviour during construction activities, for example, as a result of:

- Incorrect disposal of cigarette butts;
- Poor management of fuel storage and handling;
- Poorly executed or managed 'hot works'; or
- Sparks from machinery, particularly during clearing activities.

6.6.2.7. Dieback

As no infestations of *P. cinnamomi* were identified within the project area, infestations as a result of construction activities would be considered a significant impact, particularly given the susceptibility of key habitat within the project area. Dieback infestations have the potential to cause significant declines in vegetation community composition and density. As well as being a significant impact on flora and vegetation, it would also represent a significant impact on a number of conservation significant fauna species' habitat.

All machinery entering the project area has the potential to introduce dieback, if it has previously worked on an infested site. Furthermore, as some parts of the project area were unmappable for dieback infestation, there is a risk that unrecorded infestations within these areas could be transported within the project area to dieback free areas.

Introduction of soil, particularly topsoil, from external sources also increases the risk of introducing dieback.

6.6.3. Operation Phase Impacts

6.6.3.1. Shading

Various design features, such as bridges and retaining walls, have been included in the proposal with the objective of reducing the extent of vegetation clearing required. This will ensure that clearing of 'Very Good' condition vegetation and vegetation that has been determined to support flora of conservation significance or other importance will be minimised, fauna movement will be maintained as much as practicable and hydrological regimes will be sustained.

Over the long–term operation of the project, certain areas of vegetation will be impacted by solar shading and/or rainfall shading. Shading effects are a derived impact associated with the active choice of adopting elevated structures for the aforementioned benefits. The effect of these impacts will be to cause a decline in vegetation vigour and health, and may ultimately lead to a change in vegetation composition and density, weed invasion and erosion.

Bridges have been proposed at Roe Swamp and between Horse Paddock Swamp and Bibra Lake. The average clearance under the bridge proposed at Roe Swamp ranges between 3.5m and 5m above the ground. A cross–sectional view of the proposed bridge is provided in Figure 3.5-7. Retaining walls that extend above ground have been proposed through Roe Swamp and adjacent to Bibra Lake (Section 3).

Potential impacts of rainfall shading are applicable under the proposed bridge at the northern section of Roe Swamp, as well as immediately adjacent to proposed retaining walls, depending on the angle of rainfall.

Typically, rain will fall perpendicular to the ground, with a slight angle based on the direction of prevailing winds. In the Perth region, rainfall occurs predominantly during winter, between May and August, and at this time of the year, prevailing winds are from a south–westerly direction (BoM 2011b). Based on this, it is estimated that the area under the bridge deck, as well as a small area to the north–east of the bridge will be shaded from direct rainfall. Given that rain is likely to blow in under the bridge from the south–west during windy conditions, the area of rain shade is estimated to be equivalent to the area of the bridge deck (i.e. in the order of 0.4 hectares). This compares to an area of approximately 0.7 hectares that would be required to be cleared in this location if a solid carriageway was constructed with batters and culverts instead of a bridge.

A lack of direct rainfall under the bridge at Roe Swamp is expected to have a minimal impact on vegetation, due to its groundwater dependent classification. Since the area will be shaded from sunlight, water requirements will be reduced.

During winter, when the majority of rainfall occurs, the soil moisture in the vicinity of Roe Swamp is relatively high and likely to provide sufficient surface moisture to maintain current vegetation. Furthermore, the bridge crosses Roe Swamp at a low point and, during heavy rainfall, there is likely to be some surface water conveyance under the bridge to supplement the areas shaded from direct rainfall.

Potential impacts of shading from direct sunlight will be applicable to areas under the bridge proposed at Roe Swamp and adjacent to proposed retaining walls. Shading will only occur on the southern side of the road and will be most significant for the section immediately west of the bridge at Roe Swamp. Shading will also occur for the section immediately east of the bridge, between Bibra Lake and Horse Paddock Swamp. Impacts of shading relate to reduced photosynthetic potential, due to diminished sunlight levels, and also reduced recruitment of some species that require soil temperatures achieved by thermal heating. Both are discussed in more detail below.

Throughout the year, the inclination of the sun varies and, therefore, the location of shadow also varies from day to day. The average orientation of the proposed project is generally east–west and therefore most shading will occur directly under the bridge. The photoperiod, intensity of insolation and angle of the sun also varies throughout the year.

It is possible to model where shading will occur, based on the location and inclination of the sun at various times of the day, in association with the project design. This has been done for the bridge at Roe Swamp and the adjacent embankment. Figure 6.6-3 shows an example of this shading model that captures shadows cast at 1430hrs on 21 June. This period represents the time at which the longest shadow is cast, given the orientation of the alignment and the day at which the sun is at its lowest midday inclination.

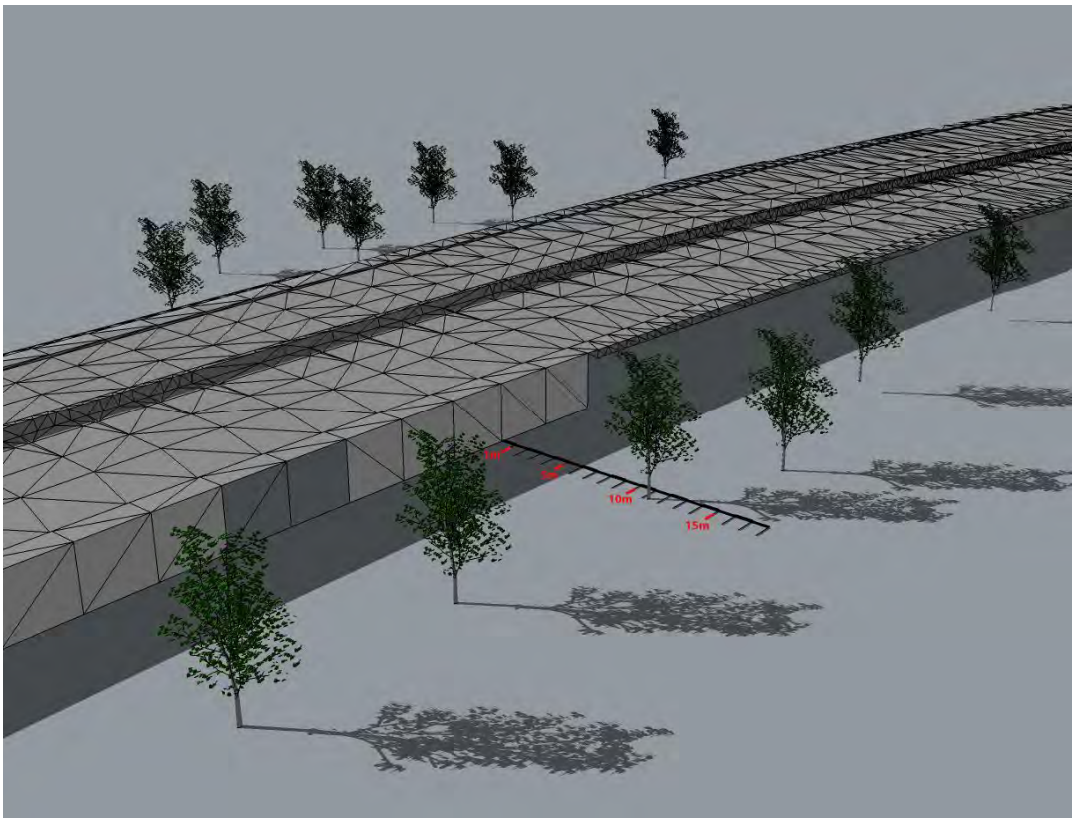


Figure 6.6-3: Shadow Fall from Retaining Wall and Bridge at 1430hrs on 21 June

The scale in Figure 6.6-3 shows that, at this time, the shadow extends for six metres from the formation edge. It is possible to quantify both the spatial extent of shading and duration throughout the day and the year. This has been carried out in a series of modelled images. These outputs were layered, so that a single image shows the spatial extent of shading and the colour grade of the shadow indicates the duration of the shade in that location; that is, darker shadows depict shading over a longer duration.

Figure 6.6-4, Figure 6.6-5 and Figure 6.6-6 show the modelled shadow throughout the day at winter and summer solstices (21 June and 21 December, respectively) and also during spring equinox (21 September).

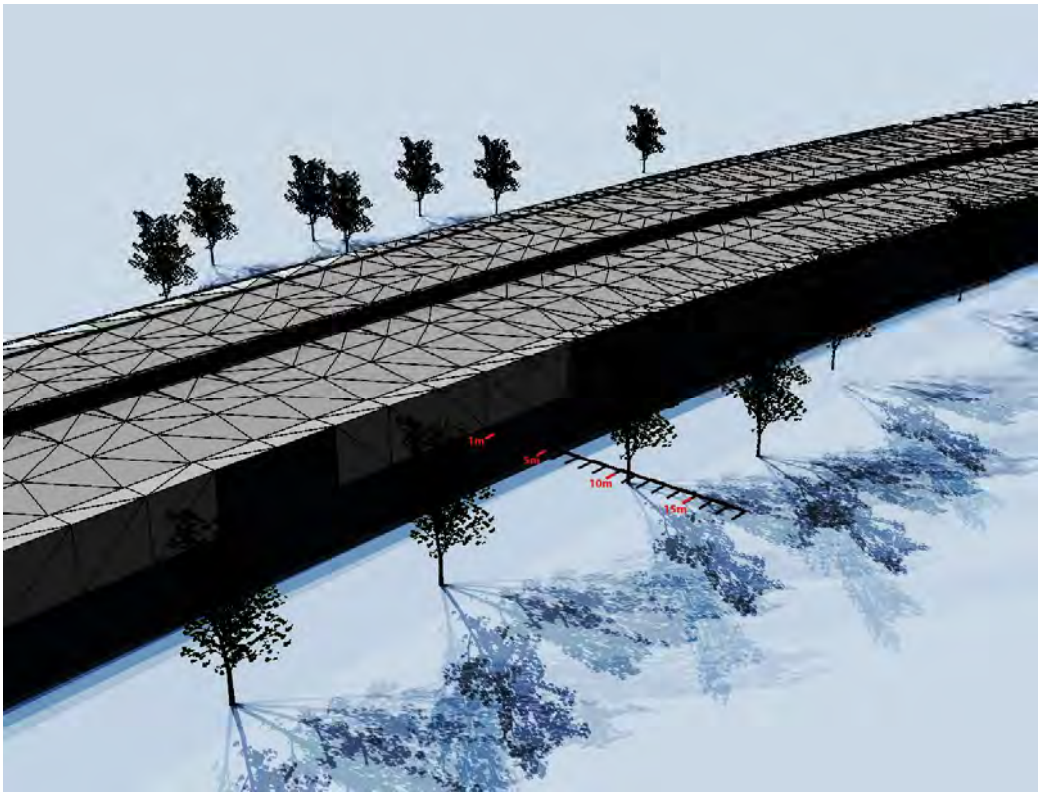


Figure 6.6-4: Winter Solstice Shading

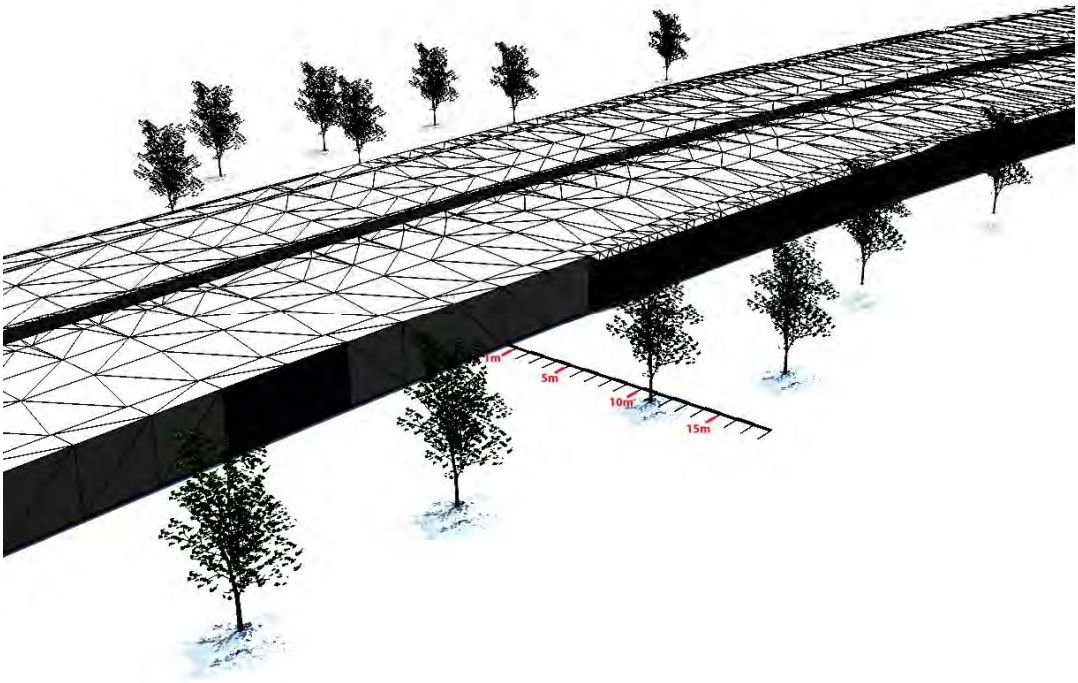


Figure 6.6-5: Summer Solstice Shading

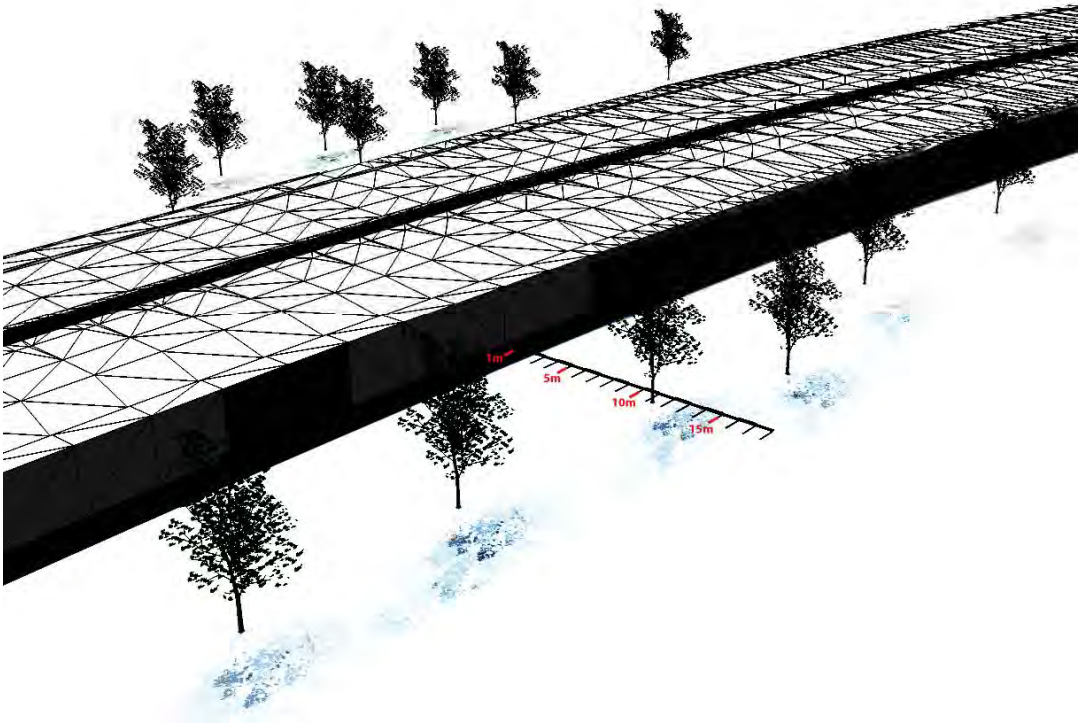


Figure 6.6-6: Equinox Shading

As shown in the model outputs, solar shading in the vicinity of the bridge and retaining wall (southern side) will be most extensive when the sun is at its lowest angle in the sky during the winter solstice (Figure 6.6-4). This is also at a time when light intensity and photosynthetic rates are naturally low. Shading at ground level during the main growth and flowering seasons in spring and early summer will be less than 2m from the southern edge of the infrastructure.

Figure 6.6-7 shows the extent and duration of shading in the vicinity of the bridge and the retaining wall throughout the year, all times of the day.

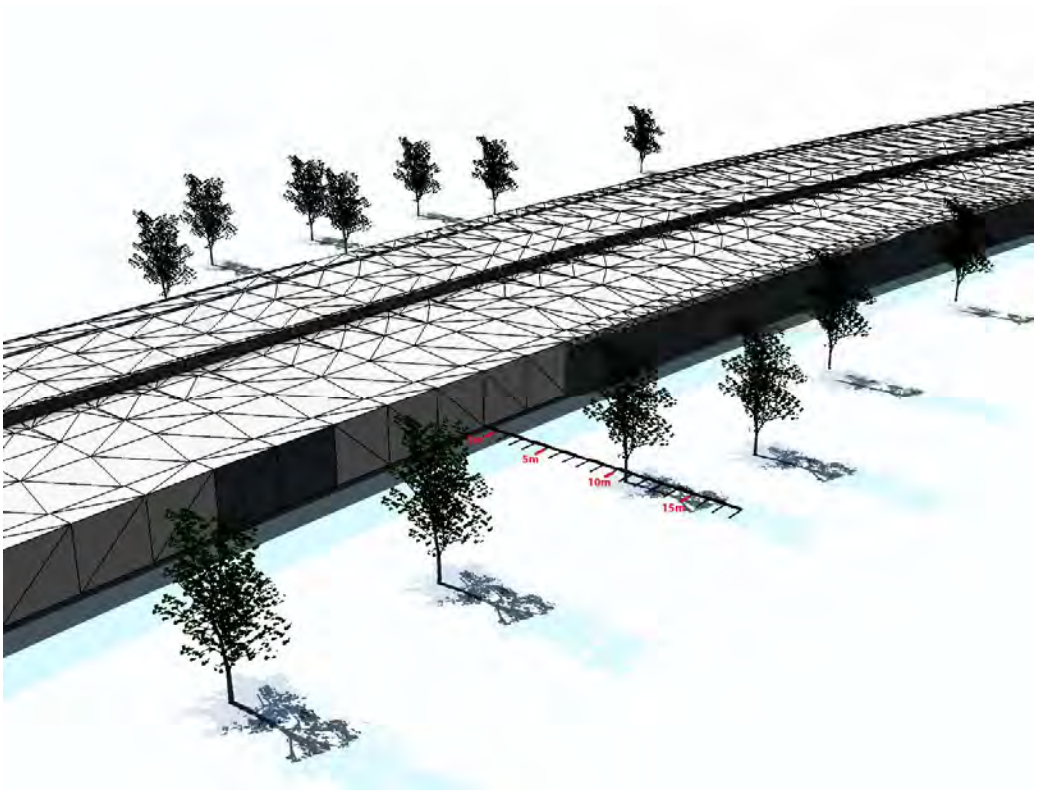


Figure 6.6-7: Shading from Retaining Wall and Bridge Throughout the Year

Table 6.6-8 summarises the percentage of time that ground level shading will occur at various distances from the base of the proposed infrastructure. The maximum shadow length (7–13m from the base of the bridge or retaining walls) occurs entirely during winter, when insolation and plant growth rates are low. However, for reasons outlined below, the scale of the impact will be significantly less.

Solar shading by the bridge and retaining walls will affect up to 0.8ha of vegetation

Table 6.6-8: Shaded Vegetation South of the Roe Swamp Bridge and Embankment

South Shade Zone (Width from Edge of Infrastructure)	Shaded Area (ha)	Approximate Proportion of Daylight Hours Shaded
0–0.5m	<0.1	87.5%
0–2m	<0.1	75%
2–7m	<0.1–0.2	18.8%
7–13m	0.2–0.4	<3%

The shading calculated is additional to the shading directly under the bridge deck, which is an area of approximately 0.4 hectares. This area, whilst it will not be cleared, is likely to be impacted by shading, resulting in a modification to the existing vegetation community composition. If the vegetation were cleared for construction of a conventional road formation with sloped embankments (batters), approximately 0.7 hectares would be cleared. The installation of the bridge therefore avoids direct clearing of approximately 0.3 hectares, which represents almost three times the area that will be shaded 75 percent of the time or greater. Furthermore, the 3m clearance buffer that will be required for construction purposes encompasses most of this 'shade zone' and therefore shading will be of rehabilitated vegetation. There are options to revegetate such areas using more shade–tolerant local species, many of which occur in this area naturally, under the dense canopy that results in significant and prolonged shading of the understorey.

Adjacent to and beneath the bridge, vegetation is all in 'Very Good' condition and is comprised of vegetation community ErCtS, which is dense wetland vegetation of *Eucalyptus rudis*, *Banksia attenuata* and *Melaleuca preissiana* over *Taxandria linearifolia*, over *Cyathochaeta teretifolia* (P3). This community is significant for a number of reasons, including being limited in the local context and supporting populations of Priority and regionally significant flora.

The vegetation community adjacent to most of the retaining wall is CcBKfS, which is mostly in 'Good' condition in this location. This community is a forest of *Corymbia calophylla* over *Banksia* and *Kunzea*. This community is of significance, because it supports populations of Priority and regionally significant flora.

At the western end of the retaining wall is a small area of the vegetation community MpKgS in 'Degraded' condition. This community is open woodland of *Melaleuca preissiana* and occasional *Eucalyptus rudis* over *Kunzea* with Arum Lily infestations. This community appears to be of local significance due to a limited representation; however, this is because it is an incidental area of a degraded vegetation type, not because it is locally rare. This community is also of significance as it supports a population of regionally significant flora.

The impacts of shading that lead to reduced photosynthetic potential are likely to be reduced growth and reduced proliferation of flora that are accustomed to sunny conditions. The morphology of plants is also likely to be affected, for example elongation of petioles (stems) and branches and other such adaptations, have the potential to result in reduced plant vigour and possibly eventual plant and species decline.

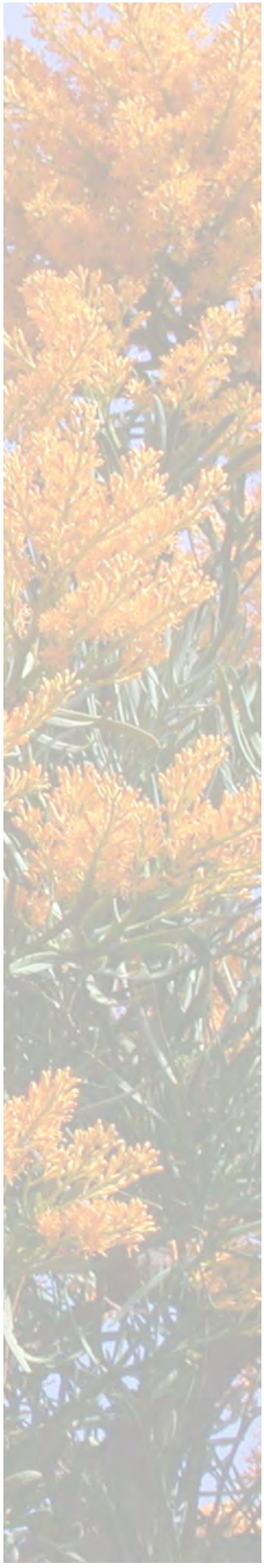
Shadowing from the bridge and the embankment may impact on the structure of vegetation, due to changes in soil temperature. Over 70 percent of *Banksia* woodland species require dormancy breaking treatments for seed germination and survival. These treatments include soil temperatures between 16 and 22 degrees Celsius between April and May (warm stratification) to coincide with rainfall, so that soil moisture requirements of greater than 4 percent are met (Merritt *et al*. 2007). Most species also require dry soil conditions after ripening of seeds, which requires soil moisture to drop to less than 1 percent after spring (Merritt *et al*. 2007). Therefore, vegetation recruitment may be impacted due to lower soil temperatures and increased soil moisture for longer periods of time. Table 6.6-9 summarises the requirements of some of the GDE indicator species present within the shaded areas and the predicted impact that this may have on seed germination.

Table 6.6-9: GDE Indicator Species Present Within Bridge Shade Footprint and Their Method of Reproduction

Shrub Species Present Beneath Bridge Footprint	Seed Dormancy Release/Germination Syndromes (Merritt *et al*. 2007)	Bridge Impact on Natural Regeneration Potential
Astartea scoparia	Non–dormant, but require incubation under appropriate germination conditions including moisture	Possible, but stratification not required
Baumea juncea	Stratification requirements	Yes
Baumea rubiginosa	Stratification requirements	Yes
Hypocalymma angustifolium	Non–dormant, but require incubation under appropriate germination conditions including moisture	Possible, but stratification not required
Kunzea glabrescens	Non–dormant, but require incubation under appropriate germination conditions including moisture	Possible, but stratification not required
Meeboldina scariosa	Stratification requirements	Yes
Taxandria linearifolia	Non–dormant, but require incubation under appropriate germination conditions including moisture	Possible, but stratification not required

The vegetation in the vicinity of the proposed bridge at Roe Swamp is currently shaded by a dense canopy of trees. Shading from the bridge is not expected to diminish existing sunlight levels on a limited area of existing low–light vegetation. Various flora species are expected to adjust to altered light levels over time. With proper management, potentially including targeted weed control for shade tolerant species such as Arum Lily, it is not expected that successional change in vegetation composition will lead to an increase in weeds, as most weeds typically proliferate with increased sunlight.

The installation of and proposed construction for the bridge avoids direct clearing of approximately 0.3 hectares. Although not cleared, the area of vegetation under the bridge is likely to be impacted by shading, resulting in a modification to the existing vegetation community composition. However, these impacts are predicted to be low. Shading from the retaining walls at ground level will extend a maximum of six metres from the base of the formation. Light will penetrate to progressively lower strata as the distance from the formation increases. Conseqently, shading impacts from the proposed retaining walls are also predicted to be low.



6.6.3.2. Edge Effects

Altered light regimes, competition for water, desiccation and availability of nutrients along the cleared edges of the proposed project may result in a change in species composition and increase the risk of weed invasion, initially on those edges and thereafter into the remnant area. Edge effects, a collective term for some of these follow–on effects of fragmentation, is also known as the tendency for increased variety and diversity at community junctions (Odum 1971).

A new edge of a vegetated area is a disturbance that allows for the potential invasion of weeds. They may readily colonise disturbed areas where conditions, such as increased light penetration and water availability, are favourable for the growth of invasive annual weed species. A reduction in competition for light, water and nutrients at the edges created by the proposed project will result in the increased potential for weed invasion.

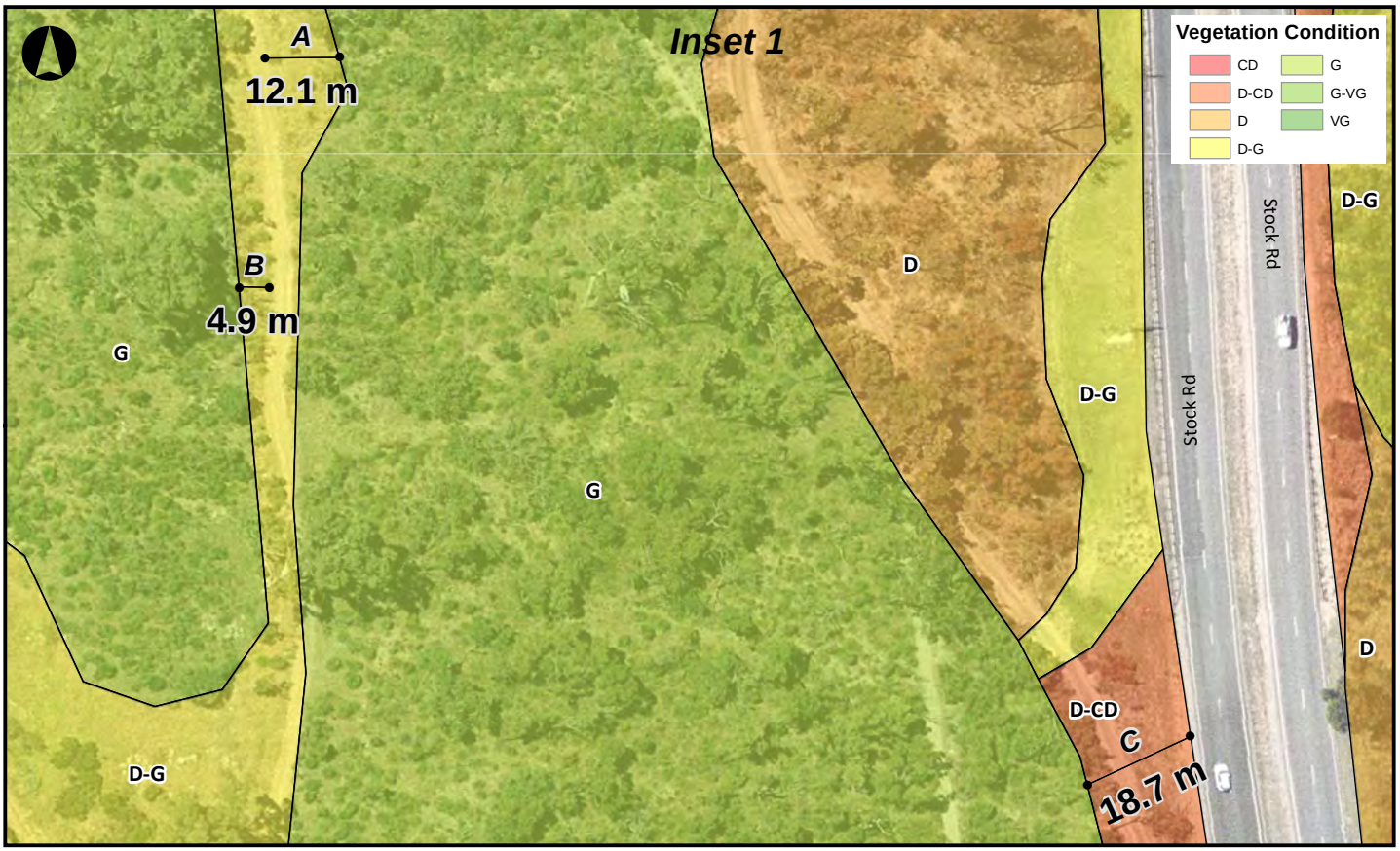
Generally, the longer the edge, the larger the area prone to edge effects. Additionally, more angular edges will result in greater edge effects. The value of the vegetation for providing fauna habitat in such a situation is also reduced. Regular edges or corners increase the disturbance and invasion is present at multiple edges in such localised areas. Rounded edges and regular shapes minimise edge effects. It follows that the smaller the area (i.e. larger edge to area ratio), the greater the risk of impact occurring.

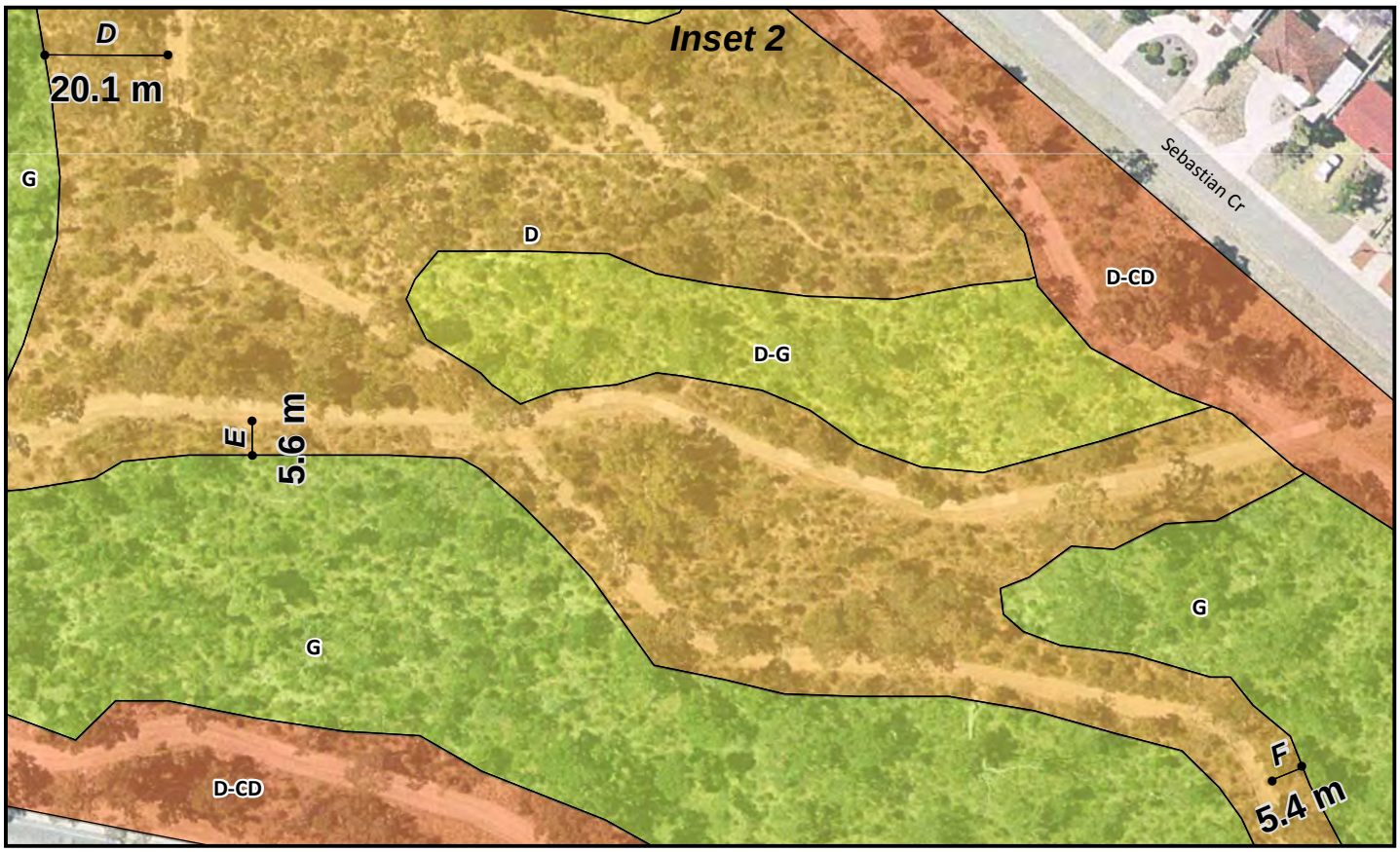
For vegetation that serves as habitat, the extent of the effect varies with the length of the edge, the contrast in edge, the width of the habitat and the type and stability of the vegetation. Refer to Section 5.8 for further details.

6.6.3.2.1. Current Edge Effects and Weed Incursion

Edge effects will vary based on the nature of the edge and the land use associated with it. For example, in the existing project area, weed incursion adjacent to sandy, informal tracks and firebreaks that intersect intact native vegetation is more severe than in areas adjacent to more recently constructed major roads and highways. Weed incursion can be measured by the distance from the edge that degraded vegetation has been recorded to the point where the vegetation condition improves to the best condition recorded in that location.

The analysis depicted in Figure 6.6-8, Figure 6.6-9 and Figure 6.6-10 shows weed incursion distances from tracks, road construction and operation. It is important to note that there are other variables that can significantly affect the observable degradation additional to weed incursion, such as impacts by rabbits, which are particularly evident in the area north of Hope Road and west of Bibra Drive. In the bushland adjacent to the firebreaks in this location, the weed incursion is up to 66m, as shown in Figure 6.6-9. Also illustrated is the degradation from weed incursion adjacent to informal tracks and firebreaks that is, on average, approximately 14m. Adjacent to Stock Road (constructed in the mid–1970s), weed invasion from the firebreaks is commonly approximately 20m or less (Figure 6.6-8). Weed incursion into the areas of retained bushland adjacent to the revegetated batters of the existing Roe Highway/Kwinana Freeway interchange are, on average, less than 10m and often virtually zero adjacent to fill batters (Figure 6.6-10).





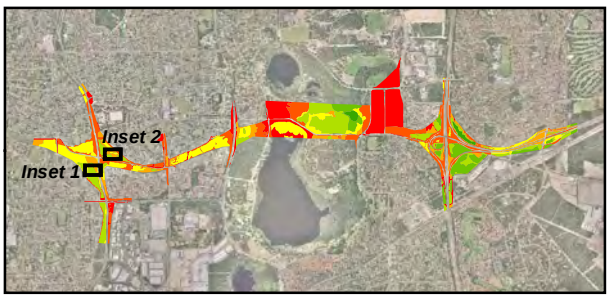
Existing Weed Incursion - Stock Road and Sebastian Crescent

South Metro Connect

Figure 6.6-8

0 10 20 30 40

Metres



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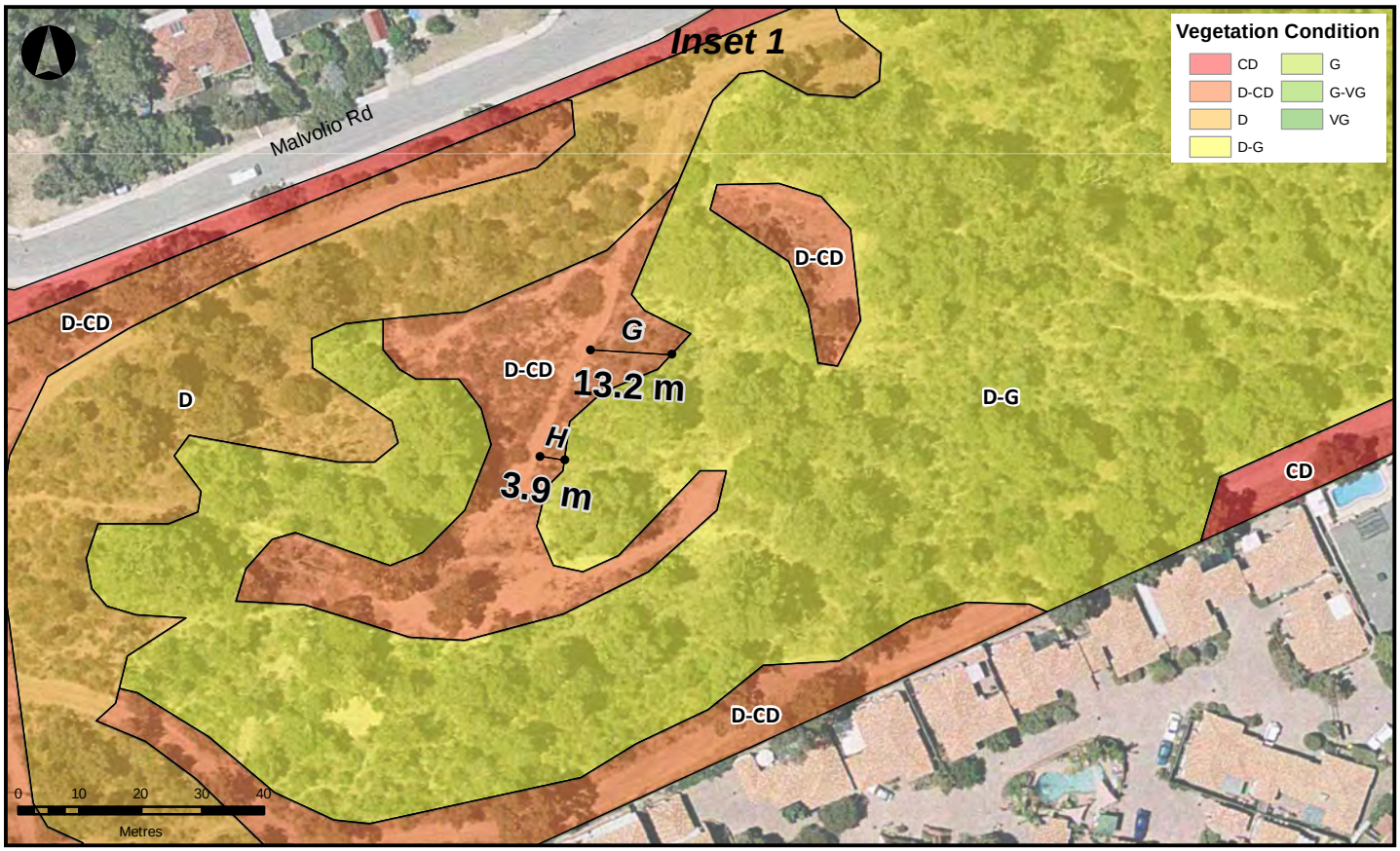
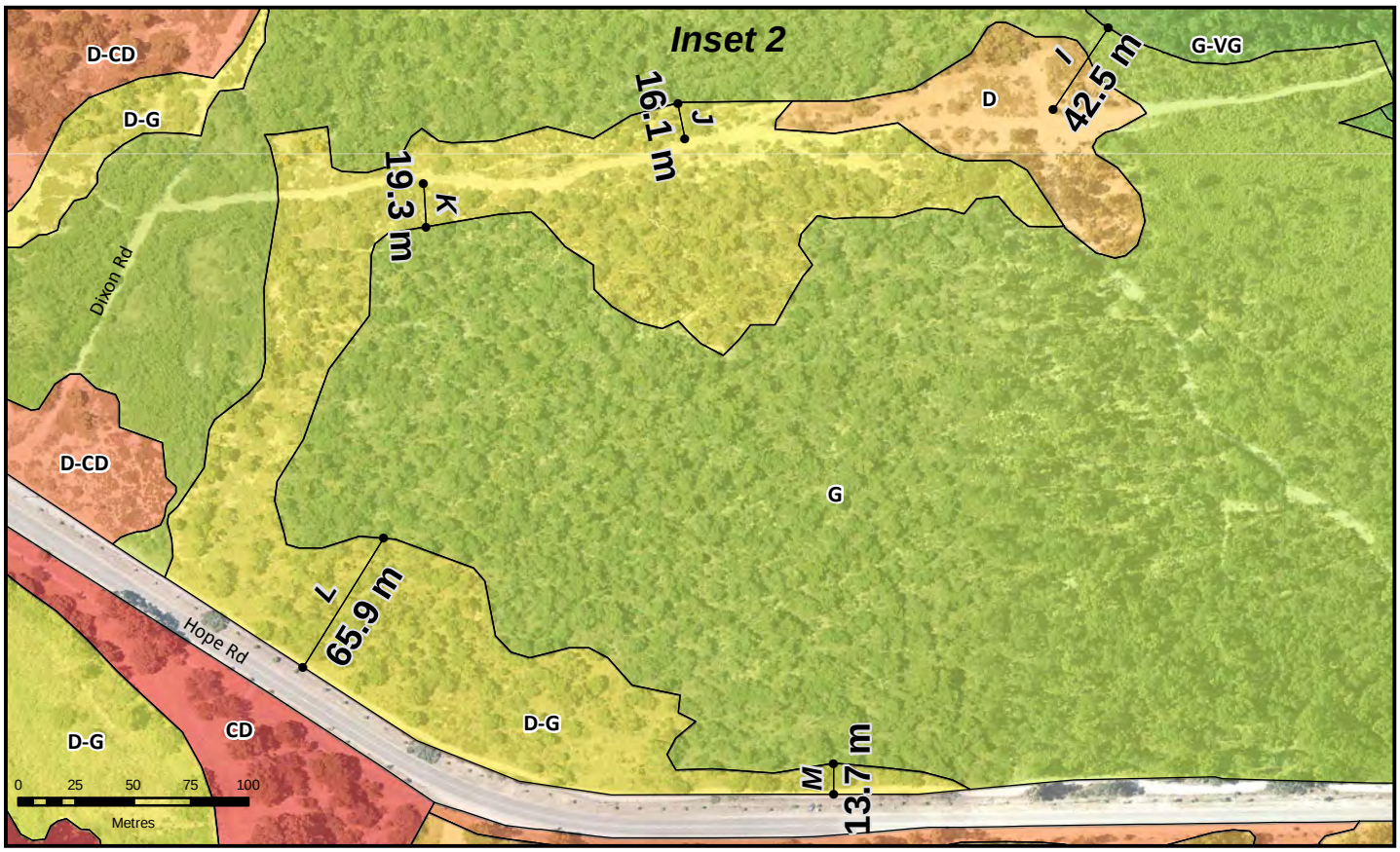
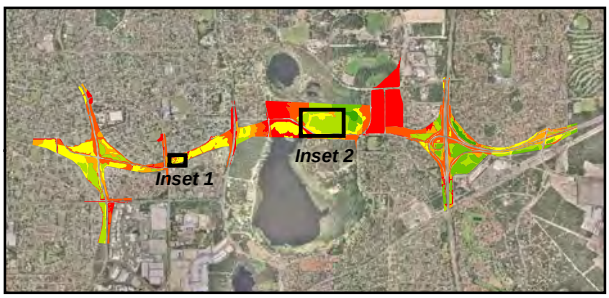




Existing Weed Incursion - Malvolio Road and Hope Road

South Metro Connect

Figure 6.6-9



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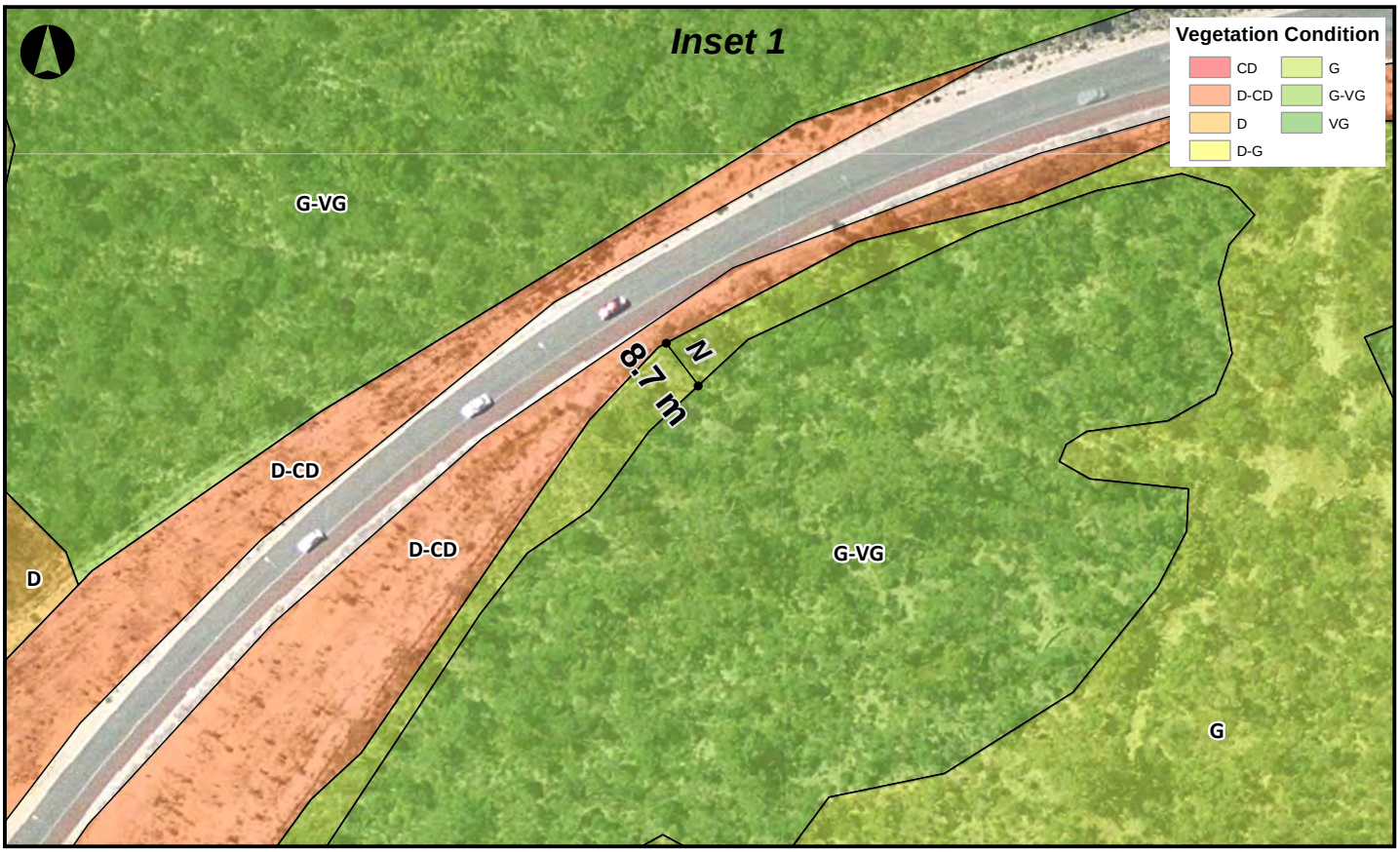
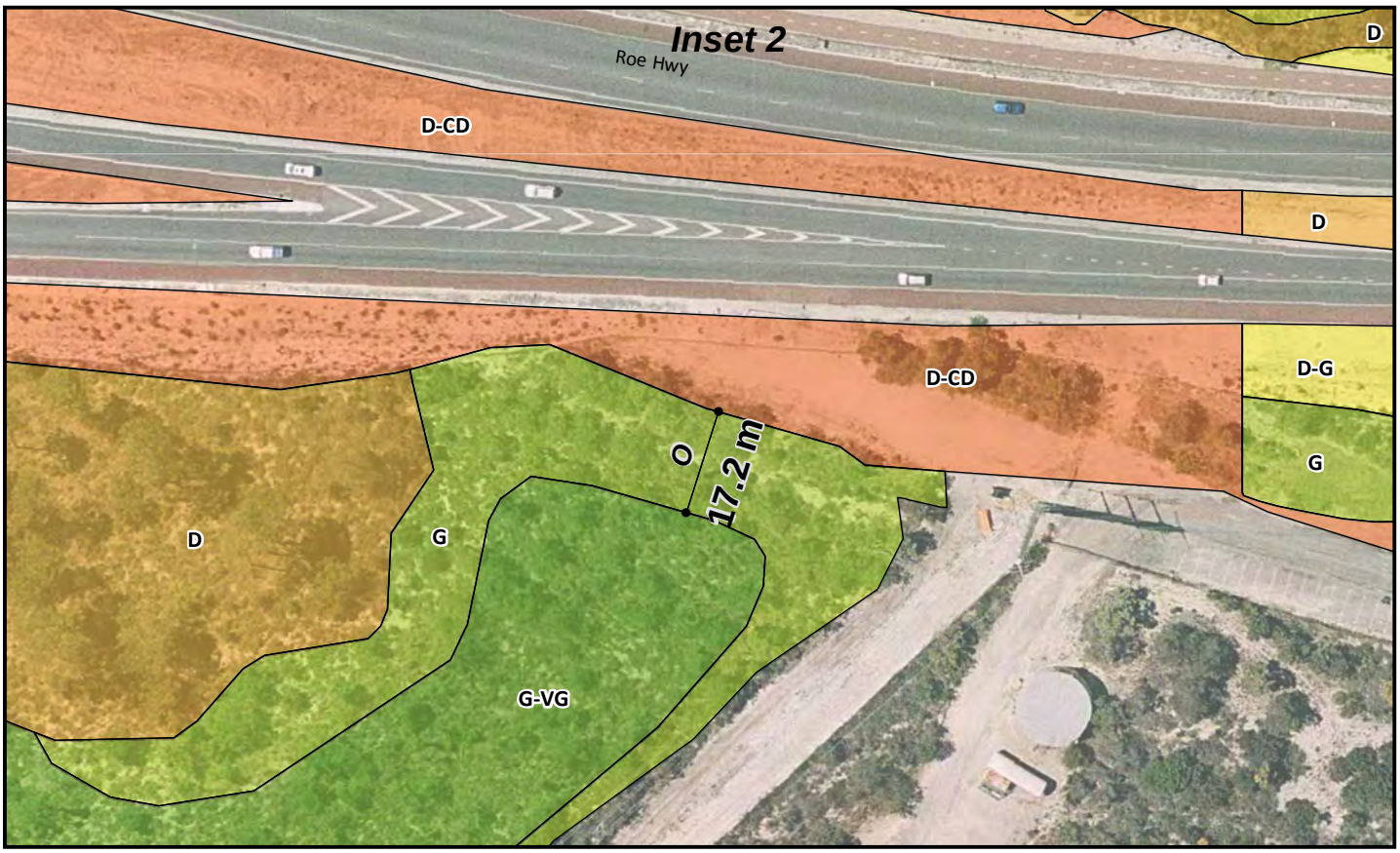




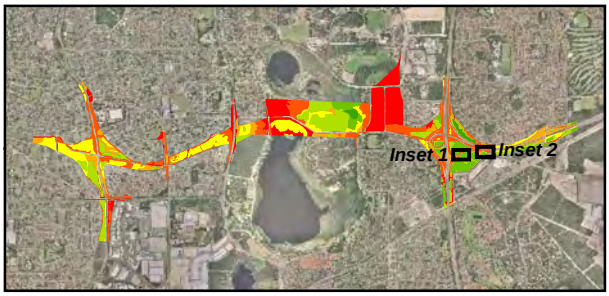
Existing Weed Incursion - Roe Hwy / Kwinana Fwy Interchange

South Metro Connect

Figure 6.6-10

0 10 20 30 40

Metres



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Weed incursion is not expected to be significant

Weed incursion caused by the proposed project is not expected to be significant, due to the similarity to the existing Roe Highway (i.e. Roe Highway Stage 7), which has undergone minimal weed incursion since its construction. Furthermore, proposed closure of informal tracks and various restoration works are expected to reduce existing weed loads in the local bushland and result in a net improvement in vegetation condition (with active restoration).

6.6.3.2.2. Predicted Edge Effects and Weed Incursion Risk

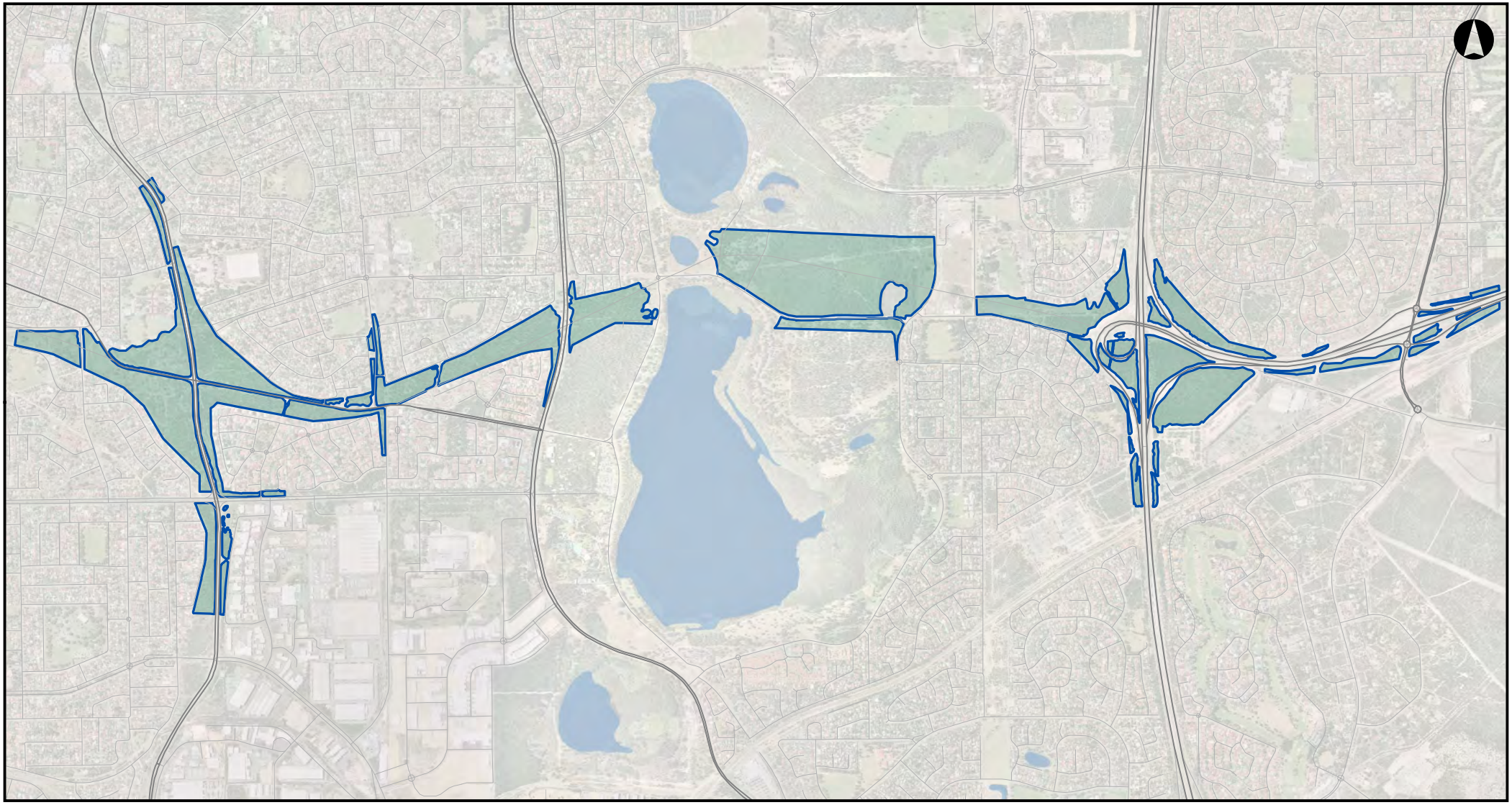
There will be an overall reduction in edge effects

Figure 6.6-11 to Figure 6.6-14 demonstrate the current edges of bushland areas in the study area and the additional edges that will result following clearing and construction of the proposed project. These edges have been calculated by digitising the existing edges of all cleared areas within the project area, including roads, cleared areas and tracks. The design footprint layer has then been added and additional edges determined. This has enabled a calculation of the existing edge:area ratio, which has been determined as 1:5.8. This means that for every linear metre of edge (tracks, roads, etc.) the vegetation remnant is $6m^2$. The analysis determined that the proposed project footprint would result in a change of this ratio to 1:12.1. This means that for every linear metre of edge there will be $12m^2$ of vegetation remnant. This translates to a reduction in the edge:area ratio to less than half of the current ratio. Effectively, fragmentation of the remnant vegetation will also be reduced and this will be further enhanced by proposed rehabilitation and closure of some tracks that currently intersect the bushland.

This increase in edge to area ratio following project construction will be more than double, which reflects decreased fragmentation of the remaining bushland. The restoration programme will aim to eliminate some of these edges via rehabilitation of tracks and decommissioning Hope Road.

6.6.3.3. Herbicides

Inappropriate herbicide application, as part of ongoing maintenance and weed management during and after construction, could affect native flora and vegetation. Annual and non-woody species are particularly susceptible to common herbicides used to control grass weed species. The risks of adverse impacts on native vegetation from herbicide application in adjacent weedy areas are greater for broad scale ('blanket') application, as opposed to spot treatments. Risks are also greater during windy conditions.



Extent of Native Vegetation Within Project Area

South Metro Connect

Figure 6.6-11

0 250 500 750 1,000

Metres

1:28,000 (A4)

Extent of Intact Native Vegetation within Project Area

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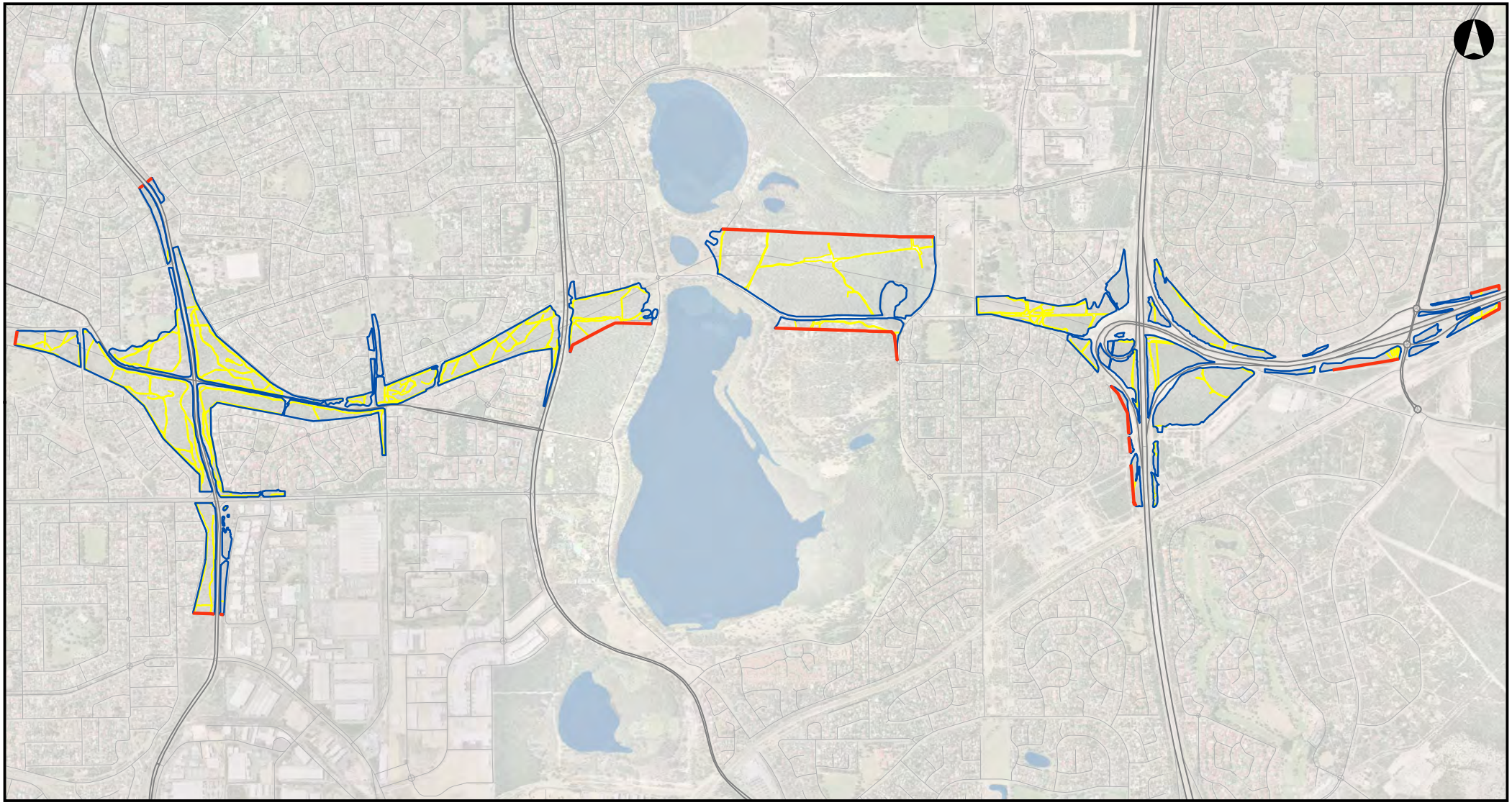

Vegetation Edges within the Project Area, excluding Project Area Boundaries within Remnant Vegetation

South Metro Connect

Figure 6.6-12

0 250 500 750 1,000

Metres

1:28,000 (A4)

Outside Edges of Intact Native Vegetation Within Project Area

Edges of Native Vegetation Within Project Area

Outside Non-edges of intact native vegetation within Project Area
(not included in calculations)

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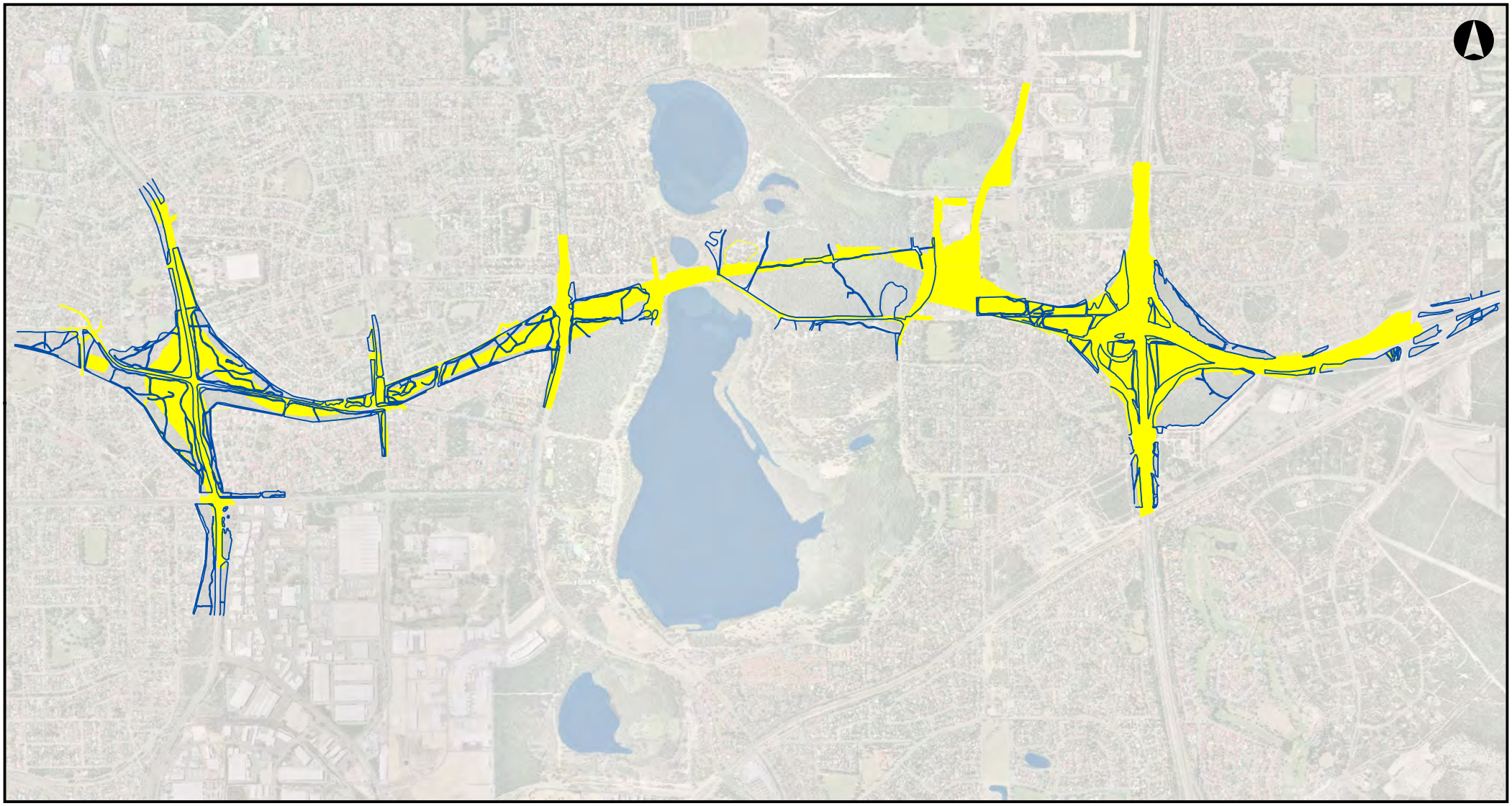

All Existing Vegetation Edges of the Project Area in relation to Construction Footprint, excluding Project Area Boundaries within Remnant Vegetation

South Metro Connect

Figure 6.6-13

0 250 500 750 1,000

Metres

1:28,000 (A4)

All Edges of Intact Native Vegetation Within Project Area

Construction Footprint

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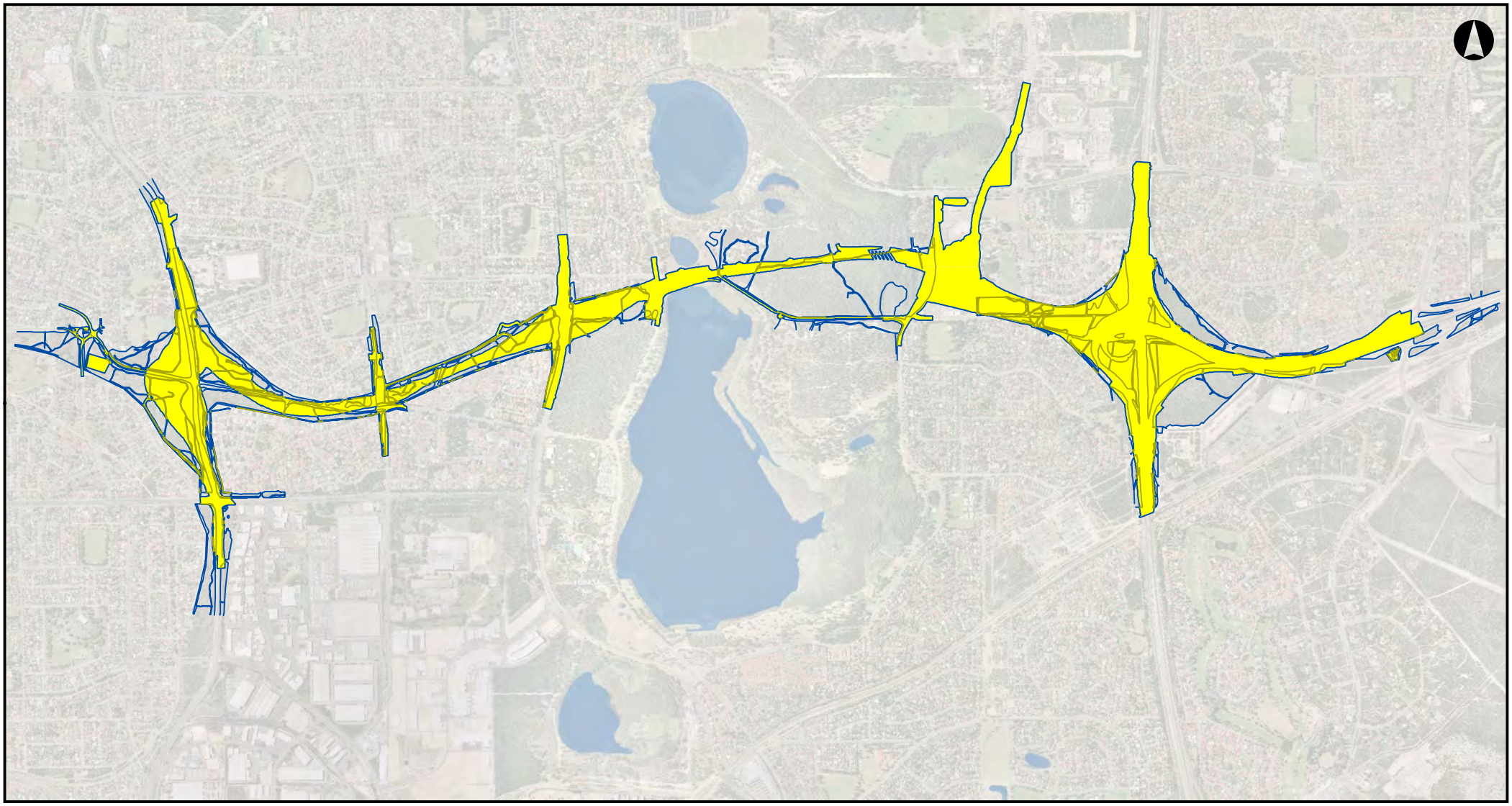

Vegetation Edges Created by Construction Footprint, including Existing Edges Outside of Footprint

South Metro Connect

Figure 6.6-14

0 250 500 750 1,000

Metres

1:28,000 (A4)

Current Edges of Intact Native Vegetation Under Construction Footprint

All Edges of Intact Native Vegetation Following Project Construction

Construction Footprint

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Last Modified 3/05/2011 at 01:13 PM by jonesk4 M:\60100953 - Roe Hwy Ext\6 Draft Docs\6.1 Reports\Environmental\4.1.3.C Revised PER\Figures\Final Figures\Figure_6_6_14_Vegetation edges created by construction footprint including existing edges outside footprint.mxd

6.6.4. Management and Mitigation

The following sections describe the management and mitigation measures which will be implemented to minimise potential impacts on flora and vegetation.

6.6.4.1. Management of Vegetation Clearing

The most important contribution to the conservation of the natural vegetation within the project area has been made through design decisions that avoid and minimise clearing. The focus of the development phase of the proposed project has been to carefully select the alignment to avoid areas of high quality vegetation and significant vegetation such as areas within Bush Forever, significant flora habitat and vegetation within the CCW, wherever possible, as well as to reduce the footprint of the proposal. The following avoidance measures have been implemented prior to the calculation of vegetation clearing impacts of the proposed project:

- Selection of an alignment which follows already cleared areas, where possible (including already disturbed power line corridor);
- Adjustments to the final vertical alignment of the carriageways, thus reducing the amount of cut and fill and therefore the width of the footprint;
- Adjustment of the design speed to enable sharper curvature in the alignment and thus avoid areas of better quality vegetation, significant vegetation communities and populations of significant flora, as far as practicable;
- Proposed bridge at Roe Swamp will maintain surface and groundwater hydrological regimes, to preserve vegetation that are dependent on these regimes;
- Construction of the elevated structure (bridge) at Roe Swamp using a construction methodology that avoids the need for:
    - Continuous clearing under the structure that would otherwise be required for a non-elevated road carriageway; and
    - An access road and associated vegetation clearing.
- Incorporation of retaining walls (in lieu of batters) to reduce the width of the footprint;
- Narrow median to reduce footprint;
- Placement and design of drainage and stormwater management facilities to avoid clearing and maintain or enhance vegetation and local hydrological conditions to the benefit of existing wetland vegetation and rehabilitation efforts; and
- Relocation of the Murdoch Drive interchange to avoid the construction of an interchange within Roe Swamp.

Construction methodologies to further minimise the extent of vegetation clearing will also be adopted. For instance, the width of the proposed bridge at Roe Swamp is designed to have numerous spans, which will permit the substructure (piling and headstocks) and superstructure (beam installation and deck concreting) construction to be undertaken with a reasonable sized crane accommodated on the superstructure. In meeting these requirements, the choice of construction method reduces the degree of impact on the wetland and the associated flora and vegetation.

The clearing area based on the design will be surveyed and clearly demarcated to prevent accidental over-clearing. During demarcation of the clearing boundary significant flora, such as large habitat trees that are located on or close to the edge of clearing, will be inspected and included within the area of retained vegetation, if appropriate and if practicable. The importance of remaining within the boundary will be communicated to construction contractors, as part of inductions. Avoidance of other impacts on retained vegetation will also be communicated during inductions, such as prevention of entry to retained vegetation areas for unnecessary purposes.

A comprehensive vegetation management plan will be developed prior to project construction. The following procedures and best practices will be implemented during the vegetation clearing phase:

- Clearing boundaries will be field surveyed, marked, verified and fenced prior to clearing commencing and specific trees close to the clearing zone will be tagged for retention;
- Clearing boundaries will be marked on plans and drawings;
- Vehicles will be fitted with GPS surveillance, to ensure operators are aware of clearing boundaries;
- Temporary fencing will be erected to protect areas of significant and good quality vegetation, and significant flora populations;
- Environmentally significant areas will be clearly marked prior to construction activities;
- No additional clearing of native vegetation for site compounds, laydown areas or side tracks will be permitted;
- Trees to be trimmed and/or preserved will be clearly tagged with different colour flagging tape;
- Weed infested areas will be identified and cleared separately;
- No weed infested material will be used for rehabilitation efforts;
- Non-weedy topsoil will be incorporated in the revegetation programme;
- Herbicides applied on cleared areas to prevent weed growth during construction will be applied during favourable (low wind) conditions, thereby avoiding impacts on adjacent retained vegetation; and
- A Soil Hygiene Plan will be prepared and implemented to prevent the spread of dieback and weeds.

6.6.4.2. Fragmentation

Design features, such as the bridge structure at Roe Swamp and underpasses, will maintain connectivity between the northern and southern sides of the proposed road. These connections between remnant vegetation on either side of the proposed project will minimise the impacts of fragmentation. To further reduce fragmentation within the project area, it is proposed that Hope Road will be closed near the entrance to Native Animal Rehabilitation Centre (ARC) and the area west of this point will be rehabilitated and revegetated, with the exception of a corridor sufficient to accommodate a 5m wide a Principal Shared Path (PSP), which is currently proposed to follow the existing Hope Road alignment.

6.6.4.3. Edge Effects

The concept design will decrease the edge to area ratio within the project area. In order to further reduce the adverse impacts of edge effects, some existing and newly created edges within the project area (such as those along the portion of Hope Road proposed to be rehabilitated) will be examined and considered in detail in terms of their potential to be restored, revegetated or regenerated, to enable reintegration of these areas with intact vegetation and habitat.

Following construction, the retained and rehabilitated vegetation on-site will be monitored to assess vegetation condition and weed infestations, and will focus on edges of retained or rehabilitated vegetation. A weed control programme for the site will also focus on controlling weeds on bushland margins. Supplementary planting and soil stabilisation (e.g. mulch) may be carried out, in order to minimise weed invasion of bushland edges by removing the open, sandy opportunity for weed invasion.

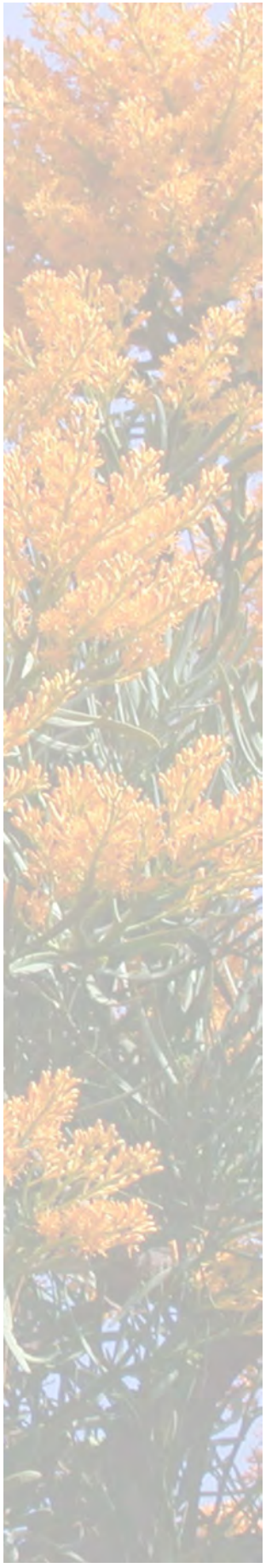
6.6.4.4. Weeds

Proliferation of weeds in rehabilitated areas can cause failure of revegetation efforts; once established, weeds present a reoccurring maintenance challenge. Weedy species established in rehabilitated areas can spread into adjacent remnant vegetation.

Given that the introduction of weeds into rehabilitation areas can occur as a result of re-use of weed-infested topsoil, only weed-free topsoil will be directly spread onto rehabilitation areas. However, Main Roads' experience on projects, such as the Kwinana Freeway and more recently the Perth Bunbury Highway, has demonstrated that benefits derived from composting site-won material, adding organic material, higher nutrient levels and soil micro-organisms present in topsoil, far outweigh the adverse effects of using weedy topsoil. Weedy topsoil will therefore be stripped and composted prior to use on rehabilitation areas, in order to sterilise the seedbank.

With appropriate weed hygiene measures enforced during and after construction activities, it is anticipated that weed dispersal will be controlled and the spread of weeds will be minimised.

Detailed mapping of the vegetation condition has been carried out and will be combined with mapping of the locations of significantly weed infested areas and areas of Declared Plants (pest weeds). This mapping will contribute to the site management of the spread of weeds during the construction phase that will be achieved via the preparation and implementation of a Soil Hygiene Plan. This plan will identify zones of varying weed classifications, clearing plans within these classifications and specifications for clearing, mulching, topsoil stripping and stockpiling. The procedures will address the use, storage and re-use of vegetative matter and topsoil to manage the spread of weeds and control of Declared Plants.



6.6.4.5. Dust

Areas cleared during construction will be stabilised as rapidly as practicable, primarily through the application of water to dampen the exposed soil. Topsoil stockpiles will be stabilised in accordance with best management practice to ensure topsoil values are maximised. As soon as the construction schedule allows, mulch will be applied to the new batters, embankments and other completed works. This will assist in controlling erosion and scour during rainfall events, before revegetation can provide additional stability, and will control dust during dry and potentially windy conditions. Wind erosion preventative fencing may be required in some locations of the project area during construction, to protect vegetation, wetlands, water-bodies, fauna and residential areas from dust. A dust management plan will be prepared, detailing dust management procedures to be followed during construction.

6.6.4.6. Altered Surface Hydrology and Groundwater

A variety of management measures aimed at minimising the risk of hydrological impacts of the project area are presented in Sections 6.2 and 6.3. Successful management of these risks will minimise the impacts of changes in hydrology and groundwater on flora and vegetation, particularly GDE communities.

6.6.4.7. Chemical Spills

The risk of accidental discharge of oils or other hazardous materials into the environment during construction will be managed by the preparation and implementation of a CEMP. Details of the CEMP are discussed in Section 6.4.

6.6.4.8. Fire

Fire will be managed during construction through the development and implementation of a CEMP. Specific procedures to minimise the potential for fires resulting from construction activities within the project area will include:

- No burning of vegetative material or rubbish will be allowed;
- No fires are to be deliberately lit;
- Cigarette butts will be disposed of appropriately in designated containers;
- Clearing activities will be prohibited during high fire danger periods;
- Machinery used during proclaimed high fire danger periods that could discharge sparks will be fitted with spark arrestors and set up on ground free of dry vegetation;
- All personnel involved in 'hot work' will be adequately trained in fire prevention, safety and basic fire fighting skills;
- Hot works being undertaken within 50m of vegetation, including grass, will be performed under supervision and will have fire fighting equipment on hand;
- In the event that a fire is started within the project area or adjacent bushland, personnel are to immediately put out the fire (if it is safe to do so), contact the Fire and Emergency Services Authority of Western Australia (FESA), inform their supervisor and inform representatives of Main Roads, who will liaise with FESA; and
- Fire management procedures for the construction phase, as listed, will be communicated to site personnel during site inductions.

The risk of fire during the operational phase is considered to be low. Disposal of cigarette butts from vehicles is likely to present the highest potential for fire.

6.6.4.9. Dieback

Although dieback infestations have not been confirmed within the project area, classifications of 'unmappable' and 'uninterpretable' require that appropriate measures are undertaken to prevent the potential introduction or spread of dieback in the project area. In addition to impacts on surrounding remnant vegetation, the introduction of dieback will impact the success of revegetation on the project. Some of the species proposed for use in project landscaping and revegetation are likely to be susceptible to dieback. It is therefore important to prevent the potential for impact of dieback on vegetation and rehabilitation, by preventing the introduction of dieback.

Mapping various dieback classifications within the project area (Appendix L) will assist in the management of weed incursion during construction. The Soil Hygiene Plan will include plans showing zones of varying dieback classifications, clearing plans within these classifications and specifications for clearing, mulching, topsoil stripping and stockpiling. Procedures will address the use, storage and re-use of vegetative matter and topsoil for the management and control of dieback.

In order to avoid the potential introduction or spread of harmful *Phytophthora cinnamomi* within the project area, appropriate site hygiene and management measures will be developed and implemented within relevant areas. In particular, machinery or vehicles will be cleaned before entering dieback free (uninfested) zones. The area west of Progress Drive and areas mapped as 'unmappable' will be treated as dieback infected. Thus, no material (fill or topsoil) sourced from these areas will be used elsewhere during project construction or rehabilitation. The boundaries of these areas are shown in Appendix L.

6.6.4.10. Shading

Shading from sunlight and direct rainfall could result in declining vegetation vigour and, potentially, a reduction in vegetation. Monitoring of vegetation (retained and rehabilitated) will be carried out following the completion of construction and will include particular monitoring of retained vegetation located under bridge structures and adjacent to embankments, where shading will occur at various times of the year. If the results of this monitoring indicate a decline in vegetation cover, supplementary planting will be carried out, as part of the ongoing revegetation maintenance programme.

The species selected for supplementary plantings will be tolerant to lower light levels and also require less surface moisture, where possible. Much of the vegetation currently supported by the fringes of Roe Swamp is growing in low light conditions, due to a dense tree canopy. Therefore, it is expected that many of these sedge and wetland fringing species will be suitable, such as *Cyathochaeta teretifolia* (P3). Seed collection for such species will commence during summer, following Ministerial approval. If shading leads to vegetation decline over time, in addition to supplementary plantings, material suitable for fauna refuge, such as logs, will also be applied to cover bare areas.

Despite the potential for a long-term reduction in vegetation cover to occur in limited areas, it is important to maintain cover and continuity under bridges and other structures for the purposes of fauna movement, as well as maintaining hydrological regimes.

6.6.4.11. Herbicides

Herbicides used for weed control have the potential to affect non-pest, native flora species. It is important to use herbicides to control weed invasion, but to do so prudently and safely. Weed treatments will be conducted by accredited contractors in accordance with a Weed Management Plan. Herbicide application will not be used within or in close proximity to areas of significant vegetation or flora populations, or during windy conditions. Non-chemical forms of weed control will be researched.

6.6.4.12. Rehabilitation and Revegetation

Rehabilitation and revegetation will be carried out in areas disturbed for construction activities and in existing degraded areas. The rehabilitation and revegetation design will utilise locally occurring native plant species. Success in the revegetation of these areas will provide some mitigation for the clearing of the natural vegetation, by stabilising the site and replacing some of the biomass.

Several areas that are currently degraded or completely degraded are proposed to be restored. Such initiatives include the option to close access to the western end of Hope Road, remove the road surface, rehabilitate the site and then revegetate certain sections, whilst maintaining an alignment for the Principal Shared Path (PSP).

In order to ensure that best use can be made of locally available seed, seed collection will be scheduled to commence as soon as possible from suitable bushland in the local area.

Due to the fact that much of the proposal area is currently in degraded condition or worse, there are opportunities to improve the quality of retained vegetation and existing cleared areas via revegetation initiatives. The specific areas and the treatments to be carried out will be determined as part of the preparation of a detailed revegetation and restoration design. Such a design would specify treatments in zones for earthworks (including dieback and weed hygiene), planting design (direct seed, tubestock, seed mixes, species selections), soil stabilisation, erosion control and other treatments to enhance the visual and recreational amenity of the site.

An area currently under consideration for significant enhancement includes a road drainage bioretention basin located east of Horse Paddock Swamp. It is proposed that existing trees (Flooded Gums and Paperbarks) will be retained and that a low bund will be constructed on the degraded ground around the mature trees to create a basin that will be supplemented with suitable wetland species. Two infiltration basins will be excavated in bare patches into which first flush water will be discharged (See Figure 6.4-2 to Figure 6.4-4). Currently the vegetation in this location is in 'Degraded to Completely Degraded' condition and is almost completely void of native understorey. Weed infestations are significant, including by the problematic weed, Pig Face. The proposed basin will significantly improve the vegetation condition, as well as the habitat value of this area, and will ultimately serve as a reconstructed wetland habitat.

6.6.4.13. Vegetation Management Plan

A detailed, site specific Vegetation Management Plan will be prepared and implemented prior to the construction phase of the proposed project. This will include measures to avoid, minimise, reduce, rectify and manage impacts on flora and vegetation during the project phases (detailed design, construction and operation). The management plan will include a monitoring and reporting programme to manage or control the potential impacts from the proposed project. The management plan will be implemented on completion of detailed engineering design, but prior to commencement of ground disturbing construction activity.

6.6.5. Summary and Conclusions

This section summarises the key findings related to impacts on vegetation and flora. It describes the residual impacts on this factor, discusses offsets proposed to mitigate these and makes conclusions in relation to key matters raised by EPA Bulletin 1088.

6.6.5.1. Residual Impacts

After all mitigations are implemented, some residual impacts will remain. The single most significant residual impact after mitigation is applied, as it relates to direct impacts on flora and vegetation, is vegetation clearing. The footprint for construction of the project is currently estimated to require the clearing of 79.3 hectares of native vegetation. Of this, 37.5 hectares is intact native vegetation ('Degraded to Good' condition or better). Included in this amount is 2ha of intact native vegetation within the Roe Swamp CCW boundary and 7ha of intact native vegetation classified as GDEs.

The vegetation communities BahS and CcAf will be completely removed from the project area. However, the FCT that make up the vegetation communities present in the project area are documented to be 'Well Reserved' (Gibson *et al.* 1994). In addition, given the degraded nature of CcAf and its location immediately adjacent to the existing Kwinana Freeway/Farrington Road intersection, the removal of this particular vegetation community is not considered to be significant.

Vegetation clearing will also result in the loss of 7ha of Bush Forever, including 4ha of intact native vegetation. Following clearing, the vegetation complex to be cleared from this site (Bassendean Complex – Central and South) will still remain at above 10 percent of its pre-European extent, which is the Bush Forever target for vegetation types in the Swan Coastal Plain.

In the unlikely event that there is a change to hydrological conveyance following mitigation, there may be a minor successional shift from the current GDE association of species to a different community type for 12 of the 70 mapped GDE sub-communities within a 50m zone of effect.

A total of 15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants, will be impacted by the proposed clearing. Most of the recorded Priority Flora plants within the proposed clearing footprint are *Dampiera triloba* (P1), a small herb species that is locally abundant. This species is inconspicuous and targeted searches in the local region would likely record significant numbers of this small plant.

A summary of the mitigation, management and residual impacts for flora and vegetation is presented in Table 6.6-10.

Table 6.6-10: Residual Impacts on Flora and Vegetation

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction			
Vegetation clearing	Loss of 37.5ha intact native flora and vegetation and associated floral biodiversity	Reduction in total clearing footprint via design measures including: • Adjustments to the final level of the carriageways, to reduce road profiles and volumes for embankments • Inclusion of environmental design features, resulting in the reduction in clearing requirements by 7ha • Bridge structure at Roe Swamp axis to minimise clearing of functional wetland vegetation • Alignment on formerly disturbed access tracks with existing clearing and lower vegetation value • Construction methodology that avoids the need for continuous clearing and access tracks	Loss of a total of 38ha of intact native flora and vegetation, including 7ha of GDE sub-communities Loss of 2.1ha of BahS vegetation community type from project area Loss of 7ha of Bush Forever, including 4ha of intact native vegetation Loss of 15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants (most of which are of one small herb species that is locally abundant)

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
		• Incorporation of retaining walls (in lieu of batters) to reduce width of the footprint • Restoration of existing degraded areas in the project area through revegetation and landscaping programme, including creation of bioretention basins	
	In the absence of adequate management controls, limited clearing of vegetation outside of the project footprint will occur	Preparation and implementation of a Vegetation Management Plan including clearing plans for site crews and specifying inductions, demarcation of clearing boundaries and the presence of a Site Environmental Officer during clearing and construction activities	With adequate controls such as demarcation of clearing boundaries, training of construction crews and the presence of a Site Environmental Officer in place over-clearing will be prevented
Vegetation removal, topsoil stripping, excavation of road cuttings	If weed-infested topsoil or mulch is re-used for rehabilitation or weed seeds are inadvertently introduced by vehicles, then weeds will invade previously uninfested areas of the project area, causing adverse impacts on native vegetation	Construction management of vehicle and plant hygiene in accordance with a Site Vehicle Hygiene Plan Soil Hygiene Management Plan will be prepared and implemented for construction phase Conduct ongoing annual weed control activities, in accordance with a Weed Management Plan	Proposed mitigation measures will minimise the extent of increase in weeds
	Clearing of vegetation will expose the ground within the construction footprint. During dry and windy conditions, dust will be mobilised and settle on adjacent areas of retained native vegetation, preventing photosynthesis and, in extreme cases, causing sufficient damage to kill individual plants	Dust control measures during construction (e.g. stabilisation of cleared areas, use of mulch) Refer to Section 6.13 for additional mitigation measures	Dust is not anticipated to cause indirect loss of additional vegetation
Placement of fill, compaction of embankment foundations and other earthworks	If the proposed project alters surface hydrology and groundwater, this will result in successional changes in GDE species associations in response to changed	Refer to Sections 6.2 and 6.3	If, following mitigation, there is a change to hydrological conveyance, there may be a successional shift from the current GDE association of species to a different community type for 12

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	water availability		of the 70 mapped GDE sub-communities within a 50m zone of effect
Operation of plant and machinery	Careless behaviour during construction (i.e. incorrect disposal of cigarette butts or poor management of fuel storage and handling) will result in accidental lighting of fire. Fires cause loss of certain flora species and degradation of vegetation communities	Development and implementation of a CEMP Prohibition of fire lighting during construction Provision of designated cigarette butt disposal containers Construction machinery fitted with spark arresters Personnel and vehicles fitted with fire fighting equipment Communication of fire management procedures to personnel via site inductions	Potential for fire substantially reduced
	An accidental spill of harmful substances will cause localised injury or death of vegetation	Strict protocols regarding location of and requirements for maintenance, refuelling of construction machinery Development of an Emergency Response Plan (ERP) Development of a CEMP Refer to Section 6.4 for more detailed mitigation	The implementation of a CEMP, an ERP and maintenance and servicing protocols during construction are considered to be sufficient to minimise potential for adverse impacts to occur
	The introduction of dieback into the project area via vehicles inadvertently carrying the pathogen will result in effects on vegetation, including the thinning of vegetative cover and a reduction in biodiversity and recreational values of vegetation	Construction management of vehicle and plant hygiene in accordance with a Site Vehicle Hygiene Plan Soil Hygiene Management Plan will be prepared and implemented for construction phase	Dieback is unlikely to be introduced
Operation			
Physical presence of road	Bridge structures and retaining walls will result in shading of uncleared vegetation beneath these structures and adjacent to embankments, resulting in declined vegetation vigour of affected vegetation	Ongoing monitoring of vegetation located under bridge structures and adjacent to embankments with supplementary planting, where necessary, as part of revegetation maintenance programme Selection of species tolerant to low levels of light and water for supplementary planting	Vegetation occurring beneath bridge structures will be maintained

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Although the proposed project will increase the edge to area ratio of the project area, it will create some new edges in areas where there were previously none. Where edges are created, altered conditions will increase the risk of weed invasion and consequent degradation of vegetation composition and condition	Examination of some existing and newly created edges for their potential to be restored, revegetated or regenerated, to enable reintegration of these areas with intact vegetation and habitat Closure of Hope Road near the entrance to Native ARC and the rehabilitation/revegetation of the area west of this point Ongoing post-construction monitoring of retained and rehabilitated vegetation, as part of a weed control programme	Edge effects overall will be reduced
Road maintenance	Inappropriate use of herbicides will cause death of native flora	Weed treatments to be undertaken by accredited contractors in accordance with Weed Management Plan No herbicide application within close proximity to areas of significant vegetation or during windy conditions	The proposed mitigation measures will adequately protect native vegetation from adverse impact

6.6.5.2. Offset

An offset package is proposed to address the residual impacts of the proposed project, including those on flora and vegetation. The main offset proposed for this factor is the acquisition of land for conservation purposes, giving preference to land located in the southern metropolitan region, on the Swan Coastal Plain. The preferred offset site is classified as a Bush Forever site and contains four of the five FCTs that will be impacted by the proposed project. In addition, the site contains the Bassendean Complex – Central and South vegetation type. The proposed project will remove 36ha of vegetation of this particular complex, which already has less than 30 percent of its pre-European extent remaining. The selection of this particular offset site will therefore ensure that, while there is a net loss, the long-term security of a portion of this vegetation type is achieved.

Additional offsets will be achieved through the transfer of approximately 9ha of land currently zoned as Primary Regional Road within the MRS to the Beeliar Regional Park, and the restoration of Horse Paddock Swamp.

Further details of the proposed flora and vegetation offset are provided in Section 10. This offset package, in combination with management measures outlined earlier, will ensure that the EPA objectives in relation to flora and vegetation are met.

6.6.5.3. EPA Bulletin 1088 Matters

Table 6.6-11 highlights the EPA concerns for vegetation and flora associated with the proposed project as stated in Bulletin 1088 (EPA 2003).

Table 6.6-11: EPA Concerns for Vegetation and Flora as Stated in Bulletin 1088

Bulletin 1088 Concern*	Proposed Project Concept Response
Construction of the Roe Highway extension would involve clearing of remnant native vegetation within Bush Forever Site 244	The proposed project will require the clearing of 7ha (less than 2%) of Bush Forever Site 244. Of the area to be cleared, 4ha has been classified as intact native vegetation *Bush Forever* (WAPC 2000a; 2000b) recognises a target of at least 10 percent retention of the original extent of each vegetation complex for the Swan Coastal Plain portion of the Perth metropolitan region, which is acknowledged as a constrained area Bush Forever Site 244 lies on the Bassendean Complex – Central and South, which is currently represented by 24% of its original extent. Implementation of the proposed project will reduce this area by 36ha, ensuring that the remaining extent of this complex within the Swan Coastal Plain remains above the 10% threshold stipulated by Bush Forever. In addition, the proposed offset site will ensure long-term security of land tenure for another Bush Forever site which contains vegetation of the Bassendean Complex – Central and South
Construction of the highway extension would also result in off-site impacts on vegetation of the Karrakatta Complex – Central and South, situated south of the alignment and within Bush Forever Site 244	The impact assessment has not revealed evidence of potential off-site impacts on vegetation of the Karrakatta Complex – Central and South, which is situated south of the alignment and within Bush Forever Site 244 During construction, accidental off-site clearing will be prevented through preparation and implementation of a Vegetation Management Plan. This plan will require inductions and clearing plans for site crews, demarcation of clearing boundaries and the presence of a Site Environmental Officer during clearing and construction activities. A Construction Environmental Management Plan will be implemented to prevent other potential off-site impacts that could affect vegetation such as accidental spills of hazardous substances, fire, and spread of weeds or dieback An ongoing weed control programme will also be implemented following construction to manage potential edge effects during operation. This programme will minimise potential impacts on vegetation adjacent to the proposed project, including that of the Karrakatta Complex – Central and South within Bush Forever Site 244

Bulletin 1088 Concern*	Proposed Project Concept Response
Construction of the highway extension would impact vegetation located to the west of Progress Drive (identified as Karrakatta Complex – Central and South) and to the east of Bibra Drive (identified as Bassendean Complex – Central and South)	The proposed project will result in the removal of 21ha of Karrakatta Complex – Central and South and 36ha of Bassendean Complex – Central and South. The EPA has an objective of retaining at least 30% of the pre-European extent of vegetation types (EPA 2000). Both of these vegetation complexes are already below this threshold, at 18.2% and 23.6% of their pre-European extents respectively. The proposed project will reduce the current extent remaining of both of these vegetation complexes by 0.3% Restoration of previously degraded sites within the project area, transfer of 9ha (net) of MRS road reserve to the Beeliar Regional Park and acquisition of land for conservation purposes within are anticipated to contribute to an overall net benefit in relation to vegetation values
The highway extension would cause a loss of gradation from wetland to upland vegetation It would also result in the loss of regionally significant vegetation which is not well represented within the Eastern Chain of the Beeliar Wetlands	It is assessed as unlikely that significant physical changes to hydrological conveyance will occur as a result of the proposed project. Nevertheless, if there is a change to hydrological conveyance, there may be a successional shift from the current GDE association of species to a different community type for 12 of the 70 mapped GDE sub-communities within a 50m zone of effect. It is important to note that succession is not necessarily an adverse effect and may result in improved vegetation condition ratings (particularly in the case of degraded vegetation that may have responded to previous negative impacts or effects). Up to two of these may be detrimentally impacted Clearing will result in the loss of 15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants (most of which are of one small herb species that is locally abundant) All of the FCTs supported by the project area are documented to be 'Well Reserved' and at 'Low Risk' of extinction (Appendix K) There are no historical or current records of State listed DRF from within the project area. There are also no listed TECs or PECs within the project area. As a result, no threatened flora or TECs or PECs will be cleared as a consequence of the proposed project
Clearing of vegetation within the Roe Swamp complex would lead to significant impacts on the functions, values and fauna habitats of this wetland, as well as on the ecological linkages it currently maintains with North Lake and the wetland complex to the north	As discussed in Section 6.2, clearing of land will occur in Roe Swamp to the total extent of 5.4ha (including 0.5ha of temporary clearing) out of an area of 53.7ha. An additional 2.3ha of wetland buffer will also be cleared Roe Swamp has been previously severed and is currently fragmented by Farrington and Hope Roads. Also, a power line easement/access track runs east to west and the proposed project will adopt disturbance along the same alignment The risk of severance of ecological linkages between Roe Swamp and North Lake and the wetland complex to the north is addressed by the proposal of a bridge spanning the topographic low point from east to west over Roe Swamp. Additional apertures for passage will be installed through the embankment

Bulletin 1088 Concern*	Proposed Project Concept Response
Viability and long-term management of the vegetation within the area will be reduced as a result of the area being further fragmented by the highway extension	The area is currently fragmented by Hope Road, which will be partially rehabilitated as a result of the proposed project to restore linkage within the area. In addition, a power line easement/track for a transmission line currently runs east to west and the proposed project will adopt disturbance on the same footprint to minimise additional fragmentation Fragmentation of the area will be further reduced by bridges proposed at Roe Swamp and between Horse Paddock Swamp and Bibra Lake. In addition, inclusion of fauna underpasses along the length of the proposed project will further reduce impacts of fragmentation

*These points have been paraphrased from Bulletin 1088 (EPA 2003).

6.7. Fauna

The EPA's objective for fauna is:

> *To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.*

EPA Bulletin 1088 (2003) identified fauna as one of the key environmental values potentially impacted by the proposed project, as it was defined at the time. In Bulletin 1088, the EPA lists the following potential impacts on fauna:

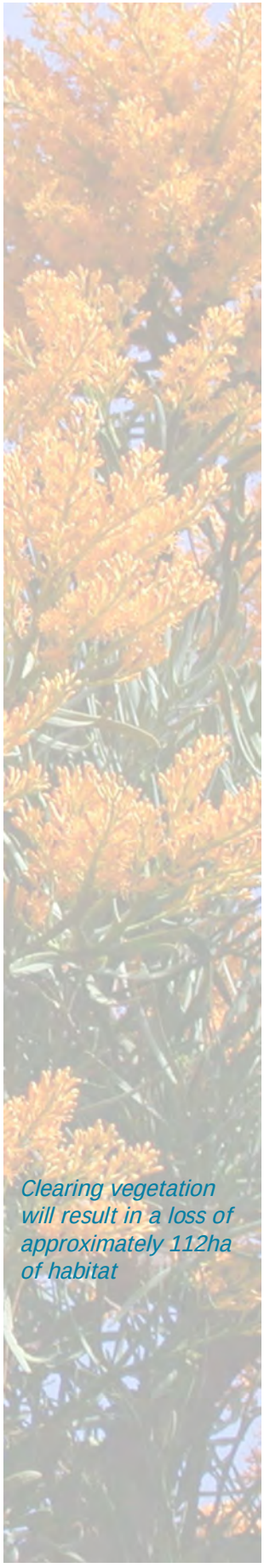
- Construction within the alignment would directly impact the significant faunal values of the area through loss of habitat and breeding areas, and through impacts on faunal movement via severance of some strategic linkages between wetlands and upland vegetation of the area; and
- Construction of the highway would sever the area, thereby reducing its size and resulting in impacts on fauna habitats and their long-term viability.

6.7.1. Potential Impacts

Aspects of the project have the potential to lead to a variety of impacts on fauna and fauna habitat. Potential impacts have been highlighted by community and stakeholders, as well as the EPA in its Bulletin 1088 (2003).

Many of the potential impacts have already been mitigated through the inclusion of certain design elements as presented in Section 3. Design solutions and best management practices have been developed to avoid and minimise the following potential impacts:

- Construction activities may result in impacts on aquatic wildlife and migratory birds from hydrocarbon spills leaching or draining into ground or surface water; as well as from sedimentation and increased turbidity – refuelling will occur outside of wetland areas in contained, designated service yards. In the unlikely event of a ruptured fuel tank during construction, clean-up procedures will ensure immediate containment and removal of spills. Earthworks will include the installation of temporary stormwater containment to prevent sediment reaching the wetlands (refer to Section 6.4);
- Bulk chemical tanker spills may impact fauna health – road geometry, barriers and stormwater retention system will ensure that the risk of a bulk chemical tanker spilling its load into a wetland area is minimal (refer to Section 6.4);
- Vehicle emissions may result in decline in fauna habitat and species – the project emissions are assessed as being within regulatory limits (refer to Section 6.13);
- The replacement high tension power lines may result in bird mortality as a result of collision – as the powerlines are replacing an existing hazard, there will be no net increase in impact. Powerlines will be fitted with reflectors to reduce the likelihood of bird strike;
- Once operational, vehicle movements may result in fauna injury or mortality from direct strike from traffic;



Clearing vegetation will result in a loss of approximately 112ha of habitat

- The physical presence of the road may result in impacts on aquatic fauna and migratory birds from sedimentation, increased turbidity and bioaccumulation of contaminants through food webs – road drainage has been designed to contain and treat all road runoff to prevent sediment reaching the wetlands (refer to Section 6.4); and
- A detailed assessment of predicted fauna impacts is provided in Sections 6.7.2 and 6.7.3.

6.7.2. Construction Phase Impacts

Construction activities are likely to result in a number of impacts on fauna and faunal values within the project area. Construction is predicted to result in the following impacts:

- Habitat loss and fragmentation, predominantly as a result of clearing;
- Fauna strike with construction machinery, particularly during clearing activities;
- Displacement of fauna as a result of noise and vibration; and
- Unplanned fire.

6.7.2.1. Habitat Loss and Fragmentation

Habitat removal and fragmentation are key threatening processes in the project area, both locally and in the context of cumulative habitat loss, due to ongoing urbanisation across the Swan Coastal Plain. Clearing or degradation of vegetation and soils, and changes to surface and groundwater regimes in the project area, may contribute to cumulative habitat loss in the region (15km radius of project area), which is occurring due to urban pressure on the Swan Coastal Plain. Other regional locations where clearing of *Banksia* woodland has been approved include Jandakot Airport (167ha) and Fiona Stanley Hospital (25ha).

Vegetation clearing and fragmentation will also impact ecological linkages. Ecological linkages are areas of linear habitats (wildlife corridors) that connect patches of remnant habitat and are assessed in Section 6.8. Areas reduced in size due to fragmentation are increasingly vulnerable to edge effects, which are discussed as an operation phase impact in Section 6.7.3.

Clearing of vegetation and the installation of drainage basins will result in the loss of up to 112ha of fauna habitat. This includes 40ha (36 percent) of *Eucalyptus/Banksia* woodland, 26ha (23 percent) of *Eucalyptus/Xanthorrhoea* woodland and 13ha (12 percent) of other native remnant vegetation. The clearing includes 20ha (17 percent) of various other woodland types, rehabilitated vegetation, parklands and roadside verges that provide fauna habitat. The remaining clearing is of areas that hold little value for fauna, in particular 13ha (12 percent) of 'degraded' condition vegetation with low value habitat.

Loss of habitat for conservation significant species is discussed in terms of local extent (the project area) and regional extent (nominated as the area within a 15km radius of the project area). The regional extent was defined on the basis of available regional information, in particular habitat data for Carnaby's Black Cockatoo. This regional extent is therefore not based on biogeographic classifications. However, it was considered adequate for this assessment, as several remnant native bushlands within the 15km radius provide important fauna habitats in a largely cleared landscape. The 15km radius was applied to the conservation significant species of the project area, as far as possible, for consistency.

Fragmentation by the proposed project will primarily affect fauna by increasing the distance between habitat patches. This will limit the potential for fauna movement between the fragmented areas, by reducing the size of a habitat such that, in extreme cases, resources are insufficient to sustain critical population maintenance functions. The amount of required habitat space varies depending on the species. Much of the project area has already been fragmented by urban infrastructure and walking tracks.

Presently, the project area is fragmented by urban development

Table 6.7-1: Habitat Impacts

Major Fauna Habitat Type	Conservation Significant Species Typically Utilising Each Habitat Type	Local Extent (Project Area, ha)	Extent of Loss (ha)
Eucalyptus/ *Banksia* woodland	Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Peregrine Falcon, Perth Lined Lerista, Western Brush Wallaby, Southern Brown Bandicoot, Black-striped Snake, Rainbow Bee-eater, Graceful Sun-moth	93.7	40.2
Eucalyptus/ *Xanthorrhoea* woodland	Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Peregrine Falcon, Perth Lined Lerista, Southern Brown Bandicoot, Rainbow Bee-eater	39.2	26.3
Eucalyptus/ *Melaleuca* woodland	Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Peregrine Falcon, Southern Brown Bandicoot, Rainbow Bee-eater	19.0	5.0
Banksia woodland	Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Peregrine Falcon, Western Brush Wallaby, Southern Brown Bandicoot, Perth Lined Lerista, Black-striped Snake, Rainbow Bee-eater	25.9	3.1
Rehabilitated *Banksia* woodland	Peregrine Falcon, Perth Lined Lerista, Rainbow Bee-eater	23.7	16.7
Kunzea shrublands	Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Peregrine Falcon, Perth Lined Lerista, Rainbow Bee-eater	7.2	1.7
Sedgeland	Wetland birds	1.7	0.1
Parkland	Carnaby's Black Cockatoo, Forest Red-tailed Black Cockatoo, Peregrine Falcon, Perth Lined Lerista, Rainbow Bee-eater	4.2	1.8
Riparian vegetation	Australasian Bittern, Australian Little Bittern, Peregrine Falcon	6.5	0.3

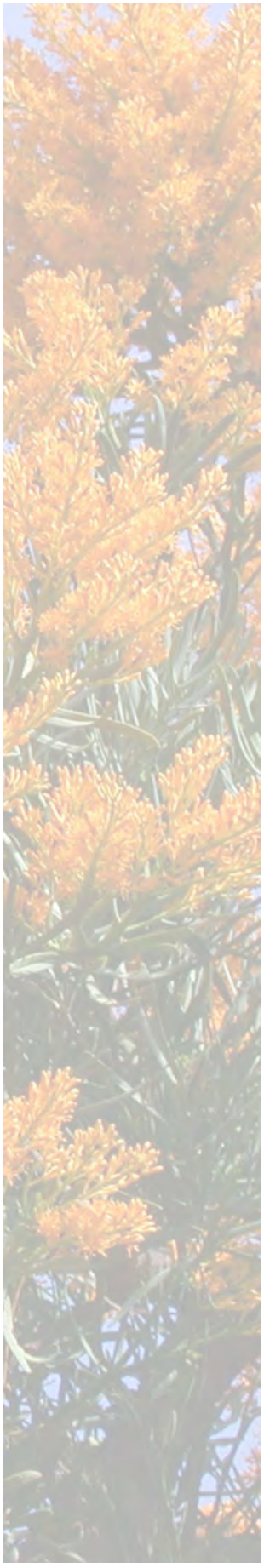
Major Fauna Habitat Type	Conservation Significant Species Typically Utilising Each Habitat Type	Local Extent (Project Area, ha)	Extent of Loss (ha)
Roadside batters (planted with non-local species)	Peregrine Falcon, Perth Lined Lerista, Rainbow Bee-eater	6.7	3.4
Degraded low value habitat	Infrequently inhabited	40.4	13.4
Total		253.7	111.8

Existing conservation significant species within the project area are discussed in Section 5.9 under their respective subsections. A summary of habitat loss for each conservation significant species is provided in Table 6.7-2.

Table 6.7-2: Habitat Loss for Conservation Significant Species

Species or Group	Potential Impact	Habitat Loss in Project Area	Percentage Loss at Local Scale[a]	Percentage Loss at Regional Scale[b]
Carnaby's Black Cockatoo (*Calyptorhynchus latirostris*)	Loss of foraging habitat	78.3ha	44%	0.85%
	Loss of potential nesting habitat significant trees	249 significant trees (DBH >500mm. i.e. potentially able to form nesting hollows)	41%	n.c.
		20 of the significant trees contain existing potential nest hollows	28%	n.c.
	Loss of potential nesting habitat	Loss of 2.5ha of potential nesting habitat (based on 100m^2 radius around each significant tree to be cleared)	41%	n.c.
Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*)	Loss of foraging habitat	73.2ha	45%	n.c. but likely to be similar to Carnaby's Black Cockatoo
	Loss of potential nesting habitat significant trees	249 significant trees (DBH >500mm. i.e. potentially able to form nesting hollows)	41%	n.c.
		20 of the significant trees contain existing potential nest hollows	29%	n.c.

Species or Group	Potential Impact	Habitat Loss in Project Area	Percentage Loss at Local Scale[a]	Percentage Loss at Regional Scale[b]
	Loss of potential nesting habitat	Loss of 2.5ha of potential nesting habitat (based on 100m^2 radius around each significant tree to be cleared)	41%	n.c.
Australasian Bittern (*Botaurus poiciloptilus*)	Loss of potential habitat	0.3ha	4%	n.c. but negligible
Australian Little Bittern (*Ixobrychus dubius*)	Loss of potential habitat	0.3ha	4%	n.c. but negligible
Peregrine Falcon (*Falco peregrinus*)	Loss of potential habitat	111.8ha	44%	n.c. but negligible
Western Brush Wallaby (*Macropus irma*)	Loss of potential habitat	72.7ha	43%	1.0% (habitat within Bush Forever)
Southern Brown Bandicoot (*Isoodon obesulus fusciventer*)	Loss of available habitat	72.5ha	45%	0.7% (habitat within Bush Forever)
Perth Lined Lerista (*Lerista lineata*)	Loss of available habitat	91.4ha	50%	1.1% (habitat within 15km radius)
Black-striped Snake (*Neelaps calonotus*)	Loss of potential habitat	72.7ha	43%	0.8% (habitat within Bush Forever)
Jewelled Sandplain Ctenotus (*Ctenotus gemmula*)	Loss of potential habitat	34ha	36%	n.c.
Migratory Birds • Rainbow Bee-eater (*Merops ornatus*)	Loss of potential habitat	89.9ha	47%	n.c. but negligible
Migratory Birds • Other	n/a	n/a	n/a	n/a
Wetland Birds	Loss of available habitat	3.7ha	14%	n.c.
	Loss of trees potentially suitable for breeding wetland birds (containing nest hollows >10cm diameter)	17 trees	n.c.	n.c.



Species or Group	Potential Impact	Habitat Loss in Project Area	Percentage Loss at Local Scale[a]	Percentage Loss at Regional Scale[b]
Graceful Sun-moth (*Synemon gratiosa*)	Loss of known habitat (where Graceful Sun-moths were recorded)	5.6ha	64%	n.c.
	Loss of suitable habitat (Recorded individual plants to be removed)	1,112 plants	34%	n.c.
	Loss of vegetation communities that contain *L. hermaphrodita* (excludes known and suitable habitat)	60.5ha	48%	n.c.

[a]Local scale - project area
[b]Regional scale - 15km radius of project area
DBH – diameter at breast height
n/a – not applicable
n.c. – not calculated

6.7.2.1.1. Carnaby's and Forest Red-tailed Black Cockatoos

Habitat loss on the Swan Coastal Plain has been identified as a key threat for Carnaby's and Forest Red-tailed Black Cockatoos. Carnaby's Black Cockatoo has defined breeding and non-breeding seasons, as well as distinct seasonal habitat requirements for breeding/nesting, roosting and foraging. Recent surveys estimate between 8,000 and 10,000 Carnaby's Black Cockatoos use the Swan Region of the Swan Coastal Plain (Burnham *et al*. 2010). Figure 6.7-1 illustrates the proposed project impacts on black cockatoo foraging habitats.

The loss of foraging habitat for the Carnaby's and Forest Red-tailed black cockatoos is approximately 78ha and 73ha, respectively

Information is lacking on the critical breeding, roosting and foraging habitat of the Forest Red-tailed Black Cockatoo on the Swan Coastal Plain. The project area supports stands of Marri (*Corymbia calophylla*) and Jarrah (*Eucalyptus marginata*) that may provide foraging habitat for flocks that range within the Perth metropolitan region; however, the importance of this habitat to the Forest Red-tailed Black Cockatoo is less clear. The habitat mapped as *Banksia* woodlands is included in foraging habitat area calculations for this species, as it supports populations of Marri and Jarrah.

Vegetation clearing will result in a loss of approximately 78ha (44 percent) of available Carnaby's Black Cockatoo foraging habitat. For the Forest Red-tailed Black-Cockatoo, vegetation clearing will result in a loss of approximately 73ha (45 percent) of available foraging habitat within the project area.

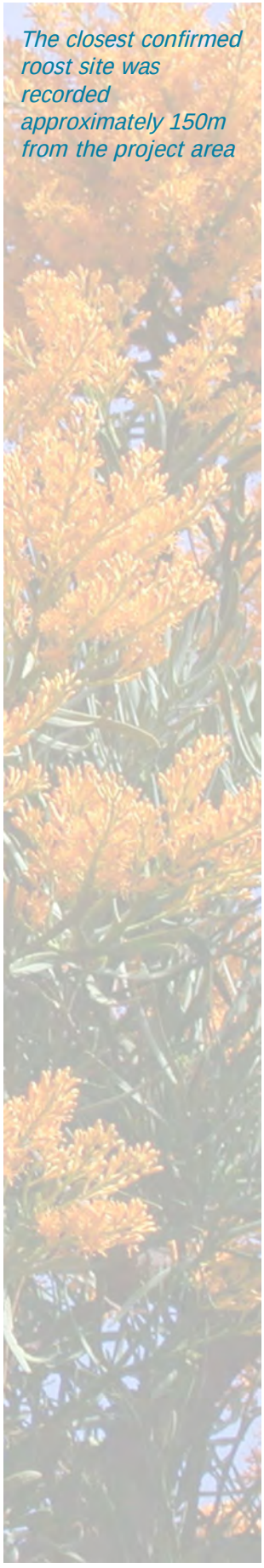
The closest confirmed nesting records of black cockatoos is approximately 27km south of project area

Carnaby's and Forest Red-tailed Black Cockatoos are not known to nest within the project area or project region. The closest confirmed nesting sites for these species within the Swan Coastal Plain are located approximately 27km and 47km south of the project area at Baldivis and Stake Hill, respectively (Kirkby 2010; Johnstone and Kirkby 2009). A shortage of nest hollows is another limiting factor, particularly Forest Red-tailed Black Cockatoos. This species requires large nest hollows (80–90cm diameter), which are considered to be scarce, as trees with large enough hollows are at least 130 years old (DEWHA 2010c).

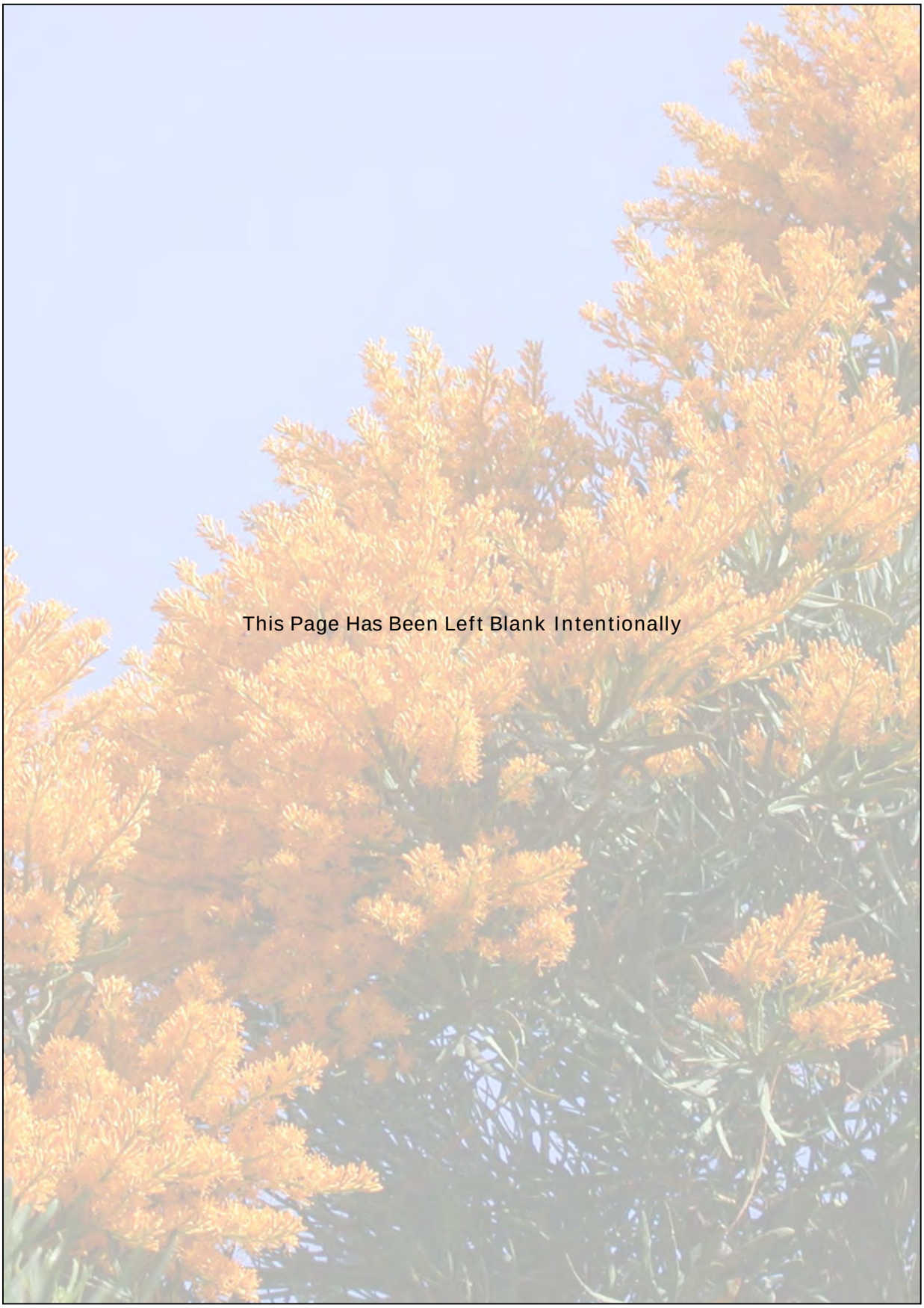
For both species of black cockatoo, vegetation clearing will cause the loss of significant trees with existing hollows suitable for potential future nesting; and other trees of suitable size that are capable of developing hollows in time (Figure 6.7-2). Proposed clearing for the project exceeds some of the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) significant impact thresholds for black cockatoos (Table 6.7-3). Approximately 249 significant trees (41 percent) will be affected by the proposed project. All but approximately 10 of these are located west of Progress Drive. Of the significant trees to be cleared, 20 contain hollows with a sufficient size for potential future nesting (28 percent), all of which are growing west of Progress Drive. Loss of nesting habitat is of lower concern, as neither species is presently known to breed in the Perth metropolitan region.

In order to assign a spatial value to the number of significant trees being removed, an area of 100m^2 has been applied to each tree. That is, each significant tree is considered to occupy an area of approximately 10m x 10m. No reduction in overall spatial extent has been made to account for overlap, ensuring the total area used is on the conservative side. Based on this method, the total area of potential nesting habitat to be removed is approximately 2.5ha.

The closest confirmed roost site was recorded approximately 150m from the project area



Presently, there are no known cockatoo roost sites within the project area. However, 12 known roost sites are located between 2km and 5km from the project area. While there are no predicted impacts on roost sites, their proximity to the project area means that impacts on foraging habitat within the project area may reduce the value of these roost sites for the species.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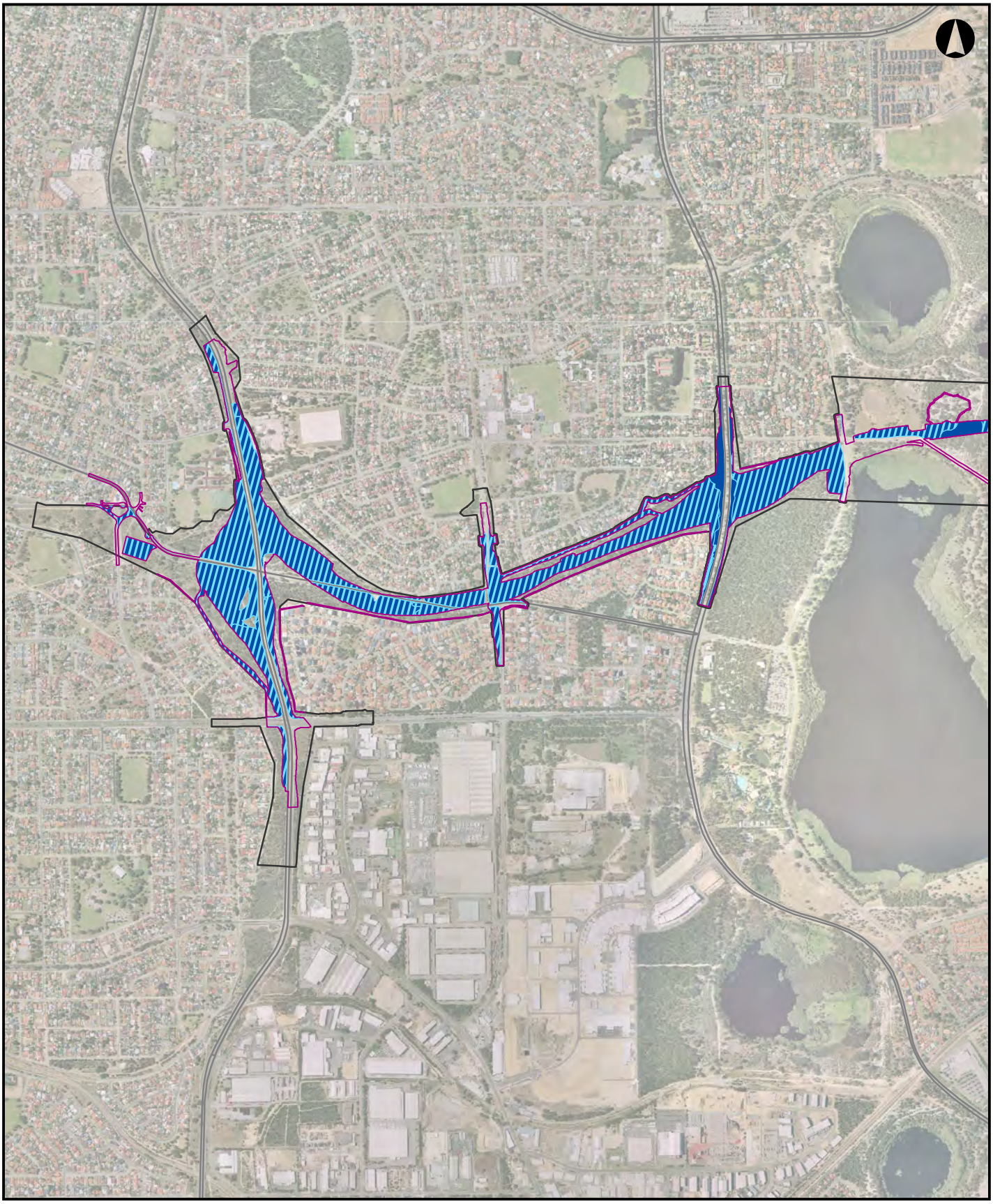

Impacts on Carnaby's and Forest Red-tailed Black Cockatoo Foraging Habitat

South Metro Connect

Figure 6.7-1a

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Carnaby's Black Cockatoo Foraging Habitat Impacted by Construction Footprint
- Forest Red-Tailed Black Cockatoo Foraging Habitat Impacted by Construction Footprint
- Construction Footprint
- Project Area

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Impacts on Carnaby's and Forest Red-tailed Black Cockatoo Foraging Habitat

South Metro Connect

Figure 6.7-1b

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Carnaby's Black Cockatoo Foraging Habitat Impacted by Construction Footprint
- Forest Red-Tailed Black Cockatoo Foraging Habitat Impacted by Construction Footprint
- Construction Footprint
- Project Area

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Impacts on Carnaby's and Forest Red-tailed Black Cockatoo Potential Nesting Habitat

South Metro Connect

Figure 6.7-2a

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos Impacted by Construction Footprint
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos Impacted by Construction Footprint (DBH > 500mm)
- Construction Footprint
- Project Area

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Impacts on Carnaby's and Forest Red-tailed Black Cockatoo Potential Nesting Habitat

South Metro Connect

Figure 6.7-2b

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos Impacted by Construction Footprint
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos Impacted by Construction Footprint (DBH > 500mm)
- Construction Footprint
- Project Area

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The proposed project is unlikely to exceed the DSEWPaC impact threshold for fragmentation

In general, habitat fragmentation poses a risk to the long-term survival of Carnaby's and Forest Red-tailed Black Cockatoos. These species move from one habitat fragment to another, relying on both native bushland and non-endemic or parkland areas to move across the Swan Coastal Plain. However, fragmentation from the proposed project is unlikely to exceed the DSEWPaC significant impact threshold (Table 6.7-3). The consequences of habitat loss and fragmentation on Carnaby's and Forest Red-tailed Black Cockatoos in the project area include:

- A reduction in the quality of foraging habitat, which is in the vicinity of 12 known roost sites, ranging from 2km to 5km from the project area; and
- Clearing of 249 significant trees, 20 that contain hollows of sufficient size for potential future nesting.

These impacts are significant on a local scale for both species and may be significant on a regional scale.

Table 6.7-3: Significant Impact Thresholds for Carnaby's and Forest Red-tailed Black-Cockatoos

DSEWPaC 'Significant Impact Threshold Values'[1]	Proposed Project Effects	Local Context (Project Area)	Regional Context (15km Radius of Project Area)[2]
Clearing of more than 1ha of foraging habitat	78.3ha of suitable Carnaby's Black Cockatoo and 73.2ha of Forest Red-tailed Black Cockatoo foraging habitat will be cleared	Represents 44% of total suitable foraging habitat (177.3ha) for Carnaby's Black Cockatoo and 45% for Forest Red-tailed Black Cockatoo	Represents 0.85% of potential foraging habitat in the region for Carnaby's Black Cockatoo (9,133ha, encompassing 6,796ha within DEC managed estate and regional parks, and 8,401ha within Bush Forever sites. These two areas are non-exclusive)
Clearing of a known roosting site (including individual trees used for roosting)	No known roost locations	No known roost locations will be disturbed	n/a
Clearing of potential nesting habitat in woodland stands of 0.5ha or more that contain three or more breeding trees of a suitable size (DBH greater than 500mm)	249 significant trees will be cleared, including 20 trees with existing potential nesting hollows (no nesting or roosting has been observed within the project area) 2.5ha loss of potential future nesting habitat (assuming each significant tree occupies an area of $100m^2$)	Represents 41% of total number of significant trees (605 trees) within the project area, and 28% of trees with existing potential nesting hollows (71 trees)	Numbers of potential, suitable and known breeding trees are unknown in the region

DSEWPaC 'Significant Impact Threshold Values'[1]	Proposed Project Effects	Local Context (Project Area)	Regional Context (15km Radius of Project Area)[2]
Fragmentation of habitat by creation of a new gap of more than 4km between patches of habitat	No gaps nearing this value will be created	Cockatoos are known to fly over traffic, thus existing local linkages will be maintained to some degree	Cockatoos are known to fly over traffic; however, existing regional linkages will be maintained
Altering hydrology or fire regimes, so that black cockatoo habitat of more than 1ha would become degraded or destroyed	Project is unlikely to affect deep rooted habitat for either species	n/a	n/a

Source: Harris 2010

[1]Relevant if there is a real chance or possibility one or more of these occurs

[2]Actual nesting Carnaby's or Forest Red-tailed Black Cockatoos have not been recorded within 15km of the project area

n/a – not applicable

6.7.2.1.2. Australasian Bittern and Australian Little Bittern

The Australasian Bittern and Australian Little Bittern are not known to occur within the project area (Appendix O). Suitable habitat in the project area is represented by the 6.5ha of dense *Typha* beds that have been mapped at the northern end of Bibra Lake (riparian vegetation in Figure 5.9-1). Approximately 0.3ha (four percent) of this area will be disturbed by the proposed project and is therefore negligible in scale. This habitat exists elsewhere in greater extents within North and Bibra lakes.

6.7.2.1.3. Peregrine Falcon

The Peregrine Falcon was not recorded during surveys conducted for the proposed project, but was previously recorded at Bibra Lake in 2002 (DEC 2010b) and may potentially occur from time to time. Habitat loss is a current threat to this species.

Clearing of vegetation will cause the loss of potential habitat for the Peregrine Falcon, which is represented within the project area by woodlands and shrublands (Figure 5.9-1). Vegetation clearing will result in a loss of approximately 112ha (44 percent) of potentially suitable habitat. This extent needs to be considered in the context of the species' large territorial range, lack of specific habitat preferences and rare occurrence in the project area. In view of these factors, the scale of impact on this species is negligible.

6.7.2.1.4. Migratory Birds

With the exception of the Rainbow Bee-eater, migratory species (under the *Environment Protection and Biodiversity Conservation Act*) will not be directly affected by habitat loss or habitat fragmentation as there will be no loss of shoreline or lakebed habitats within the project area (Appendix M).

Within the project area, the Rainbow Bee-eater utilises many foraging habitats and has been recorded nesting in open sandy areas/tracks. Vegetation clearing will result in a loss of 90ha (47 percent) of potentially suitable habitat. Clearing will occur at the location of a known nesting site (*Kunzea* shrubland habitat/degraded low value habitat). The Rainbow Bee-eater is considered common in most areas it inhabits and is a habitat generalist (in terms of both foraging and nesting). The species is known to nest in a variety of nest sites, including river banks, sloping ground, creeks, dams, roadside cuttings, quarries, gravel mounds, etc. (DEWHA 2010b). Some birds return to the same nesting area each year (Carruthers 1975; Lane 1963; Waterman 1965; Boland 2004).

Based on records made during surveys (26 records during the spring vertebrate fauna survey and frequent records during other surveys), the Rainbow Bee-eater is common in the project area, Bibra Lake area and the region. The consequences of habitat loss for the Rainbow Bee-eater are expected to include:

- Reduction in suitable breeding habitat; and
- Reduction in open woodland foraging habitat.

Given the lack of specific habitat preference by the species, including its observed tendency to nest within disturbed areas, the scale of this impact is negligible.

6.7.2.1.5. Wetland Birds

None of the wetland birds recorded within the project area are listed as protected species. Nevertheless, removal of vegetation will cause the loss of potential foraging, breeding and roosting habitat for wetland birds, including limited areas of riparian vegetation and woodland habitats. Vegetation clearing will result in a loss of 3.7ha (14.4 percent) of habitat for wetland birds. This has different implications for different groups.

Removal of emergent rushes and other riparian vegetation near the northern shore of Bibra Lake reduces habitat for members of the family Rallidae, such as crakes, rails, the Dusky Moorhen and Purple Swamphen, which favour well-vegetated margins of wetlands (Appendix O). Approximately 0.3ha (four percent) of available riparian habitat will be cleared for the proposed project.

Removal of *Eucalyptus-Melaleuca* woodland habitats (Roe Swamp) may affect species such as the Nankeen Night-Heron that may use roosting sites in this type of habitat. Within the project area, removal of vegetation will result in a loss of 2.0ha (11 percent) of *Eucalyptus-Melaleuca* woodland habitat, which is moderate in scale. However, no significant roost sites for this or other species have been recorded within the project area.

Clearing may result in the loss of tree hollows suitable for breeding by the Grey Teal, Australian Wood Duck, Australian Shelduck and Pacific Black Duck. These species have been recorded at Bibra Lake, North Lake, Horse Paddock Swamp and Lower Swamp, with breeding records for some of these species at these wetlands (Appendix O). Specifically, clearing will cause the loss of 17 trees within the project area that are potentially suitable for breeding of the above mentioned duck species and Grey Teal. While this impact could be potentially high, these species were not observed to be nesting within the project area during the survey period.

Vegetation clearing will result in a loss of 17 trees suitable as breeding habitat for wetland birds

It is possible that the proposed project may create a barrier to movement of wetland bird species. Wetland birds that may be at risk are the Grey Teal, Australian Shelduck, Pacific Black Duck, Australian Wood Duck, Australian Reed-Warbler and Little Grassbird. Ducks that walk flightless ducklings from their tree hollows to forage in Bibra Lake, Horse Paddock Swamp and/or North Lake would be at risk from the barrier created by the proposed project. Proposed bridges and underpasses will provide connectivity and accessibility for ducks between habitats north and south of the proposed project.

The regional extent of wetland bird habitat is unknown, but it is restricted to wetlands, rivers and man-made areas, such as stormwater basins, drains, dams and lakes. The consequences of habitat loss to wetland birds in the project area may be:

- A limited reduction in foraging habitat, particularly with regard to riparian vegetation (northern edge of Bibra Lake) and parkland/grassland areas;
- A reduction in potential roosting habitat with the clearing of *Melaleuca* woodland (northern edge Roe Swamp) that are suitable as potential roosts areas for some wetland bird species;
- A reduction in potential breeding habitat with the clearing of 17 significant trees that are suitable for potential breeding of some wetland bird species;
- Reduced connectivity between Bibra Lake and Horse Paddock Swamp/North Lake that will limit wetland bird movement between these areas; and
- Inability of juveniles to easily access foraging areas between North and Bibra lakes because of the physical barrier of the proposed project.

Impacts on wetland bird species from habitat loss are variable; they are likely to be high at a local scale for some duck species (particularly the Grey Teal, Australian Wood Duck, Australian Shelduck and Pacific Black Duck); moderate for wetland bird species utilising *Eucalyptus*/*Melaleuca* woodland habitats (e.g. the Nankeen Night Heron) and minor for other wetland species confined largely to riparian habitat and open water. Impacts on wetland birds from habitat loss are likely to be minor at the regional scale.

6.7.2.1.6. Western Brush Wallaby

The Western Brush Wallaby was not recorded in the project area, but has been previously recorded during surveys conducted at nearby sites (Dell and Cooper 1992; Bamford and Bamford 2000; Bamford *et al*. 2002; ENV 2009). It may potentially utilise *Eucalyptus-Banksia* woodland within the project area. An historical reduction in habitat and numbers across WA is mainly related to agricultural clearing and predation by foxes. Loss of suitable habitat is an ongoing concern for the species, which requires large tracts of contiguous habitat (Appendix M).

Vegetation clearing will result in a loss of 72ha of Southern Brown Bandicoot habitat

Project surveys suggest that individual bandicoots have a home range of less than 1ha and movement between sub-populations appears limited

While not its preferred habitat, *Eucalyptus-Banksia* woodland provides suitable habitat within the project area (Figure 5.9-1). Clearing of vegetation will result in the loss of approximately 40.0ha (43 percent) of this habitat type for the Western Brush Wallaby. The area to be cleared represents less than one percent of habitat within Bush Forever sites within the region. Given the lack of current records of this species within the project area, its large territorial range and the lack of its preferred habitat within the project area, this impact will be minimal.

Given the lack of current evidence that this species resides within the project area, and its requirements for larger habitat patches than available, impacts on this species from habitat loss and fragmentation are minor.

As a large mammal, the Western Brush Wallaby requires large tracts of contiguous habitat. Cumulative habitat fragmentation on the Swan Coastal Plain presents a possible risk to the population viability of this species in the region.

6.7.2.1.7. Southern Brown Bandicoot

There are numerous records of the Southern Brown Bandicoot within and adjacent to the project area and the population within the project area is considered to be regionally significant. Habitat loss is a key threatening process affecting this species. It is often associated with wetlands on the Swan Coastal Plain, which are under increasing pressure from urbanisation.

Habitat loss and fragmentation pose the most significant risks to the Southern Brown Bandicoot from the proposed project. Key habitat within the project area is represented by *Eucalyptus-Xanthorrhoea* woodland, *Eucalyptus-Banksia* woodland and *Eucalyptus-Melaleuca* woodland, of which there is 153ha in the project area. Vegetation clearing will result in a loss of approximately 72ha (45 percent) of available Southern Brown Bandicoot habitat. On a regional scale, the area of proposed disturbance represents approximately 0.7 percent of suitable Bush Forever habitat type.

Fragmentation may isolate interbreeding populations. Preliminary results from surveys suggest that individuals within the project area have a small home range, possibly less than 1ha. Movement between sub-populations within the study area appears limited; therefore, impacts of the proposed project are likely to be highly localised (Appendix N).

Clearing of vegetation during the construction phase may result in the mortality of individuals. Significant mortality of individuals could result in the loss of sub-populations occurring within the project area.

The consequences of habitat loss and fragmentation for the Southern Brown Bandicoot in the project area include:

- Loss of sufficient area of suitable habitat to maintain viable populations (carrying capacity); and
- Reduction in available linkages to other habitats.

While the scale of this impact may be considered high at a local scale, it is unlikely to result in a decline in species populations at either a local or regional scale.

6.7.2.1.8. Perth Lined Lerista

The Perth Lined Lerista has a restricted distribution across the Swan Coastal Plain with no records existing north of the Swan River (Maryan 2010). The species was recorded within and adjacent to the project area during project and previous surveys. Suitable habitat for this species exists throughout the project area, aside from areas with peaty silt soils in and around Roe Swamp, Horse Paddock Swamp and Murdoch Drain (Appendix M).

Vegetation clearing will result in a loss of 91ha of Perth Lined Lerista habitat

Habitat loss and fragmentation pose the highest risks to the Perth Lined Lerista from the proposed project. Within the project area, vegetation clearing will result in a loss of approximately 91ha (50 percent) of available habitat for this species.

Habitat fragmentation presents a risk to the Perth Lined Lerista, particularly in terms of further restricting the distribution and isolating populations. Habitat fragmentation in the project area will likely contribute to the existing cumulative degradation caused by urban encroachment. This species is particularly vulnerable to fragmentation and isolation, because of their burrowing nature and susceptibility to predation and desiccation. For example, the existing Western Power high tension power line maintenance track likely represents a barrier to movement of this species from one side to the other.

While the project area is likely to contain a number of discrete isolated populations of Perth Lined Lerista, due to existing fragmentation (e.g. power line easement and road network), the proposed project may result in further population fragmentation, leading to ultimate loss of the species in small habitat fragments, particularly in the western section between North Lake Road and Stock Road. However, the species would persist over much of the project area outside the proposed footprint. Habitat loss and fragmentation within the project area may result in:

- Loss of sufficient area of suitable habitat to maintain viable populations (carrying capacity) – unlikely due to the relatively short range of individuals of this species;
- Creation of habitat patches that are separated by distances that restrict movement between patches– the proposed project does not create severances for this species additional to those created by the powerline easement; and
- Compromised population diversity and genetic transfer, therefore reproductive success.

Although there are likely to be some impacts on this species as a result of habitat loss and fragmentation, they are unlikely to result in a significant reduction in the viability of the species. The scale of this impact on this species will be negligible.

6.7.2.1.9. Black-striped Snake

The Black-striped Snake was not recorded in the project area, but may occur as potential habitat exists and individuals have been previously recorded at nearby Jandakot Airport (Bamford *et al.* 2002). The Black-striped Snake may potentially utilise *Banksia* woodland associated with pale sandy soils. Loss or fragmentation of potentially suitable habitat and ecological linkages are key threats to this species.

Within the project area, vegetation clearing will result in a loss of approximately 73ha (43 percent) of this species' potential habitat. This represents 0.8 percent of the regional Bush Forever habitat extent. The consequences and significance of habitat loss and fragmentation are similar to those stated for the Perth Lined Lerista.

6.7.2.1.10. Jewelled Sandplain Ctenotus

The Jewelled Sandplain Ctenotus (*Ctenotus gemmula*) is considered scarce to rare on the Swan Coastal Plain within the Perth metropolitan region (Bush *et al.* 2010; Wilson and Swan 2010). It was not recorded in the project area but may occur in *Eucalyptus-Banksia* woodlands within the project area. Vegetation clearing will result in a loss of approximately 34ha (36 percent) of its potential habitat.

Impacts on the Jewelled Sandplain Ctenotus from habitat loss and fragmentation are minor on both a local and regional scale.

6.7.2.1.11. Oblong Turtle

The long necked or Oblong Turtle was recorded in the project area at Bibra Lake and is expected to occur at North Lake. It also uses the adjacent upland areas for breeding and nesting. Approximately 6.5ha of suitable upland habitat occurs between North Lake Road and Bibra Drive within the project area.

Vegetation clearing will result in a loss of approximately 0.3ha (four percent) of potential nesting habitat for the Oblong Turtle. No impacts are expected to occur in North Lake or Bibra Lake by the proposed project; therefore, no impacts will occur on the species' foraging habitat.

A number of factors (e.g. retaining walls, steep lake side banks and dense *Typha*) have been identified as limiting access to potentially suitable upland nesting habitat for the Oblong Turtle within the study area (Appendix R).

Presently, potential northern movements of the turtle from Bibra Lake to Horse Paddock Swamp are restricted by the dense patch of *Typha*. Oblong turtles are not likely to cross over this area without openings, clearings or animal tracks (Kuchling 2010). A relatively flat portion of the *Typha* located in the north-eastern corner of Bibra Lake may allow turtles to cross to upland areas east of Horse Paddock Swamp (Appendix R).

The consequences of habitat loss and fragmentation for the Oblong Turtle in the project area include:

- Reduction in breeding and nesting habitat; and
- Reduction in movement between habitat at North and Bibra lakes.

The impacts of habitat loss and fragmentation on the Oblong Turtle are likely to be moderate at the local scale and minor at the regional scale.

6.7.2.1.12. Graceful Sun-moth

The Graceful Sun-moth is dependent on two known host plant species, *Lomandra hermaphrodita* and *L. maritima*. Loss of habitat is a key threat to the species, as much of the potential habitat for the Graceful Sun-moth occurs in areas subject to urban development pressures, particularly the coastal and sub-coastal parts of the Perth Metropolitan Region. Graceful Sun-moth habitat has been mapped as:

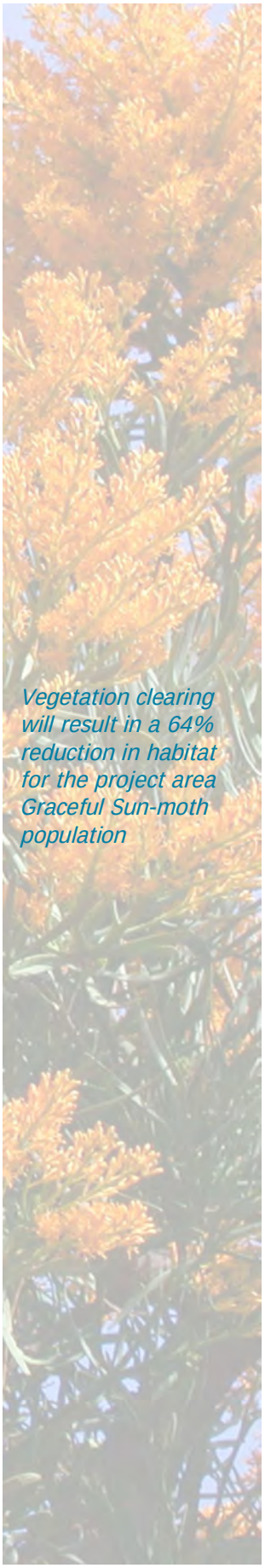
- 'Confirmed habitat' – north-west and north-east quadrants of the Stock Road/Forest Road intersection where adults have been recorded;
- 'Suitable habitat' – actual locations of *L. hermaphrodita* plants; and
- 'Potential habitat' – vegetation communities where *L. hermaphrodita* was recorded.

Six adults of a Graceful Sun-moth population were recorded in the north-west quadrant of the Stock Road/Forrest Road interchange in 2010. These were repeated and additional records were made in the north-east quadrant of this interchange during a March 2011 survey. The total extent of confirmed habitat for this population is 8.7ha, of which 5.6ha (64 percent) will be removed.

A detailed gridded assessment was undertaken in approximately 12 percent of the project area, identifying approximately 3,275 individual plants of suitable habitat. Of this suitable habitat, approximately 1,112 individual plants (34 percent) will be directly disturbed by vegetation clearing.

Approximately 127.5ha of the project area comprises vegetation communities that contain *L. hermaphrodita*. Vegetation clearing will result in the loss of 60.5ha (48 percent) of these vegetation communities, excluding the confirmed habitat (8.7ha).

Impacts on the Graceful Sun-moth from the proposed project are expected to be significant at a local scale. The clearing of vegetation in the project area will result in mortality of moth larvae, which feed on the roots or rhizomes of host plants for most of the year. This will reduce the population numbers from apparently low abundances, with the consequence of severely disrupting the population by lowering the level of breeding activity below a critical threshold for viability.



Vegetation clearing will result in a 64% reduction in habitat for the project area Graceful Sun-moth population

As discussed in Section 5.9, the population recorded in the project area is already unlikely to be viable, due to the combined pressures of habitat loss and habitat fragmentation, as well as the small area where they are located (Bishop *et al.* 2009). A re-assessment of the current conservation status of this species may be justified following outcomes from Graceful Sun-moth surveys in March 2011 and further research findings (DEC 2011). The likely consequences of habitat loss and fragmentation for the Graceful Sun-moth in the project area include:

- Loss of sufficient area of confirmed and suitable habitat to maintain population viability of recorded population (carrying capacity);
- Mortality of larvae and population disruption leading to loss of known population;
- Reduction in additional potential habitat;
- A small reduction in the number of host plants for this species, due to edge effects leading to a decline in reproductive success within the known population;
- Disruption to contiguous tracts of bushland, so the potential for breeding activity falls below a critical threshold for viability; and
- Creation of isolated fragments of habitat insufficient in size to maintain viable populations (carrying capacity).

Impacts of habitat loss and fragmentation on the Graceful Sun-moth are high at a local scale. Given the lack of records of this species within the project region, these impacts are also considered to be moderate to high at a regional scale.

6.7.2.1.13. Subterranean Fauna

An assessment of potential impacts was undertaken in the unlikely event that troglofauna may be present in the project area. The proposed project requires a number of cuts into substrate. The largest of these, at the south-west and north-east corners of the Forrest Road/Stock Road intersection, is required to maintain the road grade (referred to as 'the intersection cut').

There are three potential threatening processes relating to the proposed project that may impact troglobitic species and their habitats:

1) Habitat contamination during construction and operation;
2) Direct removal of habitat; and
3) Changes in microclimates (temperature and humidity) from drastic changes in groundwater levels.

The potential scale of impact on troglofauna from contamination is unlikely, since proposed drainage systems direct stormwater and potentially released contaminants towards basins; therefore, it is not considered further. The direct removal of habitat may affect troglofauna, if suitable habitat is present. Drastic changes in groundwater levels are thought to have the potential to render geological strata unsuitable for troglofauna habitation in certain circumstances, as troglofauna habitats are highly stabile environments, where temperature and humidity vary marginally throughout the year.

A review of the local geology using lithology logging from 20 pre-existing bores (data supplied by the Department of Water) was completed in order to profile the geology in and around the study area. These bores were selected to assess geological transects in a north-south and an east-west direction.

The geology of the study area changes markedly in an east-west direction. It is apparent that west of Bibra Lake (the most easterly logs available), grey sands and limestone dominate the profile to a depth of over 50m, with limestone at surface in some places. This limestone ridge is thought to prevent the generally east-west flowing groundwater from continuing in this direction and instead forcing it north through North Lake. Moving west up and over the ridge it is apparent that sands cover the ridge to a depth of at least 10 to 15 metres. The 'intersection cut', with a maximum depth of 11 metres, may encounter the top of the limestone strata.

The north-south oriented lithology displays similar patterns to the east-west transect, with limestone strata generally covered with sand layers of at least 10 metres. Some limestone outcropping is apparent, but on the whole, remains at depths below the maximum depth of the 'intersection cut'.

No standing groundwater levels were available for 20 drill holes within the project area. A review of the bore logs for BH1 (at Stock Road), BH2 (at Stock Road), BH3 (corresponds to the deepest part of the cut) and BH4 (next to Coolbellup Avenue) revealed that although the bores were drilled to 20m, they did not encounter groundwater. As the 'intersection cut' will be no greater than 11m deep, it will not go below groundwater and there is unlikely to be an alteration of the subterranean temperature and humidity profiles.

It is unlikely that the project will impact populations of subterranean fauna.

6.7.2.1.14. Other Conservation Significant Invertebrates

Six out of eight additional conservation significant invertebrates identified during database searches could potentially occur within the project area, as suitable habitat exists for these species. The six potentially occurring species include a scorpion fly, two native bees, a butterfly and two crickets (Appendix P).

Potential impacts on these species should be considered in context of the lack of knowledge of some species' habitat preferences or requirements, and generally limited records and/or distribution on the Swan Coastal Plain. Potential habitat loss varies between species due to differences in habitat preferences and requirements, and the available area of each suitable habitat type in the project area (Table 6.7-4). Furthermore, the larvae of *Throscodectes xiphos* and *Vanessa itea* are dependent on a specific host plant which, if absent, minimises the value of their habitat.

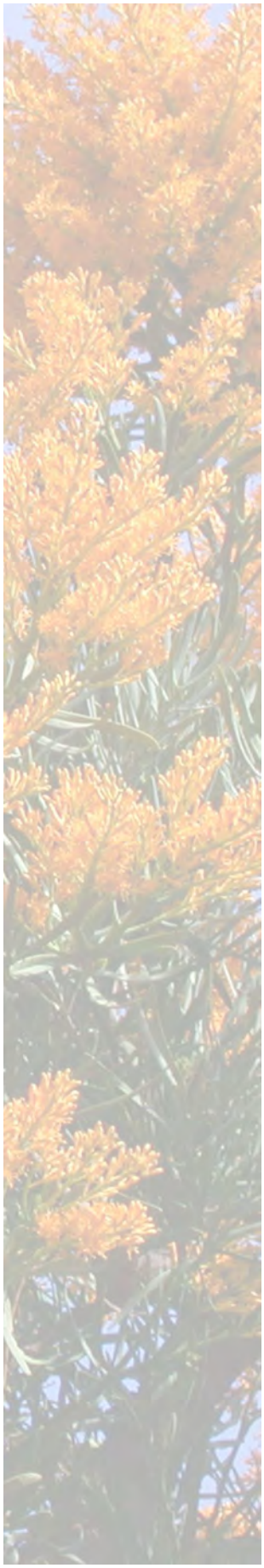


Table 6.7-4: Predicted Habitat Loss for Potentially Occurring Conservation Significant Invertebrate Species

Species	Description of Potential Habitat in Project Area	Available Potential Habitat in Project Area (ha)	Proportion Disturbed in Existing Footprint (ha)	Percent Disturbed
Neopasiphae simplicior (native bee)	*Lobelia tenuior* within *Eucalyptus-Melaleuca* woodland	7.5	0.2	3%
Throscodectes xiphos (cricket)	*Eucalyptus-Banksia* woodland and Bassendean vegetation complex (eastern portion of project area)	133.1	61.5	46%
Austromerope poultoni (Scorpion Fly)	Uncertain: likely to be leaf litter, logs and rocks near wetlands and drainage systems	13.9	1.0	0.7%
Leioproctus contrarius (native bee)	Woodlands and shrublands supporting *Goodeniaceae*	122.3	66.0	54%
Vanessa itea (Yellow Admiral Butterfly)	Woodland habitats	166.5	86.1	51%
Austrosaga spinifer (cricket)	*Banksia* heaths Low woodlands	127.3	59.9	47%

The scale of habitat loss within the project area is expected to be higher for:

- *Leioproctus contrarius* – nearly half of the potential foraging habitat will be cleared;
- *Throscodectes xiphos* – around a third of potential habitat will be disturbed, but the species is typically associated with the Grand Spider Orchid (*Caladenia huegelii*), which was not recorded during project surveys; and
- *Vanessa itea* – a larger area of potential habitat will be disturbed, although it is considered to be a habitat generalist during the adult stage. It has been known to utilise *Arctotheca calendula* during larval stage, although this is not preferred habitat (Grund 2005).

One SRE species recorded in the project area, an unidentified sucking millipede (*Siphonotidae sp.*), may be of conservation significance. However, further identification of this species is required. A single specimen was collected from *Eucalyptus* Woodland with *Banksia* habitat in the north-east quadrant of the Stock Road/Forrest Road interchange. Vegetation clearing will result in the removal of habitat from its only known location within the project area. Positive identification of this species is underway, so its specific habitat requirements are unclear. Consequently, the extent of habitat loss cannot be calculated at this time; and the scale of impact from the proposed project has yet to be determined.

Habitat fragmentation and associated edge effects may lead to a decline in potential habitat within the project area for the potentially occurring conservation significant invertebrates. The process of habitat fragmentation is considered to be more critical for:

- Species with limited distribution by virtue of the mode of transport (ground-dwellers compared with fliers); and
- Habitat specialists, where fragmentation leads to separation of habitat or host plants and therefore decline in reproductive success within a population.

With the exception of the unidentified *Siphonotidae sp.*, project impacts of habitat loss and fragmentation on invertebrates are negligible to minor.

6.7.2.1.15. Other At-Risk Species

Of the vertebrate taxa of concern in the Perth metropolitan region, birds are identified as the most likely at-risk species. Although not considered State or Commonwealth conservation significant, these species (birds, reptiles and one mammal) contribute to the biodiversity of the project area. As detailed in Appendix M, ten regionally significant bird species defined in Bush Forever and recorded within the study area are considered to be at risk (Davis and Brooker 2008). Migratory and wetland birds are discussed above and in Appendix O.

Since European settlement, approximately 35 of the 71 naturally occurring passerines (50 percent) and 40 percent of the nonpasserines have declined in the Perth metropolitan region (WAPC 2000b). Fairy-wrens and thornbills are two groups of concern that have previously declined in Kings Park and other locations across the Perth metropolitan region (Davis *et al.* 2008). Among other bird species, the Splendid Fairy-wren, White-browed Scrubwren, Western Thornbill and Grey Shrikethrush have been identified as some of the sedentary (resident), insectivorous species that are declining on the Swan Coastal Plain (Gole 2003; Johnstone and Storr 2009). The Western Thornbill, in particular, is considered a habitat specialist and is limited in resources, dispersal, area and process within the Swan Coastal Plain.

Sedentary avifauna are dependent on their area of occupancy throughout their life, with the loss or fragmentation of this habitat promoting relocation or possibly the decline or loss of this species in this area.

Reptiles can be generally resilient and slow to respond to changes with isolated reserves supporting diverse reptile species. A number of reptiles recorded within the study area are considered to be at risk. Within the project area, wide-ranging reptiles, such as snakes, are likely to be most affected.

These other at-risk species recorded in the project area are presented in Table 6.7-5.

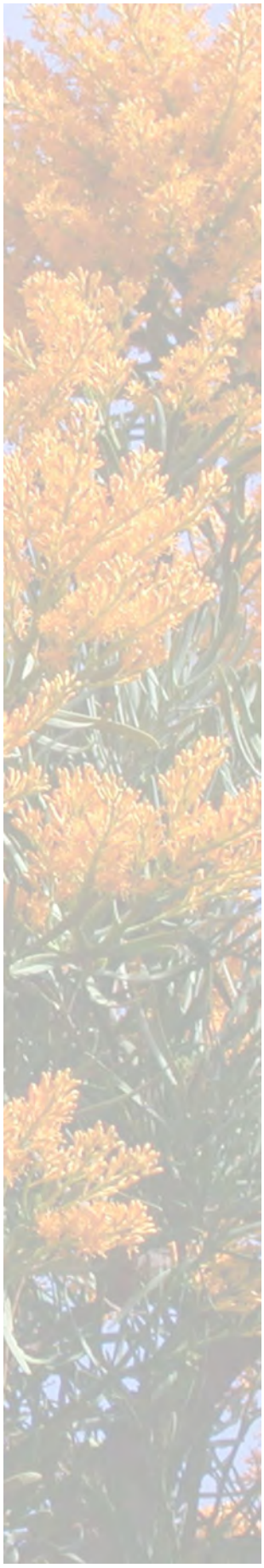


Table 6.7-5: Other At Risk Species

Species	Status	Threatening processes due to development	Habitat Loss	Percent Loss**	Scale of impact***
Western Thornbill*	HS	Habitat loss, fragmentation, fire, feral predation and competition	71.5ha	44%	Moderate
Grey Shrike-thrush	HS	Habitat loss, fragmentation, fire, predation and competition	71.5ha	44%	Moderate
Inland Thornbill	HS	Habitat loss, fragmentation, fire, predation and competition	71.5ha	44%	Moderate
Varied Sittella*	HS	Habitat loss, fragmentation, fire, predation and competition	42.2ha	37%	Moderate
Splendid Fairy-wren	HS	Habitat loss, fragmentation, fire, predation and competition	42.2ha	37%	Moderate
White-browed Scrubwren	HS	Habitat loss, fragmentation, fire, predation and competition	42.2ha	37%	Moderate
White-cheeked Honeyeater	n/a	Habitat loss, fragmentation, fire, predation and competition	40.2ha	43%	Moderate
Blue-billed Duck	n/a	Habitat loss	0.3ha	4%	Low
Red-capped Parrot	n/a	Habitat loss	71.5ha	44%	Moderate
Western Spinebill (endemic to WA)	Rare in urban areas	Habitat loss	66.5ha	50%	Moderate
Common Brushtail Possum	n/a	Habitat Loss, fragmentation, road mortality, fire, predation	42.2ha	37%	Moderate
South-western Crevice Skink	n/a	Habitat loss, fragmentation and predation	111.8ha	45%	Moderate
Western Bearded Dragon	n/a	Fire and predation	111.8ha	45%	Moderate
West Coast Ctenotus	n/a	Habitat loss, fragmentation and predation	111.8ha	45%	Moderate
Small fossorial reptiles (skinks, snakes, lizards)	n/a	Habitat loss, predation and desiccation. Inability to move long distances above ground or on hard surfaces.	111.8ha	45%	Moderate

HS = Habitat Specialist; n/a = not applicable

* Species recorded as an occasional vagrant during project investigation (Appendices N through S)

**Permanent habitat loss within the project footprint & percentage lost within project area

***In project area calculated as: Low (0 to 15%); Moderate (16 to 84%) and High (85 to 100%)

6.7.2.2. Fauna Strike

During construction, the operation of machinery can result in fauna mortalities, as a result of fauna strike. Animals occupying trees within the construction footprint may also be injured or killed during the clearing of vegetation.

6.7.2.3. Construction Noise and Vibration

Noise generated by machinery during construction has the potential to affect fauna. Construction noise will most likely lead to avoidance of the area by fauna. It is known that some form of habituation occurs in response to repeated noise, whereby fauna simply maintain activities in their natural habitat after an initial period of acclimatisation. An issue of concern may arise when acclimatisation does not occur and the noise causes a decrease of survivability and reproduction, as a result of a retreat away from favourable habitats (SKM 2006). This may be relevant for all fauna species; however, there is no species-specific information on the effects of noise. Given the short-term and localised nature of construction noise, it is anticipated that the impacts of noise on fauna will be negligible.

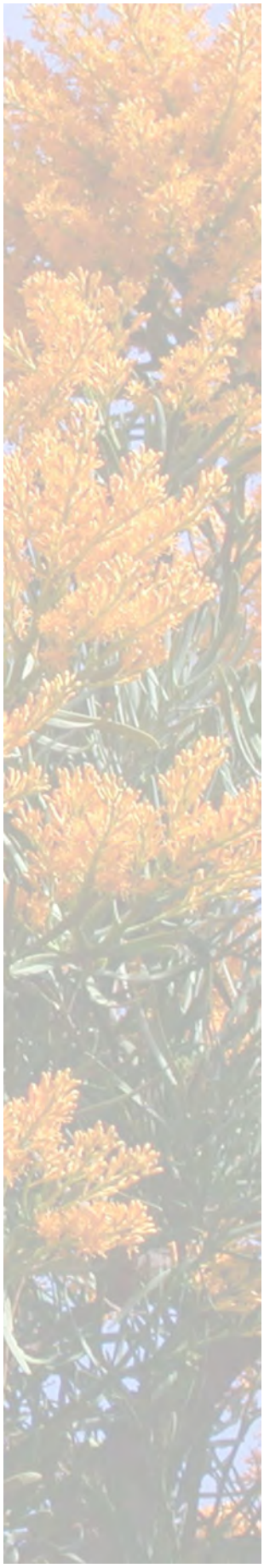
6.7.2.4. Fire

Fire is a natural phenomenon that is integral to the function of many Australian ecosystems. However, it may disrupt ecological processes through direct mortality, temporary habitat loss and fragmentation. Modification of natural fire regime as a result of construction (e.g. changes in time between burns, timing, duration and intensity of burns) has the potential to change the suitability of habitat for fauna.

Fires may accidentally start through careless behaviour during construction phase (i.e. operation of machinery or poor management of fuel storage and handling). With appropriate management and education measures, the risk of fire during construction is considered to be low.

Terrestrial fauna habitat within the project area is at risk of impact from fire, particularly those that are less mobile. The scale of potential impact of fire on a local scale is low due to the low likelihood of a fire starting as a result of the proposed project and the low potential for a fire to engulf the entire project area. Spread of fire will be inhibited by the proposed project acting as a fire break, once the corridor is cleared. The fragmented nature of habitat ensures that fire related impacts are contained to distinct areas. The consequences of fire within the project area include:

- Habitat loss and fragmentation;
- Increased competition of wetland birds for potential nesting hollows; and
- Loss of sufficient area of suitable habitat to maintain viable populations.



6.7.3. Operation Phase Impacts

This section examines the impacts on fauna that will occur during the operational life of the proposed project. The operational phase is predicted to result in:

- Road mortalities;
- Displacement and behavioural change as a result of noise and artificial night lighting;
- Altered hydrological conditions; and
- Edge effects and increased feral and domestic animals.

6.7.3.1. Road Mortalities

Once constructed, the proposed project will pose an ongoing risk to fauna, as a result of direct strike by passing traffic. This risk is highest amongst vertebrate fauna that forage on road-kill and vegetation that establishes along the side of the road, as well as fauna that have their home range bisected by roads (Coffin 2007). Amphibians and reptiles may be particularly vulnerable, as they are slow-moving and may seasonally access multiple habitats to complete their life cycles (Woltz *et al.* 2008).

Carnaby's and Forest Red-tailed Black Cockatoo may forage on remnant roadside vegetation in the absence or decline of good quality foraging habitat. These species' tendency to drop from a tree before gaining height when taking flight puts them at additional risk, when foraging alongside traffic. Abundant, good quality foraging habitat areas located near the proposed project will encourage most individuals away from the road, hence a low risk of road mortality.

The Southern Brown Bandicoot and Western Brush Wallaby would need to cross roads where their home range is divided by the proposed project, which presents the risk of road mortality. For Southern Brown Bandicoots, whose range is relatively small, this represents a negligible impact.

Some migratory and wetland birds will be at risk of road mortality in the project area, when walking or flying at low levels across roads. Where suitable habitat is available on both sides of the project area, various birds may fly at relatively low elevations. Some wetland birds are either non-breeding visitors to the project area or nest close to the wetland shore, but some species (Buff-banded Rail and Black-fronted Dotterel) can nest up to 500m from the shore (Johnstone and Storr 1998). The Whistling Kite, which uses wetland areas for foraging and often feeds on road-kill (Johnstone and Storr 1998), may also be at risk from road mortality.

There is little published information on the flight height of birds over roads. A Perth study by Wilcox (1999) recorded birds flying over a busy road adjacent to Kings Park at a height below 16m, 62 percent of the time with only one wetland bird (the Australian Shelduck) observed flying higher than 16m. Winning and Murray (1997) observed birds flying above a 42m high transmission line between a wetland and a roost site in Newcastle, New South Wales. Of the 22 wetland bird species recorded, egrets flew below 42m 62–85 percent of the time, ibis and spoonbills flew below 42m, 43–67 percent of the time and cormorants flew below 42m 40–51 percent of the time. In contrast, the Silver Gull flew below 42m 13 percent of the time (Winning and Murray 1997). The scale of this impact is considered minor. Without appropriate management and mitigation, the consequences of road mortalities in the project area will be:

- Loss of individuals from a regionally significant population (Southern Brown Bandicoots);
- Disruption/loss of adults through mortality; and
- Loss of ability of juveniles to easily access foraging areas, because of the physical barrier of the proposed project.

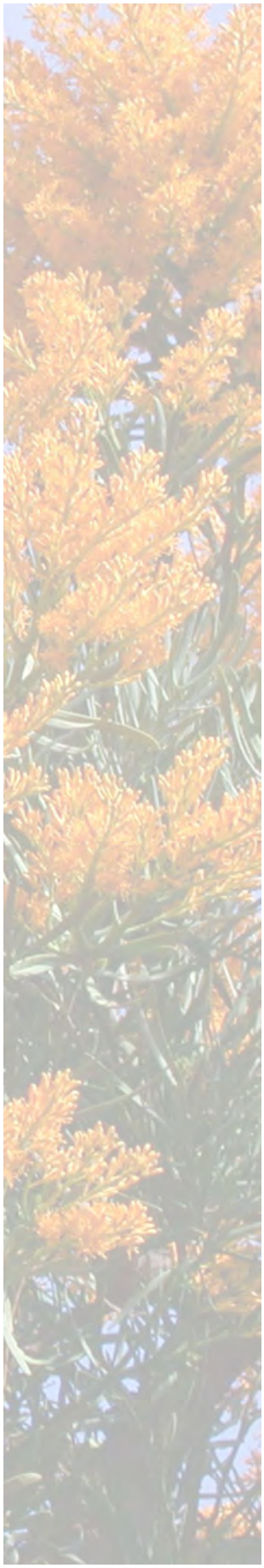
6.7.3.2. Noise

Operation of the proposed project will result in increased traffic noise and is a potential risk to migratory and wetland birds. Studies indicate that traffic noise may affect bird communication that is important for defence and mate selection (Jacobson 2005; Appendix T).

Appendix T presents an assessment of the effects of traffic noise on wetland birds. It is known that some form of habituation occurs in response to repeated noise. An issue of concern arises when acclimatisation does not occur and noise causes a decrease of survivability and reproduction, as a result of a retreat away from favourable habitats (SKM 2006). Although this may be relevant for wetland birds, there is no species-specific information on the effects of noise. As indicated in Appendix T, the effect of traffic noise on birds becomes apparent above noise levels of 55dB. Figure 6.10-10 illustrates the areas where noise levels of 55dB are expected to extend from the proposed project into the wetland areas. The noise assessment of the effects of traffic noise on wetland birds also indicates that noise levels from 50dB (A) cause physiological stress and masking of vocalisations of wetland birds.

There is insufficient research to quantify the extent of this impact. Until fauna adapt to the noise, there is expected to be a temporary displacement of populations away from areas predicted to have 55dB noise levels and greater. The consequences of noise in the project area on migratory and wetland birds are difficult to quantify but may include:

- Temporary avoidance of areas with predicted noise levels of 55dB and greater; and
- Physiological stress and masking of vocalisations at noise levels greater than 50dB(A).



6.7.3.3. Altered Hydrological Conditions

Impacts of the proposed project on surface water movement are discussed in detail in Section 6.3. In areas where studies indicate water levels require management, surface water movements will be maintained through the installation of culverts and other appropriate drainage facilities. Nevertheless, there will be minor changes to surface water movements immediately adjacent to the proposed project. The scale of this impact is considered low. There is a possibility that the downward compression force of the road formation will interrupt groundwater movement, with consequential minimal impacts on groundwater dependent vegetation (Section 6.6) and the corresponding fauna habitat.

One of the two proposed drainage basins at the Stock Road/Roe Highway interchange has been designed to make use of natural depressions in ground levels, in order to avoid excavation and hence minimise the extent of clearing. Road runoff will be discharged to this area and will inundate the existing vegetation for short periods. This is likely to impact the *Eucalyptus-Banksia* woodland community that provides habitat for various fauna species, particularly birds (including Carnaby's Black Cockatoo) and reptiles. Over time, there will be a change in composition of the vegetation community, as it reaches a new equilibrium. Successionally, this area is likely to comprise flora more tolerant to periodical wetting. This will have an effect on *Lomandra hermaphrodita* populations, which may impact the local success of Graceful Sun-moth in this area.

6.7.3.4. Edge Effects and Feral/Domestic Animals

Areas of habitat that are fragmented are susceptible to indirect impacts known as 'edge effects', whereby habitat fragments are degraded by processes including fire, erosion or the invasion of opportunistic weeds from outside the remnant habitat. These processes limit habitat resources and ultimately lead to a decline in condition and integrity of the habitat, which often involves the loss of understorey species. The depth or extent of edge effects varies between habitats. Vegetation condition mapping has determined the extent of weed infestation to an average of around five metres from the edge of disturbance, extending to 20m in some areas (Appendix K). A review of the extent of weed incursion alongside Roe Highway Stage 7 supports this finding.

Landscapes that are altered by habitat loss or fragmentation tend to increase competition for habitats, or may allow the introduction of invasive species to the project area. Competition is an existing issue within the project area, with approximately one-third of the significant trees being colonised by feral bees or rainbow lorikeets, as well as evidence of numerous rabbits throughout the project area.

Removal of native vegetation, degradation of habitat and installation of fencing along the perimeter of the alignment may lead to increased predation of ground-dwelling fauna (e.g. reptiles and mammals) by both introduced (e.g. foxes and cats) and native (e.g. predatory birds) carnivores, by reducing the level of protection afforded by the habitat. The Perth Lined Lerista and Southern Brown Bandicoot are at risk of enhanced predation. Currently, they are under pressure as a result of the habitat degradation caused by rabbits in the project area.

The potential impact of edge effects on the resident Southern Brown Bandicoot population is not clear. The current population appears to be utilising edges within the project area, where weed encroachment is displayed. Individuals have been recorded in vegetation areas classified as 'Good to Degraded' on numerous occasions. Dense introduced grasses may provide a surrogate habitat in place of native understorey for this species.

In relation to migratory birds, while edge effects may lead to decline in habitat condition for the Rainbow Bee-eater, the scale of impact on the species is considered to be negligible, given its lack of specific habitat preferences.

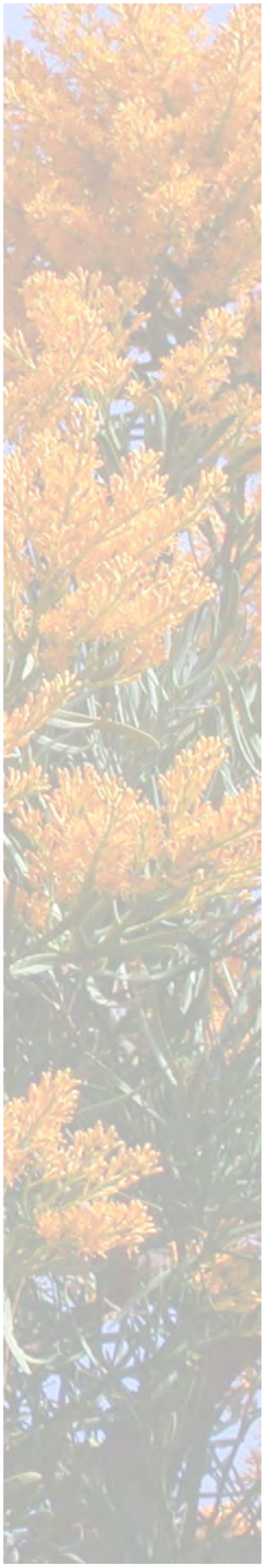
Edge effects and weed encroachment may lead to decline in *Lomandra hermaphrodita* in the project area, as well as increasing the vulnerability of adult Graceful Sun-moths to predation from outside the habitat. This host plant was recorded in degraded remnant vegetation within the project area. However, it was generally observed to decline in density towards the edges of existing roads and be absent in areas with dense weed infestation.

An analysis of the change in edge effects subsequent to the proposed project is presented in Section 6.6. This analysis demonstrates that the current edge to area ratio within the study area will be reduced following project construction, thereby reducing the scale of edge effects.

6.7.3.5. Artificial Night Lighting

Artificial night lighting will increase as a result of the proposed project. Artificial night lighting may impact on aquatic and terrestrial invertebrates, amphibians, fish, birds and mammals through altered behavioural patterns and/or disruption of diurnal movements (Longcore and Rich 2001).

A study on road lighting for shorebird breeding in grassland found a negative effect on breeding habitat within 300m of the road. This was thought to be due to the visibility of the lights themselves, as illumination from the lights diminished within 50m (Molenaar *et al.* 2006). The scale of this impact is negligible, when considered in the context of the extent of available shorebird breeding habitat within the region and lack of records of shorebirds breeding within the project area.



A decline in prey populations (e.g. frogs and fish) due to artificial night lighting may result in altered feeding habits in species, such as herons or egrets utilising North and Bibra lakes, as they are forced to search for prey elsewhere. The scale of this impact is minor. The consequences of artificial lighting in the project area are:

- Distraction and disorientation of migrating birds;
- Modified population composition, as a result of avoidance of lit areas;
- Changes to bird foraging and singing times;
- Reduction in size of prey populations (e.g. invertebrates, fish and frogs);
- Variation in choice of roosting sites;
- Increased physiological stress and changes to the timing of reproductive cycles; and
- Disorientation and displacement of nocturnal mammals.

6.7.4. Management and Mitigation

The reduction of impacts and key threatening processes in the project area has been achieved through the consideration of alternative project design options and developing management and mitigation strategies. During the project development phase, considerable attention has been given to avoid, minimise and reduce impacts on fauna and its habitat. In addition to these measures, management and mitigation has been proposed to further minimise identified impacts on fauna from the proposed project.

6.7.4.1. Habitat Loss and Fragmentation

During design development, impacts on fauna habitat and fragmentation were avoided and minimised through the inclusion of the following proposed measures:

- Alignment of the proposed project along an existing power line access track and Hope Road, to minimise requirements for habitat removal;
- Alignment of the proposed project in order to minimise impacts on or removal of the trees with existing potential nesting hollows;
- Alignment of the proposed project to minimise the length of clearing required through black cockatoo foraging habitat;
- Alignment of the proposed project in order to minimise disturbance of riparian vegetation and avoid disturbance of shoreline habitat at the northern end of Bibra Lake;
- Bridge over a portion of Roe Swamp;
- 'Incremental top-down' construction methodology for Roe Swamp bridge;
- A series of underpasses to allow for north-south fauna movement;
- Bridge between Bibra Lake and Horse Paddock Swamp;
- Modified design features to reduce the width of the footprint, and therefore amount of habitat to be disturbed (e.g. retaining walls in lieu of batters, reduction in width of median strip from 15m to 4m, adjustments to the final finished level of the carriageways to reduce the amount of cut and fill); and
- Designed the cutting west of Roe Swamp so that drainage pipes will be positioned above the local groundwater level (approximately 16.5m Australian Height Datum) to avoid dewatering and subsequent potential impacts on *Banksia* woodland.

The proposed construction method for the Roe Swamp bridge avoids the need for active clearing between the two bridge abutments, by minimising ground level access requirements. Vegetation underneath bridges will be mostly maintained to provide groundcover for fauna movement. This vegetation largely comprises *Melaleuca* woodland habitat. A decline observed in vegetation condition, due to shading in these areas, will be supplemented by planting with low light and moisture tolerant species. Ground habitat features such as fallen logs, top soil and leaf litter will be installed to supplement fauna habitat.

The proposed bridge between Horse Paddock Swamp and Bibra Lake will combine a fauna, bicycle and pedestrian underpass that links the two wetlands. This will be in the form of bridged infrastructure and will be designed with a large openness ratio and include other features, such as fallen logs, top soil and leaf litter to encourage use by fauna species.

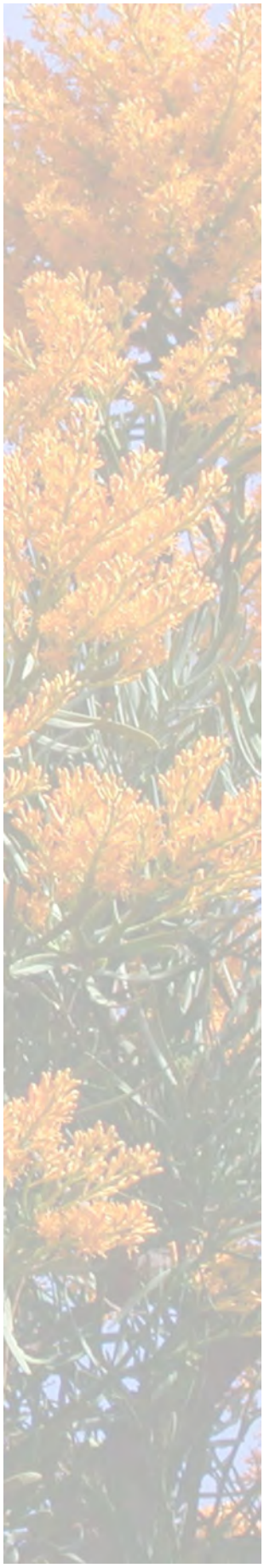
The following management and other mitigation measures will be undertaken to further minimise and reduce the impact of habitat loss:

- Delineate the extent of clearing through the erection of fencing at the boundaries of the construction zone and tagging specific trees for retention;
- Avoid clearing or disturbance outside the defined project footprint boundaries;
- Minimise damage to surrounding wetland habitats (shoreline) outside the highway footprint during construction, by fencing or clearly delineating the construction site boundaries;
- Obtain water required for construction from off-site sources, to avoid the need for on-site dewatering;
- Replace ground habitat features, such as fallen logs, top soil and leaf, where habitat loss or degradation occurs; and
- Rehabilitate cleared areas on completion of works, where possible.

6.7.4.2. Fauna Mortalities

Potential fauna mortalities will be managed during construction and operation with the implementation of the following measures:

- Install fauna-proof fencing on both sides of the proposed construction extent to contain movement of construction machinery;
- Trap and relocate fauna out of the construction zone following the installation of construction fencing;
- Install visual barriers, such as 3m vertical poles or native trees grown to sufficient height, at 3–4m intervals at critical points along the alignment to encourage birds to fly over the height of moving traffic;
- Install a series of underpasses to allow for fauna movement between habitat;
- Maintain permanent fencing within valuable habitat areas throughout the proposed project during operation; and
- Avoid the creation of foraging habitat immediately adjacent to the proposed project.



6.7.4.3. Noise

Impacts of noise on birds cannot be quantified; however, the following precautionary measures will be implemented to minimise a potential impact:

- Consider materials for visual screens that also mitigate noise impacts, where appropriate, to minimise operational effects of the proposed project on wetland bird populations in Bibra Lake and Horse Paddock Swamp;
- Avoid placement of wetland bird artificial nesting boxes within the 55dB noise contour until after monitoring of bird adaptation to noise in wetland habitats; and
- Consider quiet road surfacing materials during detailed design phase of the project for use during construction.

6.7.4.4. Fire

Fire will be managed during construction through the development and implementation of a CEMP. The management plan will aim to ensure that no uncontrolled fire occurs within the Beeliar Regional Park as a result of construction activities. Management of potential fire impacts on vegetation is outlined in Section 6.6.4.8.

Fire impacts during the operation phase of the proposed project will include the maintenance of existing fire breaks. The need for additional fire breaks will be considered in consultation with the Fire Emergency Services Authority of Western Australia (FESA) and DEC. However, it is noted that the proposed project itself serves as an extensive fire break between the north and south sides of the proposed project.

6.7.4.5. Altered Hydrological Conditions

Altered hydrological conditions will have an indirect and negligible impact on fauna and fauna habitat, except where it is caused by the installation of a drainage basin at Stock Road. The impacts from this drainage basin will be managed by using the natural depression of the site and not clearing the habitat within it. While this will result in a change in the vegetation community over time, it is considered to be a preferable outcome to clearing the basin entirely. Other fauna impacts resulting from alterations to hydrological conditions will be managed as a result of surface and groundwater impact management, as outlined in Section 6.3.

Water required for construction will be obtained from appropriate off-site sources to avoid the need for on-site dewatering. Water abstraction will be undertaken in accordance with the necessary permits required pursuant to the *Rights in Water and Irrigation Act 1914*.

6.7.4.6. Edge Effects

Edge effects will be managed through the development and implementation of the following management plans:

- Soil Hygiene Plan;
- Weed and dieback control programme; and
- Rehabilitation and revegetation programme.

6.7.4.7. Feral/Domestic Animals

The following measures will be implemented to minimise predation on and competition with native fauna:

- Retain and redistribute ground habitat features around disturbed areas, such as topsoil and large timber that contain hollows;
- Use hollow logs in fauna underpasses and other areas of open ground to facilitate fauna movement and provide cover. Where necessary, the development and use of artificial hollows in these areas will be investigated to ensure longevity;
- Place fencing flush against native vegetation to limit predation, where possible;
- Install exclusion fencing in potentially high predation areas to decrease prey accessibility and visibility;
- Replace removed habitat, such as shrubs and fallen logs, intermittently along fencing for shelter; and
- Monitor the fence line during construction to assess effectiveness on an intermittent basis.

6.7.4.8. Artificial Night Lighting

Innovations with respect to lighting through wetland areas of the proposed project will be considered during detailed design. Options being considered for use, in lieu of Main Roads' normal practice and standards and as they relate to fauna impact management, include:

- Low-level lighting aimed directly at the road surface;
- Directional lighting that avoids light spill into adjacent habitats;
- Sensor lights, particularly along the Principal Shared Path, that operate when required; and
- Screening (vegetative or artificial) of roadside to limit light spill.

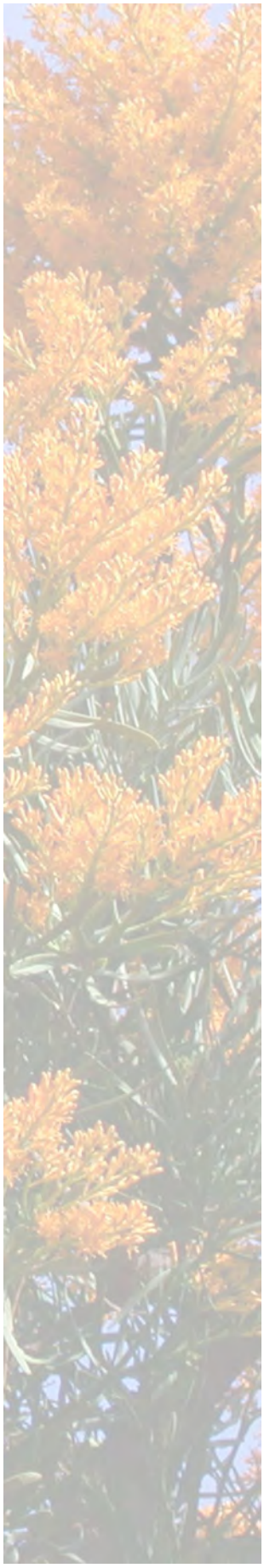
Implementation of innovative lighting depends on the conformance to road safety standards, which are the primary focus when it comes to road lighting. Lighting design will give consideration to the above strategies, where possible.

6.7.5. Summary and Conclusions

This section contains a summary of the residual impacts, management practices to minimise impacts, key points of Bulletin 1088 and offsets for fauna.

6.7.5.1. Residual Impacts

Within the project area, clearing of vegetation and the installation of drainage basins will result in the loss of approximately 112ha of fauna habitat. This will include the loss of approximately 78ha and 73ha of suitable Carnaby's Black Cockatoo and Forest Red-tailed Black Cockatoo foraging habitat, respectively. Loss of nesting habitat is of lesser concern, as neither species is presently known to breed within 25km of the project area. However, based on the assumption that a significant tree occupies 100m^2, and recognising that these species may start using these trees for nesting as



pressures on existing nesting habitat increases over time, a total of 2.5ha (249 trees) of potential black cockatoo nesting habitat will be removed.

With the exception of the Rainbow Bee-eater, migratory species will not be directly affected by habitat loss or habitat fragmentation as there will be no loss of shoreline or lakebed habitats within the project area. Given the Rainbow Bee-eater's lack of specific habitat preferences the scale of impact is considered negligible.

Vegetation clearing will result in a loss of approximately 72ha (45 percent) of available Southern Brown Bandicoot habitat within the project area. On a regional scale, the area of proposed disturbance represents approximately 0.7 percent of habitat within Bush Forever sites. Vegetation clearing will also result in a loss of approximately 91ha (50 percent) of available potential habitat for the Perth Lined Lerista. However, the species would persist over much of the project area outside the proposed footprint.

Impacts on the Graceful Sun-moth by the proposed project are expected to be significant at a local scale, with the removal of a substantial portion of confirmed GSM habitat to an extent that is considered unlikely to support a viable population.

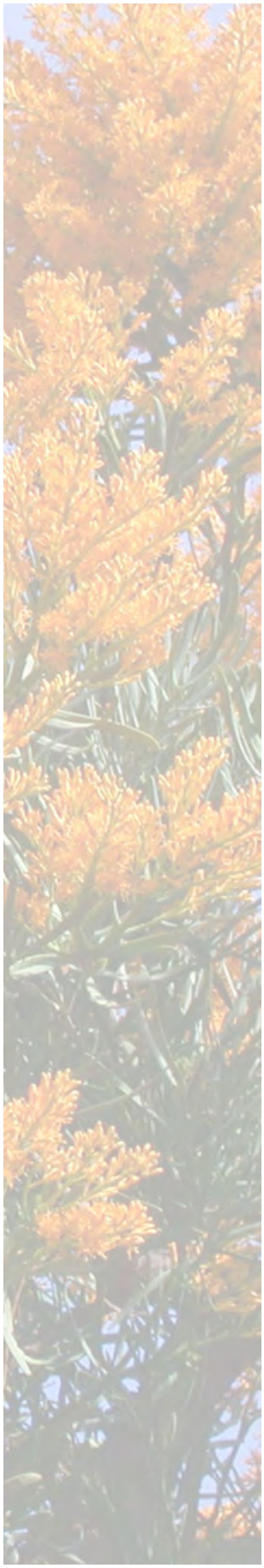
Much of the project area has already been fragmented by urban infrastructure and walking tracks. Nevertheless, fragmentation by the proposed project will primarily affect fauna by increasing the distance between habitat patches.

Although it is difficult to quantify impacts on wetland migratory birds, it is acknowledged that there will be residual impacts on these species. While avoiding impacts on other environmental values, Main Roads has avoided impacts on wetland migratory birds and other fauna species by modifications to the project design. Additionally, impacts to bird species will be minimised by the installation of nesting boxes, revegetation of habitat and installation of visual barrier to encourage birds to fly over moving traffic; as well as considerations for noise affects on bird species. Additional to these impacts, construction and operational phase noise and lighting is likely to have an indeterminate impact on these species. Accordingly, it is acknowledged that residual impacts on wetland migratory birds will occur, and these require offsetting (Section 6.7.5.3).

A summary of the mitigation, management and residual impacts for fauna is presented in Table 6.7-6.

Table 6.7-6: Residual Impacts on Fauna

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Vegetation removal	Loss of fauna habitat areas through clearing of approximately 112ha of vegetation Removal of significant trees for potential black cockatoo nesting (note: nesting is not known to occur within or near the project area or the region) Reduction in available black cockatoo foraging habitat	Avoidance measures implemented through design development phase Revegetation of 52ha of fauna habitat, including rehabilitation of 38ha of native vegetation cleared during construction and restoration of an additional 14ha Site road alignment to bypass significant potential nesting trees, where practicable	78ha loss of foraging habitat for Carnaby's Black Cockatoo 73ha loss of foraging habitat for Forest Red-tailed Black Cockatoo 2.5ha of potential nesting habitat for black cockatoos 73ha loss of habitat for Southern Brown Bandicoot 91ha habitat loss for Perth Lined Lerista Loss of confirmed non-viable Graceful Sun-moth population Reduction in potential habitat for future Graceful Sun-moth populations
	Fragmentation of fauna habitat	Installation of fauna underpasses at approximately 100m intervals between Bibra and Progress Drives, and at strategic locations west of North Lake Road	Fauna habitat will remain fragmented, but to a significantly lesser extent
	Fauna strike with plant and construction equipment will cause injury or mortality in some fauna. In addition, if fauna are not adequately evacuated from trees to be cleared, fauna may be injured or killed during clearing	Installation of fauna-proof fencing to delineate the construction zone and exclude fauna Translocation of fauna from construction zone	The proposed management and mitigation measures will minimise fauna mortality during construction
Operation and maintenance of plant and machinery	Increased noise produced by construction machinery will lead to temporary displacement of fauna	Use of quietest possible machinery available in accordance with noise management regulations	Fauna will be displaced during construction activities, but may acclimatise to noise levels



Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Careless behaviour during construction or sparks created by construction activities will result in accidental lighting of fire	Development and implementation of a CEMP Prohibition of fire lighting during construction Provision of personal cigarette butt disposal containers Construction machinery fitted with spark arresters Personnel and vehicles fitted with fire fighting equipment Communication of fire management procedures to personnel via site inductions	The proposed mitigation measures will minimise the risk of accidental fire occurring
Operation Phase			
Freight and private vehicle transport	Traffic using the proposed highway extension will cause some fauna mortalities, as a result of direct strike with vehicles	Installation of visual barriers at critical points along the alignment to encourage birds to fly over the height of traffic Creation of dual use underpass (fauna and pedestrian) Maintenance of permanent ground-level fencing throughout alignment Avoidance of creating foraging habitat immediately adjacent to highway	Very low rates of vehicle strike on flighted birds/other fauna
	Traffic noise will result in, limited temporary displacement of wetland birds from Horse Paddock Swamp and the northern end of Bibra Lake. This displacement can potentially result in reduced survivability and reproduction	Use of quiet road surfacing materials	Some displacement and behavioural changes are likely to continue
Physical presence of road	Potential localised degradation/loss of fauna habitat, as a result of changes in groundwater dependent vegetation communities	Maintenance of natural vegetation in drainage basin near Stock Road interchange Off-site abstraction of construction water Bridge over portion of Roe Swamp Refer to Section 6.3 for more detailed mitigation measures	Proposed mitigation measures will minimise potential for altered hydrological conditions and consequent degradation of fauna habitat

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Although the proposed project will reduce the edge to area ratio of the project area, it will create some new edges in areas where there were previously none. Where edges are created, altered conditions will increase the risk of competition, predation and degradation of habitat	Examination of some existing and newly created edges for their potential to be restored, revegetated or regenerated, to enable reintegration of these areas with intact vegetation and habitat Closure of Hope Road near the entrance to Native ARC and the rehabilitation/revegetation of the area west of this point Ongoing post-construction monitoring of retained and rehabilitated vegetation as part of a weed control programme Preparation and implementation of Soil Hygiene Plan	Minor edge effects
	Displacement and behavioural modifications for wetland migratory birds using habitat adjacent to the proposed project	Modified lighting to avoid light spill Use of road surfacing material that reduces traffic noise	Some displacement and behavioural changes are likely to continue

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6.7.5.2. EPA Bulletin Matters

The EPA concerns for fauna from the proposed project as stated in Bulletin 1088 (EPA 2003) are highlighted in Table 6.7-7.

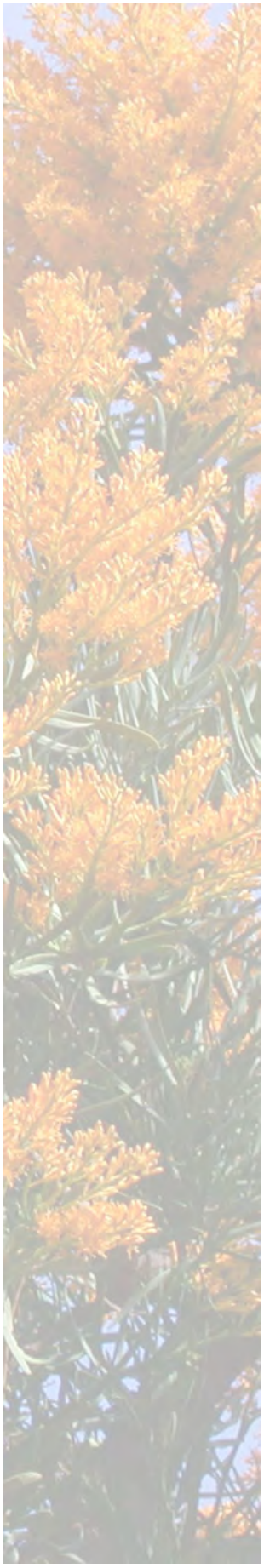


Table 6.7-7: EPA Concerns for Fauna as Stated in Bulletin 1088

Bulletin 1088 Statement	Proposed Project Concept Response
Construction within the alignment for Stage 8 of Roe Highway would lead to a direct impact on the significant faunal values for the area through loss of habitat and breeding areas, as well as creating a severance in some strategic linkages between the area's wetlands and upland vegetation which would impact on faunal movement within the area	Clearing of vegetation and the installation of drainage basins will result in the loss of approximately 112ha of fauna habitat The loss of known breeding habitat within the proposed project area is restricted to a small number of conservation significant species, none of which will be significantly impacted on a regional scale Much of the project area has already been fragmented by urban infrastructure and walking tracks. Further concerns surrounding strategic linkages will be addressed by: • The retention of fauna migration pathways will be provided by constructed fauna and hydrology passages beneath the road alignment with openings under the road (e.g. culverts and fauna underpasses) • The provision of bridges and other openings (culverts/underpasses) across swamp, other natural low topographic areas and between habitats of 'Good' (or better) vegetation condition ratings will further Rehabilitation of 38ha of the 79ha of vegetation cleared during construction
The viability of the various fauna habitats within the area is being maintained through its large size, and a proposal to construct a highway through this area would sever and reduce the area's size leading to potential impacts on the fauna habitats within the area and their long-term viability	Whilst severance issues have been addressed above the reduction in habitat size has the potential to impact the local viability of a number of conservation significant species Regionally there will be no significant impacts on conservation significant species by the proposed project

6.7.5.3. Offsets

Fauna offsets are proposed for residual impacts on Carnaby's and Forest Red-tailed black cockatoos, wetland migratory birds and the Graceful Sun-moth, as described in detail in Section 10. These include:

- The purchase and transfer of 468ha of high quality black cockatoo habitat to conservation estate as described in Offset Proposal 1, which is proposed to offset the loss of 78ha and 73ha of Carnaby's Black Cockatoo and Forest Red-tailed Cockatoo foraging habitat, respectively;
- Restoration of wetland habitat at Horse Paddock Swamp, North Lake and weed control within Roe Swamp;
- Improved management and protection of existing Graceful Sun-moth populations as well as improved understanding of options for habitat and species maintenance;
- Implement habitat improvements within Ramsar listed Thomsons Lake; and
- Undertake research into the effects of new transport infrastructure on wetland migratory birds.

6.8. Ecological Linkages

The following objective for ecological linkages is modified from Bulletin 1088:

> *Maintain ecological linkages and corridors between, within and across the Beeliar Regional Park in order to maintain the diversity and vigour of the Park's ecological systems (EPA 2003).*

The EPA (2003) identified severance of ecological linkages by the project, as it existed at that time, as a threatening process that may reduce the area's viability for conservation of species. At present, major arterial roads and other infrastructure limit the linkages between the project area and other parts of the Beeliar Regional Park and other local parks. The EPA (2003) identified potential impacts on:

- Direct linkages between North and Bibra lakes and the surrounding wetlands in the immediate area; and
- Linkages within the Eastern Chain of the Beeliar Wetlands and, subsequently, the eastern side of the Beeliar Regional Park.

These links and corridors between and within Beeliar Regional Park help to maintain the long-term diversity and vigour of the ecological systems occurring within the park and adjacent natural areas.

6.8.1. Potential Impacts

A range of potential impacts on ecological linkages were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops.

The proposed project was designed to ensure that no severance of water bodies would occur, thus minimising impacts on aquatic fauna. Furthermore, hydrological connectivity is maintained through the inclusion of apertures (bridge and culverts) through the proposed formation.

A detailed assessment of predicted ecological linkage impacts is provided in Sections 6.8.2 and 6.8.3.

6.8.2. Construction Phase Impacts

While the majority of impacts associated with the proposed project will occur initially as a result of construction activities, impacts on ecological linkages are generally manifest over a longer period of time, and the effects will be more noticeable during the operation phase of the project.

Clearing, fencing and earthworks will result in a decline in connectivity

Fencing is installed to prevent harm to fauna and over-clearing

Construction activities that will lead to impacts on ecological linkages include:

- Installation of fencing;
- Removal of vegetation; and
- Earthworks.

6.8.2.1. Decline in Connectivity

A decline in connectivity within an ecological linkage occurs as a result of the creation of habitat fragments, which are generally created during clearing and earthworks. Barriers will be created as a result of:

- The removal of vegetation, which will result in exposure risks to fauna attempting to move between fragments;
- The installation of fencing, which will create a physical barrier and will prevent the movement of fauna between the newly formed fragments; and
- Earthworks, which will create a barrier in the form of a deep cutting or a high embankment.

It is proposed that fencing will be installed along the length of the proposed project where it passes through areas of intact native vegetation (i.e. high quality habitat). The installation of this fencing is to prevent native fauna from straying into the path of construction machinery, and to ensure that construction activities are confined to the construction footprint to prevent over-clearing. However, while being an important management tool, the fencing will have an immediate impact on fauna linkages, preventing movement of terrestrial fauna in a north/south direction at a local scale.

Once fencing is installed, and fauna within the project footprint have been trapped and relocated, vegetation will be removed and topsoil stripped and stockpiled. Where the installation of fauna fencing limits the movement of terrestrial fauna, the clearing of vegetation can impact the movement of birds, particularly smaller birds that rely on dense vegetation for shelter. Furthermore, the removal of vegetation creates habitat fragments within an ecological linkage, which reduces its interconnectedness at a local scale. The proposed project will result in the removal of approximately four linear kilometres of remnant vegetation from within the project area.

Earthworks refer to the excavation of material from cuttings and importation of fill to achieve the horizontal alignment of the road formation. Earthworks exaggerate the effects of vegetation removal by creating physical barriers to movement between fragments. The profile of the proposed project ranges from an 11m deep cutting between Stock Road and Sudlow Road/Coolbellup Avenue, to an 8m high embankment between Bibra Lake and Horse Paddock Swamp.

Although significant on a local scale, as regional linkages function with a relatively low connectivity, this impact has a low significance at a regional scale.

6.8.2.2. Habitat Fragmentation

Removal of vegetation for the construction of the proposed project will result in the fragmentation of habitat. Linkages generally only become fragmented when habitat loss occurs at a scale relative to the size of the linkage.

Regional linkages are generally non-contiguous for much of their length. The habitat located within the project area is significant in size, in a regional context, and is the convergence of four significant regional linkages. The proposed project will result in the creation of fragments between all four linkages; however, the distance between resultant fragments is relatively short compared to existing severances, and this impact is generally low in significance.

Conversely, local linkages function at a smaller scale and when fragmented, result in several smaller, less sustainable or functional fragments to be created.

6.8.2.3. Decline in Functionality

An ecological linkage's functionality can decline as a result of edge effects, predation and competition, and reduced resilience to climate change. Decline in functionality can be equally significant for regional and local linkages.

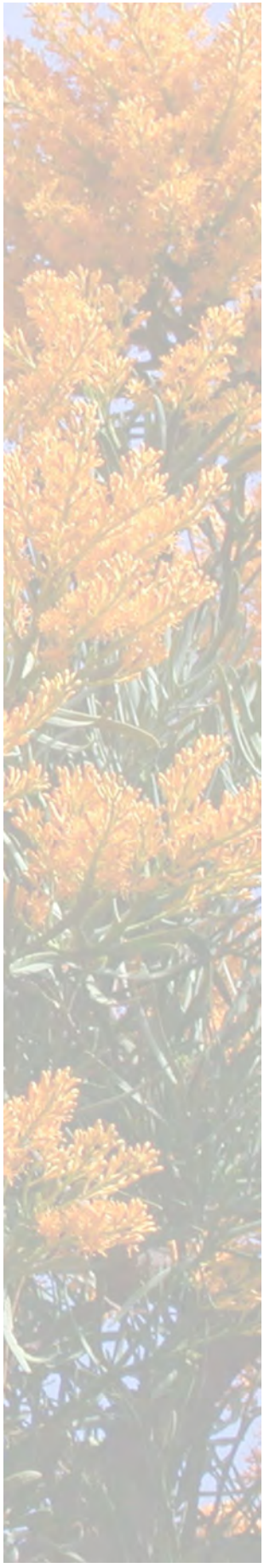
Edge effects cause the perimeter of a remnant to become degraded and can result in:

- Increased number of introduced fauna;
- Ingress of weeds;
- Alterations to microclimate (i.e. drying, altered humidity levels, increased light penetration, increased wind shear); and
- Increased competition and assemblage modifications.

Functionality of a fragment declines as a result of edge effects, which reduces its value as a component of an ecological linkage. The significance of edge effects depends on the size of the fragment, with smaller fragments more susceptible to loss of function.

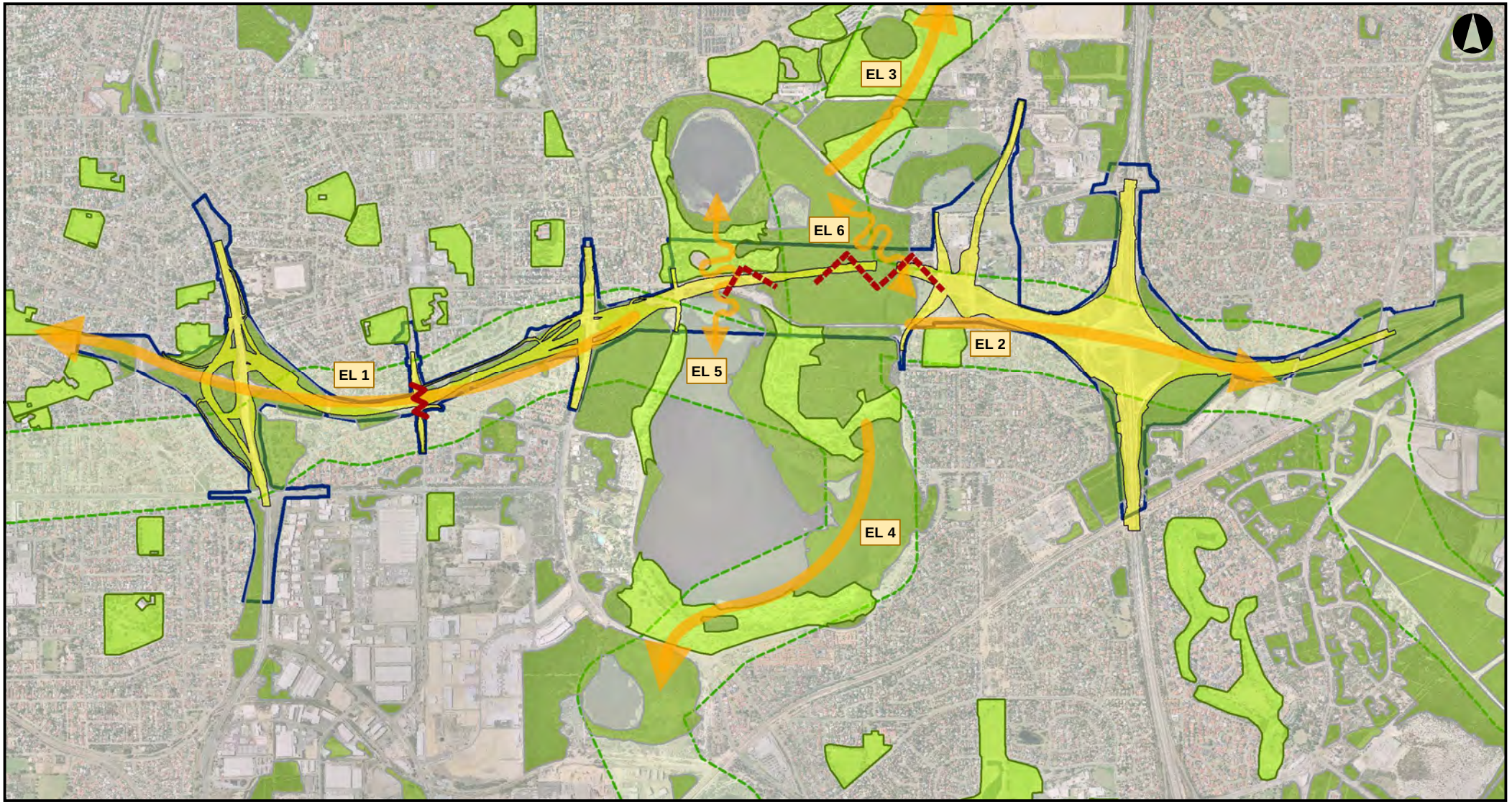
Predation and competition reduces the functionality of an ecological linkage and is generally closely associated with edge effects. Fauna within smaller fragments are more susceptible to predation and competition, as there is increased competition for refuge and resources. Edge effects have been analysed and are discussed in more detail in Section 6.6.

Climate change has the potential to impact ecological linkages. Where there is poor connectivity between linkages, the capacity for the fragments to adapt to changing conditions is reduced. This can result in fragments of the linkage declining in health to a point where they are no longer viable.



6.8.3. Operation Phase Impacts on Identified Ecological Linkages

As noted previously, severance of ecological linkages occurs primarily during construction; however, the effects of this impact are generally manifest during the operation phase. This section discusses the long term impacts of the proposed project on the individual ecological linkages identified within the project area. Impacts on individual ecological linkages defined in Section 5.10 are represented in Figure 6.8-1.



Changes to Ecological Linkages

South Metro Connect

Figure 6.8-1

0 250 500 750 1,000

Metres

1:30,000 (A4)

- Local Ecological Linkage
- Regional Ecological Linkage
- Remnant Native Vegetation
- Other Local Greenspace (Parks & Recreation)
- Regional Ecological Linkages (Provided by Perth Biodiversity Project 2003)
- Road Construction Footprint
- Potential Linkage Fragmentation
- Partial Fragmentation
- Project Area

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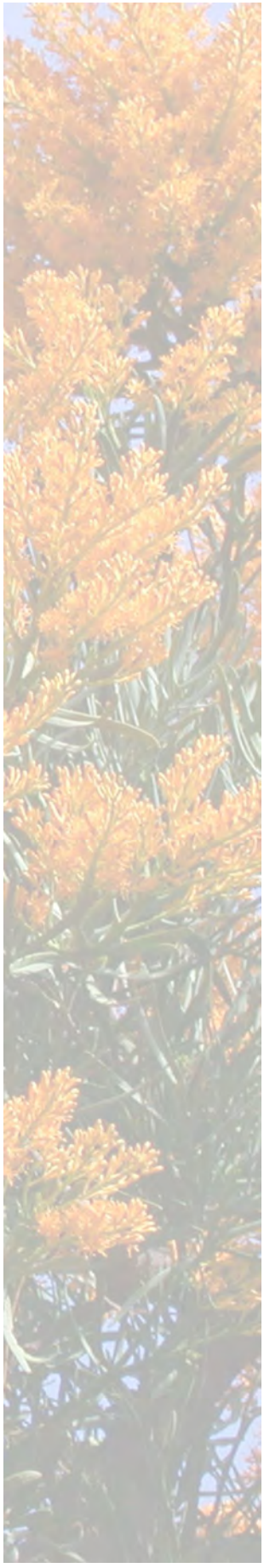
SouthmetroConnect



6.8.3.1. Ecological Linkage EL1 – Stock Road to Progress Drive

Removal of vegetation and earthworks will result in impacts on the portion of Ecological Linkage EL1 that exists between Progress Drive and Stock Road. The combination of these aspects will result in the imposition of a barrier through the middle of the linkage along its entire length, effectively dividing it into two narrow corridors. Connectivity will be lost between the north and south sides of the proposed project. Accordingly, the functionality of these two corridors for species such as large bodied reptiles and the Southern Brown Bandicoot (*Isoodon obesulus fusciventer*) will be reduced. However, due to the already fragmented nature of this linkage in an east-west direction, its importance to these species as a linkage is considered to be low.

Whilst the realignment of Coolbellup Avenue and Sudlow Road will result in widening of an existing severance within the linkage, the construction of a bridge will remove the existing barrier created by these roads, making movement in an east-west direction for terrestrial fauna less constrained.

Most avian species will utilise EL1 as a 'stepping stone' corridor and so are unlikely to be affected by the proposed project, due to their mobility.

As a regional ecological linkage that is already heavily fragmented and non-contiguous, the impact of the proposed project is considered to be low.

6.8.3.2. Ecological Linkage EL2 – Bibra Drive to Karel Avenue

The function of EL2 as an east-linking regional ecological linkage in its current form is limited, due to urban encroachment, pre-existing cleared areas and most significantly, the presence of Kwinana Freeway. EL2 will be affected by the proposed project, as vegetated areas within the existing ramps of the Roe Highway/Kwinana Freeway interchange will be almost entirely removed during construction.

The area between existing remnant vegetation near the Kwinana Freeway interchange and the edge of Roe Swamp at Bibra Drive (750m separation) is highly fragmented and almost entirely cleared. It currently provides poor fauna refuge, with only one patch of native vegetation present in this portion of the linkage. The importance of EL2 to ground dwelling fauna is low, due to the lack of connectivity and distance between fragments. The impact of the proposed project on the importance of this linkage to ground dwelling fauna will be negligible. Avian fauna are likely to utilise EL2 as a 'stepping stone'; however, due to their capacity to move longer distances the linkage's value for these species will not be significantly impacted.

6.8.3.3. Ecological Linkages EL3 and EL4- North Lake to Piney Lakes Reserve, and Bibra Lake to South Lake

The Perth Biodiversity Project (Del Marco *et al.* 2004) recognises that EL3 and EL4 are semi-contiguous as one regional ecological linkage. EL3 links the project area with habitat to the north, while EL4 links to the south. The function of EL3 and EL4 in connecting the project area with adjacent habitats is currently impeded by Farrington Road (EL3) and Hope and North Lake Roads (EL4). These existing roads provide barriers to movement of ground dwelling fauna (e.g. lizards, amphibians and small mammals) and small birds. Some connectivity across North Lake Road is maintained through the inclusion of fauna underpasses at North Lake Road.

Due to the size of remnants that will exist on either side of the proposed project once constructed, the predicted impact on the functionality of EL3 and EL4 is moderate on a regional scale. The functionality of the linkages at a local scale occurs within local linkages EL5 and EL6, which are described below.

6.8.3.4. Ecological Linkage EL5 – North Lake to Bibra Lake

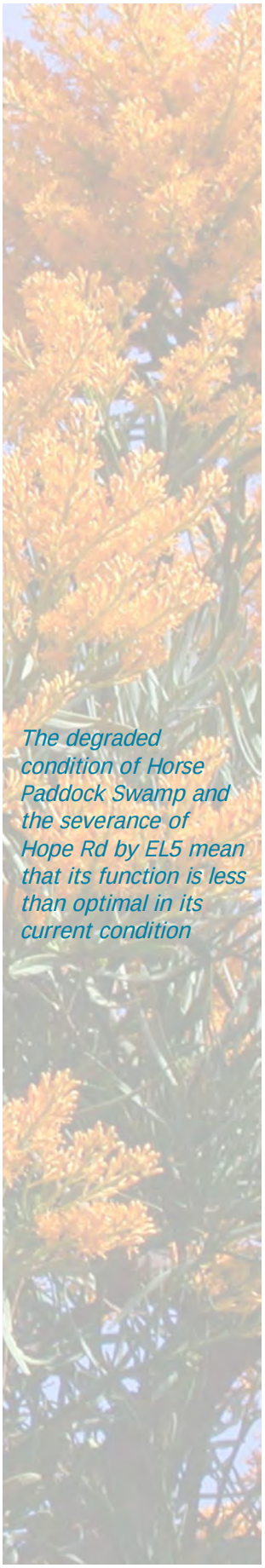
The local linkage EL5 may convey the movement of ground dwelling fauna and some small birds between North and Bibra lakes and across Horse Paddock Swamp. Currently, this linkage is severed by Hope Road.

The combination of the degraded condition of Horse Paddock Swamp and the Hope Road severance means that the function of EL5 is less than optimal under its current condition. The presence of the transmission lines further reduces the function of this linkage for birds. Notwithstanding this, the construction of a high embankment at this location will likely limit the movement of large bodied reptiles (e.g. turtles and snakes) and the Southern Brown Bandicoot, as well as ducks and teals with flightless chicks.

A degree of partial fragmentation will occur at EL5. Although the bulk of the proposed road will result in a physical severance of connectivity, the inclusion of a proposed bridge at Horse Paddock Swamp, as well as pedestrian and fauna underpasses, will provide intermittent connectivity between either side of the proposed project. These areas are illustrated in Figure 6.8-1.

6.8.3.5. Ecological Linkage EL6 - Upper Roe Swamp to Lower Roe Swamp

EL6 currently exists with a minor severance due to the existing high voltage transmission line, which includes a cleared access track that is likely to currently act as a barrier to the movement of some smaller species, including the Perth Lined Lerista. It is also severed by Farrington Road. Nevertheless, the functions of the local linkage EL6 will be impacted by the proposed project, as a result of its connectivity being severed by both cut and fill sections. This will be most significant for the movement of large-bodied reptiles and Southern Brown Bandicoot, but will also affect wetland fauna such as amphibians, the Oblong Turtle and water birds. In the absence of management strategies, the proposed project will represent a complete severance of this linkage to terrestrial fauna.



The degraded condition of Horse Paddock Swamp and the severance of Hope Rd by EL5 mean that its function is less than optimal in its current condition

Fauna and pedestrian underpasses and bridges situated along the proposed project will maintain linkages at these locations

A degree of partial fragmentation will occur at EL6. Although the bulk of the proposed road will result in a physical severance of connectivity, the inclusion of a proposed bridge at Roe Swamp, as well as proposed pedestrian and fauna underpasses, will provide intermittent connectivity between either side of the proposed project. These areas are illustrated in Figure 6.8-1.

6.8.4. Management Measures and Mitigation

This section identifies ways to mitigate impacts or repair already affected ecological linkages. The most important contribution to the conservation of ecological linkages within the project area can be made through design decisions that avoid and minimise clearing and habitat fragmentation. Additionally, bridges, fauna underpasses and pedestrian underpasses situated along the proposed project will maintain linkages at these locations. Specific management measures for individual ecological linkages are described below.

6.8.4.1. Ecological Linkage EL1

Impacts on EL1 will be minimised by the inclusion of a connection between habitats via an underpass at Coolbellup Avenue/Sudlow Road on both sides (north and south) of the proposed project. These will provide sufficient space for small mammals to move through, and will be fenced to restrict access to the proposed road.

Following installation of the proposed underpass, some connectivity will be retained between the two corridors situated on the either side of the alignment. The significance of the predicted impact is therefore reduced from high to moderate.

A fauna underpass is proposed for a section of shallow fill near Elinor Place between Coolbellup Avenue/Sudlow Road and North Lake Road, providing a linkage between the northern and southern habitat fragments. A series of underpasses are proposed for the Stock Road interchange, to allow movement of fauna to the west.

6.8.4.2. Ecological Linkage EL2

Although direct impacts on EL2 are considered negligible, the implementation of a rehabilitation programme will include the establishment of local native vegetation within the road corridor, as far as practicable. A fauna underpass under the reconstructed and elevated Bibra Drive will create a connection between Roe Swamp and areas east, which, if combined with rehabilitation, will increase the available habitat to fauna within the Roe Swamp area. The implementation of this strategy depends on the extent of land within and adjacent to the MRS reserve that is available on completion of the proposed project. The residual impact on EL2 will be unchanged and it will remain as negligible.

6.8.4.3. Ecological Linkages EL3, EL4 and EL6

Impacts on EL3, EL4 and EL6 will be managed by the inclusion of a bridge where the proposed project crosses Roe Swamp. This bridge will facilitate the movement of fauna along these linkages. The proposed construction method ('top down') will reduce the impact of the proposed project, by ensuring direct removal of vegetation under the bridge will not occur. While it is acknowledged that the vegetation under the bridge will decline over time, it is expected that some low light tolerant flora will establish and maintain a link between habitats either side of the proposed project (Section 6.6). Ongoing management and monitoring of the effectiveness of this strategy will be undertaken. Active intervention will be applied, where it is determined to be a necessary and effective option.

Additional fauna underpasses will be installed at regular intervals at locations along the proposed project's length, where vertical elevations allow (i.e. height of fill), and a proposed pedestrian underpass west of the proposed bridge will also serve to connect the two habitat remnants. It is proposed that these underpasses, whose precise locations will be determined during detailed design, will be spaced at no more than 100m intervals where the proposed project is in fill of sufficient height between Bibra Drive and Progress Drive (Refer to Section 3.5).

Fauna underpasses will be installed at regular intervals along the alignment where vertical elevations allow

The removal of through traffic from Hope Road and downgrading it to an access road for the Cockburn Wetlands Precinct will reduce the scale of the barrier that the road currently forms.

The inclusion of fauna underpasses along the length of the proposed project combined with the removal of through traffic from Hope Road will reduce impacts on the regional linkages (EL3 and EL4) from moderate to low. Furthermore, these strategies will reduce the extent of impact on local linkage (EL6) by up to 20 percent.

6.8.4.4. Ecological Linkage EL5

The impact of the proposed project on EL5 will be managed through the inclusion of an underpass designed to accommodate pedestrians, fauna and cyclists. Detailed design will investigate methods of ensuring some form of separation between the users. The section of this underpass that is set aside for fauna movements will be furnished with ground habitat features, such as fallen logs, topsoil and leaf litter.

Additional work will be undertaken to improve the existing linkage served by EL5, mainly through the implementation of a rehabilitation and restoration programme. The restoration of Horse Paddock Swamp is proposed as an offset against impacts on Roe Swamp, which will also serve to enhance connectivity between Bibra Lake and North Lake.

Restoration of Horse Paddock Swamp will enable connectivity between North and Bibra lakes

6.8.5. Summary and Conclusions

This section contains a summary of the residual impacts, management practices to minimise impacts, key points of Bulletin 1088 and offsets for ecological linkages.

6.8.5.1. Residual Impacts

Although the linkages within the Beeliar Regional Park already display a degree of severance, the proposed project will result in additional separation between fragments. Design features have been included to minimise the extent of these impacts, and it is considered unlikely that the proposed project will significantly alter the diversity and vigour of the park's ecological systems, as a result of impacts on ecological linkages.

Management, mitigation and residual impacts on proposed project area ecological linkages are summarised in Table 6.8-1. This is for aspects (activities) assessed to be moderate to high risk of impact, for both the construction and operation phases.

Table 6.8-1: Residual Impacts for Ecological Linkages

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Vegetation Removal	Decline in functionality of linkages	Provide rehabilitation of disturbed roadside areas (with vehicle safety pre-requisites) Minimise clearing of existing vegetation Restoration of degraded remnants using local provenance native plants	A temporary impact on fauna linkages that require vegetative cover and leaf litter for movement (e.g. Lerista and Southern Brown Bandicoot)
Earthworks and construction fencing	Decline in connectivity for terrestrial fauna	Installation of fauna proof fencing prior to earthmoving and other construction activities is necessary for protection of fauna from construction activities. During construction, this impact cannot be mitigated against	A temporary impact on fauna movement during the time earthworks is being conducted
Physical presence of road and transmission line	Decline in connectivity	Retain natural hydrological conveyance and fauna migration pathways by providing constructed fauna and hydrology passages beneath the road alignment with openings under the road (e.g. culverts and fauna underpasses) Provide bridge and other openings (culverts/underpasses) across swamp, other natural low topographic areas and between habitats of Good' (or better) vegetation condition ratings Provide bridges over Coolbellup Avenue/Sudlow Road and North Lake Road Replacement power lines fitted with high visibility reflectors Installation of visual barriers at critical points along the alignment to encourage birds to fly over the height of traffic	Partial fragmentation of north-south EL5 and EL6 linkages Reduction in width of the east-west EL1 linkage

6.8.5.2. EPA Bulletin 1088

Table 6.8-2 highlights the EPA concerns for ecological linkages from the proposed project as stated in Bulletin 1088 (EPA 2003).

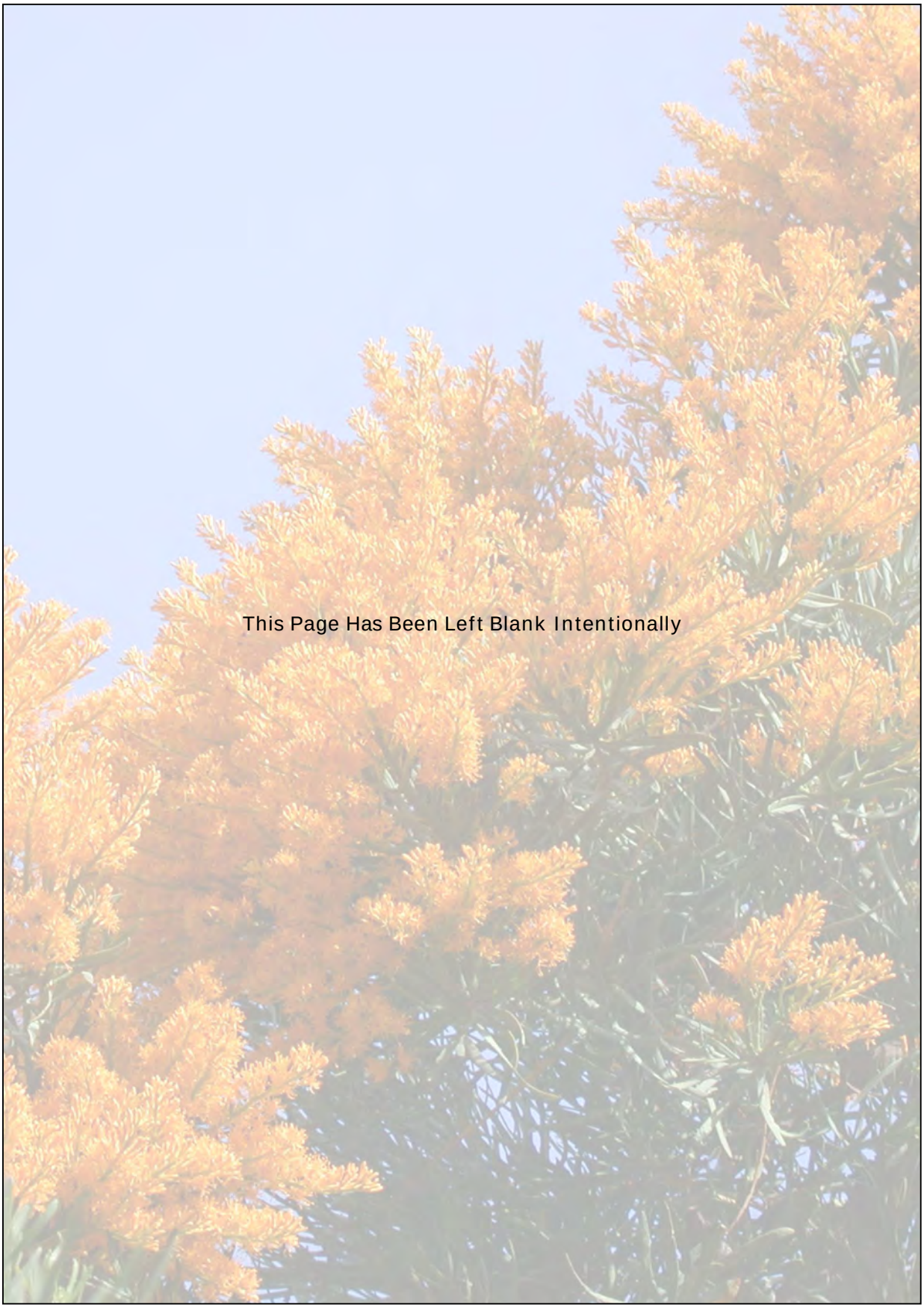
Table 6.8-2: EPA Concerns for Ecological Linkages as Stated in Bulletin 1088

Bulletin 1088 Statement	Proposed Project Concept Response
Construction within the alignment for Stage 8 of Roe Highway would significantly impact: *The direct linkages between North Lake and Bibra Lake and the surrounding wetlands in the immediate area; and* *The linkages within the Eastern Chain of the Beeliar Wetlands and subsequently, the eastern side of the Beeliar Regional Park*	Linkages within the Beeliar Regional Park already display a degree of severance and the function of ecological linkages in the vicinity of North and Bibra lakes are currently impeded by Farrington and Hope Roads, respectively Contribution to the conservation of ecological linkages within the project area will be made through design decisions that avoid and minimise clearing and habitat fragmentation Bridges, fauna underpasses and pedestrian underpasses situated along the proposed project will maintain linkages at those locations The inclusion of fauna underpasses along the length of the proposed project combined with the removal of through traffic from Hope Road will reduce impacts on the regional linkages within the immediate area and the Regional Park considerably
Construction within the alignment for Roe Highway Stage 8 would create a significant impact on the ecological linkages within the immediate area and the Regional Park as a whole, which could diminish the diversity and ecological systems for the area and the Regional Park in the long term	The most likely impact on ecological linkages will occur outside of the Beeliar Regional Park boundary As a regional ecological linkage that is already heavily fragmented and non-contiguous, the impact of the proposed project is considered to be low

6.8.5.3. Offsets

Whilst there are no offsets proposed for residual impacts on ecological linkages, the restoration of Horse Paddock Swamp is proposed as an offset against impacts on Roe Swamp, which will also serve to enhance connectivity between Bibra Lake and North Lake.

Details of these and other proposed offsets are provided in Section 10.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6.9. Aboriginal Heritage

The EPA's objective with regards to the protection of Aboriginal heritage is:

> *To ensure that changes to the biological and physical environment do not result in a significant adverse effect on historical and cultural associations.*

An assessment of the Aboriginal heritage and tourism implications of the proposed project, as it existed at the time, was conducted by Rory O'Connor in 2002 for the then Department for Planning and Infrastructure. Bulletin 1088 (EPA 2003) summarised the results of this study and cited the following potential impacts on Aboriginal Heritage:

- The alignment would traverse a mythological site at Bibra Lake as well as a known archaeological site;
- Depending on the degree of disturbance, the alignment has the potential to encroach into several other archaeological sites;
- It is possible that currently unknown archaeological sites and/or sub-surface material will be disturbed; and
- There will be a severe impact on Aboriginal tourism trails between North and Bibra lakes.

6.9.1. Potential Impacts

A range of potential impacts on Aboriginal heritage were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. Design solutions were developed for the following potential impacts:

- Installation of noise walls adjacent to roadway could cause habitat loss associated with Nyungar faunal values – avoidance measures implemented will minimise the area impacted;
- Excavation of road cuttings may cause alteration of hydrological regimes associated with Nyungar water values - the vertical alignment has been designed to ensure there is no requirement for road cuttings below the water table; and
- Freight and private transport may result in accidental mortality of fauna associated with Nyungar faunal values – installation of visual barriers (avifauna) and maintenance of ground level fencing throughout alignment will ensure fauna strike is minimised.

A detailed assessment of predicted Aboriginal heritage impacts is provided in Section 6.9.2.

6.9.2. Construction Phase Impacts

This section discusses the construction phase impacts of the proposed project on those factors that are central to the cultural beliefs and traditional way of life for Nyungar people. Traditional use of the project area by Nyungar people was based on the existence of water, fauna and flora, and includes:

- Nyungar water values;
- Nyungar fauna values;
- Nyungar botanical values; and
- Nyungar mythological values.

The impacts of the proposed project on specific water, flora, and fauna values are discussed in detail within Sections 6.2, 6.3, 6.4, 6.6 and 6.7, respectively.

6.9.2.1. Nyungar Water Values

Nyungar perspectives on groundwater are entrenched in a complex web of social and cultural belief structures that focus on groundwater and surface water resources. The Nyungar people value the total ecological system and consider it to be at risk as a result of perceived changes to groundwater. It is reported that water has cultural significance for Aboriginal people and degradation of groundwater features may represent a cultural impact, whether derived from natural or anthropogenic activity (McDonald *et al.* 2005). Predicted impacts of the proposed project on wetlands, are presented in Section 6.2. Impacts on wetland function and water resources arising from the project have the potential to impact Nyungar values by:

- Reducing the integrity of mythological values, particularly with regard to perceived effects on the mythological rainbow serpent, Waugal;
- Reducing the 'sense of place', which exists as a result of the presence of water and a functioning wetland ecology; and
- Reducing the potential for traditional cultural practices, such as fishing and hunting, to occur within the project area, as a result of loss of traditional food sources.

The project may have a small and localised impact on groundwater levels as a result of compaction and groundwater disturbance; however, as outlined in Section 6.2, this is not likely to have an impact on the functionality of the wetland system. This will not significantly impact water related cultural associations.

6.9.2.2. Nyungar Fauna Values

The predicted impacts of the proposed project on fauna are described in detail in Section 6.7. In general, the proposed project has the potential to impact fauna through the displacement and relocation of fauna from the project area for construction purposes, removal of fauna habitat and ongoing operation of the highway resulting in displacement and fauna deaths. These potential impacts affect Nyungar values by:

- Reducing the availability of traditional food sources and hence impacting the potential for Nyungar people to practice their traditional way of life; and
- Reducing close associations between individuals and plants and animals, on which Aboriginal culture is based.

Due to the low level of traditional cultural practices currently performed in this location and low percentage of significant fauna affected, these impacts are not considered to adversely impact cultural associations.

Low levels of traditional cultural practice are currently performed at this location

6.9.2.3. Nyungar Botanical Values

Wetlands, waterscapes, lakes and riparian zones were vital resource areas for Nyungar people and are still highly valued today. Wetland vegetation was a staple of the Nyungar diet, as well as providing numerous utilitarian objects. Potential impacts on groundwater dependent ecosystems (GDEs) and applicable flora and vegetation are discussed in Section 6.6.

Potential impacts on GDEs, flora and vegetation as a result of vegetation clearing for road construction is the most likely source of impacts on Nyungar botanical values. Significant flora species for Nyungar people include: *Kunzea glabrescens*, *Typha* sp., *Xanthorrea preissii*, *Melaleuca* sp. and *Nuytsia floribunda*. Impacts on these and other species of significance to Nyungar people have the potential to affect indigenous values of the project area by:

- Reducing the abundance of traditional food sources;
- Removing the source of materials traditionally used in making tools and other utilitarian objects; and
- Loss of material used to perform cultural ceremonies and other activities.

Approximately two hectares of vegetation communities supporting *Kunzea glabrescens* will be removed from within the project area. Additionally, an unquantified number of *Xanthorrea preissii* and *Melaleuca* spp. will be removed. These species are well represented both within the project area and the wider region, and this impact is therefore not considered significant.

6.9.2.4. Nyungar Mythological Values

In addition to direct cultural links based on the use of biological resources, Aboriginal mythology is closely tied to associations with various attributes of the environment. Such values include associations with:

- Forest Red-tailed Black Cockatoo;
- *Nuytsia floribunda;* and
- Waugal (rainbow serpent).

The project has the potential to cause loss of Forest Red-tailed Black Cockatoos through loss of habitat, direct strike by machinery and (during road operation) direct strike by passing traffic. It is almost certain that at some point, small numbers of individuals will be killed by passing traffic.

As a result of the proposed project, approximately 41 *Nuytsia floribunda* plants will be removed. This is a relatively small proportion of the total number of individuals, both within the project area and the wider region.

Piling activities for the installation of bridges are likely to be perceived as interfering with the Waugal, as will activities that require excavations. While piling will be minimised, as much as practicable, particularly within registered heritage sites, this impact will be unavoidable.

6.9.3. Management and Mitigation

A direct relationship exists between flora, fauna and wetlands of the project area and relative environmental values held by Nyungar people. Management measures and mitigation for impacts of the proposed project on water, flora and fauna values are discussed within Sections 6.2, 6.3, 6.4, 6.6 and 6.7, respectively.

As discussed in Section 5.16, consultation with Nyungar representatives and local groups has taken place throughout the duration of the Public Environmental Review (PER) process with the outcomes being presented under separate cover (ACHM 2010).

Appropriate mitigation and management measures for Aboriginal heritage sites will be documented during a separate, concurrent process to this environmental impact assessment, in accordance with the provisions of the *Aboriginal Heritage Act 1972 (AH Act*).

In addition, the following strategies are proposed:

- Piling will be restricted to areas outside of registered Aboriginal heritage sites; and
- A selection of *Nuytsia floribunda* trees will be translocated and used for cultural interpretive purposes, seed banks and entry statements.

6.9.4. Summary and Conclusions

While there are expected to be small impacts on Nyungar environmental values as a result of the proposed project, the lack of ongoing, direct cultural practices within the project area makes these impacts relatively minor. Appropriate management and mitigation are summarised in Table 6.9-1 and described in detail within Sections 6.2, 6.3, 6.4, 6.6 and 6.7, along with residual impacts.

Predicted changes to the biological and physical environment will not result in significant adverse effects on historical or cultural associations. This ensures that the EPA's objective for the protection of Aboriginal heritage will be met.

Consultation with Nyungar representatives and local groups has taken place throughout the duration of the PER process. Details of Aboriginal heritage surveys and consultation conducted in August 2010 have been compiled and evaluated through a separate process pursuant to the *AH Act*.

In addition, appropriate mitigation and management measures for impacts on Aboriginal heritage sites will be documented during a separate, concurrent process to this environmental impact assessment in accordance with the provisions of the *AH Act*.

Commitments by Main Roads contained within its Section 18 consent application will ensure that cultural values of the project area are recognised by the project and highlighted during construction.

Predicted changes to the Biological and Physical environment will not result in any significant adverse effects on historical and cultural associations

Table 6.9-1: Residual Impacts on Aboriginal Heritage

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Removal of vegetation	Loss of habitat associated with Nyungar faunal values, specifically 73ha of Red-tailed Black Cockatoo foraging habitat	Design of proposed project has achieved significant reductions in clearing requirements, including Red-tailed Black Cockatoo habitat. These are discussed in more detail in Section 6.7	Loss of 73ha of Forest Red-tailed Black Cockatoo foraging habitat
	Removal of: 1.7ha of *Kunzea glabrescens* dominated vegetation communities; 33.4ha of vegetation communities containing *Xanthorrea preissii;* 4.2ha of vegetation communities dominated by *Melaleuca spp*	Design of proposed project has minimised the extent of clearing required as much as practicable. These measures are discussed in more detail in Section 6.6	There is no further reduction in predicted impact

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Nyungar mythological associations include the removal of 41 individual *Nuytsia floribunda* trees	Management measures and mitigation for impacts of the proposed project on specific flora values are discussed above and within Section 6.6 A selection of *Nuytsia floribunda* trees will be translocated to suitably prominent positions to highlight Nyungar cultural values	Loss of less than 41 individual *N. floribunda* trees
Excavation of road cuttings, placement of fill and other earthworks	Reduction of the integrity of mythological values, particularly with regard to perceived effects on the Waugal, through localised alterations in groundwater distribution and surface water drainage patterns	Impacts on mythological values will be minimised through the use of spread footings to construct the bridge between Bibra Lake and Horse Paddock Swamp.	There will be some residual impact on mythological values associated with hydrology
	Reduced 'sense of place' arising from changes in hydrological regimes through localised alterations in groundwater distribution and surface water drainage patterns	Impacts on hydrological function will be minimised through the use of spread footings for bridge construction within registered Aboriginal Heritage sites	

CCW – Conservation Category Wetland

PER – Public Environmental Review

6.9.4.1. EPA Bulletin 1088

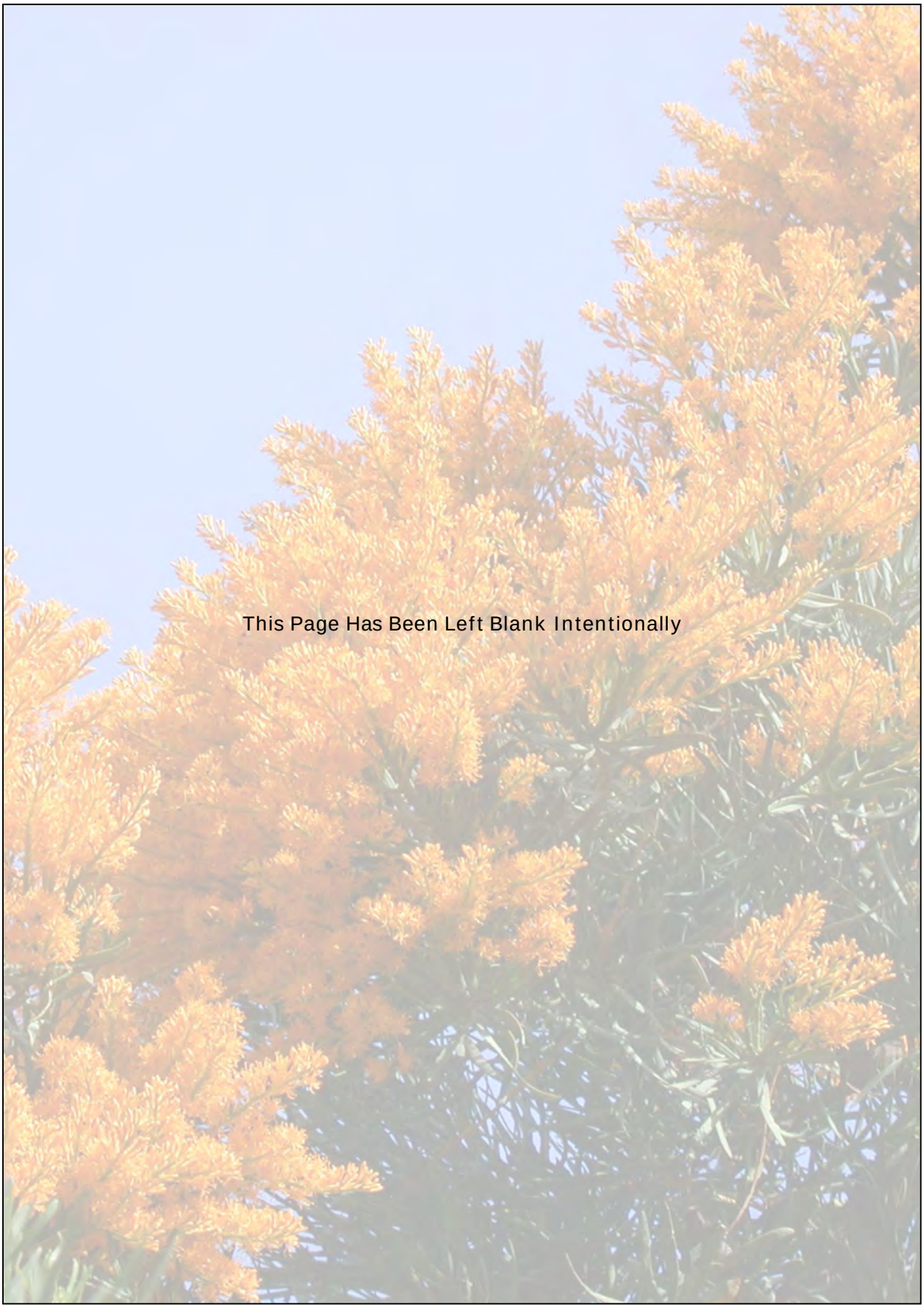
Table 6.9-2 highlights the EPA concerns for Aboriginal heritage from the proposed project as stated in Bulletin 1088 (EPA 2003).

Table 6.9-2: EPA Concerns for Aboriginal Heritage as Stated in Bulletin 1088

Bulletin 1088 Statement	Proposed Project Concept Response
The area has been identified as a significantly important cultural site for the Beeliar people, who are a dialect group of the Nyungar, as well as for other Nyungar groups	Consultation with Nyungar representatives and local groups has identified the concerns of Nyungar groups Details of Aboriginal heritage surveys and consultation have been compiled and evaluated through a separate process pursuant to the *AH Act*
Archaeological investigations of North Lake and Bibra Lake have confirmed the ethnographic evidence that the perimeters of the lakes were camping areas with a diversity of activities sites *The options assessed for Roe Highway Stage 8 and which followed the current alignment under the MRS, identified that the alignment would pass through the Bibra* *Lake mythological site, and also pass through a known archaeological site* *The alignment would intrude into several other archaeological sites. The potential for other unknown archaeological sites and/or sub-surface material being disturbed was also identified. It was also identified that there would also be a severe impact on Aboriginal tourism trails between the two lakes*	Impacts on Aboriginal heritage sites will be documented during a separate, concurrent process to this environmental impact assessment in accordance with the provisions of the *AH Act* Excluding those impacts on Aboriginal heritage sites, predicted changes to the biological and physical environment do not result in significant adverse effects on historical and cultural associations At the time of this assessment, there were no Aboriginal tourism operations in practice. The proposed project ensures that almost all trails are maintained within the project area, through the inclusion of underpasses in the design

6.9.4.2. Offsets

Residual impacts on Aboriginal heritage relate to the reduction in Forest Red-tailed Black Cockatoo foraging habitat, removal of flora important to Aboriginal cultural practices and the removal of non-iconic flora species. Offsets have been proposed to compensate for these losses, which are detailed in Section 10.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6.10. Noise

The EPA's objective with regards to noise is:

> *To protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards.*

EPA Bulletin 1088 (2003) notes that the construction of the proposed project, as it was defined at the time, would result in significant changes to the noise environment for residences and sensitive land uses in its vicinity. The EPA indicated that there would also be a significant change in the noise environment for residences and sensitive land uses nearby Forrest Road where the highway alignment is proposed to run alongside it. Bulletin 1088 raised the concern that these areas would be impacted on by noise and vibration during both construction and operation of the proposed highway.

6.10.1. Effects of Noise

EPA Draft Guidance 8 details the potential effects of audible noise as follows:

- Noise may cause disturbance to rest or recreational activities, in particular to the elderly or sick;
- Noise that occurs at night is more likely to disturb a community than noise that occurs during the day only;
- Noise has the potential to interfere with education activities, with communication or with work; and
- Noise may contain annoying characteristics that may increase its impact, such as tonality, modulation, or impulsiveness.

An individual's reaction to noise occurs through a stress response, which may be ignored or tolerated, particularly if outside of the receiver's control. Subsequent coping mechanisms vary between individuals, either by choosing to complain about the noise or conversely adapting their lifestyle to accommodate it (EPA 2007b).

6.10.2. Construction Phase Impacts

Western Australian *Environmental Protection (Noise) Regulations 1997* (WAEPNR) regulate noise emissions from construction sites, including those of road and rail infrastructure. Construction noise and vibration criteria are discussed in greater detail in Appendix U.

Construction noise and vibration impacts associated with the proposed project cannot be reliably assessed until the road design is finalised and details of construction methods, as well as construction schedules, become available. However, temporary construction noise and vibration impacts are likely along the majority of the proposed project due to its close proximity to noise and vibration sensitive receivers. A description of potential noise generation aspects of the proposed project is presented in Table 6.10-1.

Temporary construction noise and vibration impacts are likely along the majority of the proposed project

Table 6.10-1: Potential Noise Generating Activities

Potential Noise Generating Aspect	Potential Location	Potential Day/Night Activity*
Removal of vegetation and topsoil	Entire length of proposed alignment	Day
Earthworks	In vicinity of significant cut sections such as between Stock Road and Coolbellup Avenue, at North Lake Road and at the Kwinana Freeway interchange.	Day
Installation of retaining walls	Between Stock Road and Coolbellup Avenue	Day
Piling	Roe Swamp	Day
Operation and maintenance of plant and machinery	Entire length of proposed alignment	Day
Construction of structures	In vicinity of proposed structures (i.e. Stock Road, North Lake Road, Progress Drive, Roe Swamp, Bibra Drive and Kwinana Freeway)	Day/Night
Surfacing	Entire length of proposed alignment	Day
Vehicle Arrival/Departure	Entire length of proposed alignment	Day
Removal and rehabilitation of existing redundant roads	Stock Road to North Lake Road Progress Drive to Bibra Drive	Day
Transport of Cut and Fill	Entire length of proposed alignment	Day
Traffic Diversions	To be confirmed during detailed design phase but likely at Stock Road, North Lake Road, Bibra Drive and Kwinana Freeway	Day/Night

* Subject to finalisation of detailed design and construction scheduling

A more detailed, quantitative assessment of construction noise and vibration impacts will be undertaken at the detailed design phase of the proposed project, once construction details and schedules become available. This study will identify likely noise and vibration impacts in the construction phase of the project and examine potential mitigation and management measures, in accordance with *AS 2436 – 2010: Guide to noise and vibration control on construction, demolition and maintenance sites* and *EPA Draft Guidance Statement No. 8 – Environmental Noise* (EPA 2007b).

In general, vibration criteria for human disturbance are more stringent than vibration criteria for effects on building contents and structural damage. EPA Policy is that vibration emissions should be managed to meet human annoyance criteria as human annoyance tends to occur at lower levels than does building damage (EPA 2007b). Hence, compliance, wherever possible, with the more stringent limits dictated by human exposure will ensure all structural damage criteria is met.

6.10.3. Operation Phase Impacts

Operation noise and vibration impacts associated with the proposed project include:

- Noise impacts associated with new roads:
  - Stock Road to Progress Drive; and
  - Bibra Drive to Kwinana Freeway;
- Noise impacts associated with the redevelopment of existing roads (Stock Road); and
- Noise impacts on parks and recreation areas.

Operational noise criteria, future noise modelling scenarios and noise modelling results are summarised below. These have been assessed by noise modelling studies which are described in Appendix U.

6.10.3.1. Operational Noise Criteria

Criteria applicable to noise emissions from new roads or redevelopments of existing major roads are outlined in *State Planning Policy 5.4: Road and Rail Transport Noise and Freight Considerations in Land Use Planning* (SPP 5.4) (WAPC 2009c). The criteria apply to noise emissions from road transport, as received at noise-sensitive land uses such as residential dwellings, schools and child care centres. The criteria are applicable at 1m from the most exposed, habitable façade at ground floor level of the building receiving the noise.

Noise modelling results contained within this section and Appendix U are based on the project concept design, which may change as a result of the detailed design phase. Noise mitigation has also been determined on the basis of the concept design. Noise barriers shown may therefore be subject to change, should the design of the road change during the detail design phase. However, the same design principles will be applied to future revisions of the noise barriers.

Noise mitigation is proposed on the basis of the concept design

6.10.3.2. Future Noise Modelling Scenarios

In accordance with SPP 5.4, future scenarios with and without the proposed project have been modelled in order to assess noise impacts. Modelled scenarios comprise a build scenario and a no-build scenario at the year of project opening (2016) and a build and a no-build scenario in the design year, 15 years after project opening (2031). The following noise scenarios have been modelled:

- Opening year, no-build scenario (no mitigation);
- Opening year, build scenario (no mitigation);
- Design year, no-build scenario (no mitigation); and
- Design year, build scenario (no mitigation).

The scenarios do not consider the effect of additional noise mitigation due to proposed noise walls and are considered in order to determine:

1) The noise impact of the proposed project relative to the noise environment if the project did not proceed;
2) Noise arising from increasing traffic volumes through time; and
3) The need for reasonable and practicable noise mitigation measures, adjacent to the proposed infrastructure.

Mitigation measures such as noise barriers are then considered on the basis of the above scenarios and are discussed in Section 6.10.4. Comparison of build scenarios with noise mitigation versus corresponding no-build scenarios is discussed in Section 6.10.4.2, in order to determine noise impacts associated with the proposed project.

6.10.3.3. Assessment Against SPP 5.4 Noise Criteria

The SPP 5.4 noise criteria applicable to the daytime period is 5dB(A) greater than the criteria applicable in the night time period. This means that all locations where daytime noise levels exceed the corresponding night time levels by 5dB(A) or more will be controlled by daytime noise emissions. Conversely, where the difference between daytime and night time levels is less than 5dB(A), the mitigation requirements to meet criteria will be controlled by night time emissions. Analysis of existing noise levels has been undertaken to determine whether mitigation requirements are controlled by daytime or night time noise emissions.

Existing noise monitoring results show that the difference between $L_{Aeq,(Day)}$ and $L_{Aeq,(Night)}$ noise emissions is 5dB(A) or more, at all but two locations (Table 5.11-1). Both locations that show a day/night difference of less than 5dB(A) are in the vicinity of the Roe Highway/Kwinana Freeway interchange.

Given that night time noise emission is the controlling criterion around Roe Highway/Kwinana Freeway interchange, it is reasonable to assume the same will be true for the future Roe Highway/Stock Road interchange. The results show that at these locations, the night time criterion is up to 0.6dB(A) more stringent than the daytime criterion.

Noise assessments have been based on daytime noise emissions, with effects of a 0.6dB(A) night time penalty applied at locations in the vicinity of interchanges at Stock Road and Kwinana Freeway (within 500m) (Appendix U).

In response to questions raised by DEC regarding the use of this correction (Guo 2011), a review of post-construction noise monitoring results on Roe Highway Stage 7 (Lloyd George Acoustics 2006) has been undertaken to better quantify the existing difference between daytime and night-time noise levels on Roe Highway (Appendix U). The summary of results is shown graphically in Figure 6.10-1.

The difference between daytime and night time noise criteria is 5dB(A). All locations where daytime levels exceed night time noise levels by 5dB(A), or more, will therefore be controlled by daytime noise emissions (i.e. where compliance with the daytime noise criteria will also result in compliance with the night time noise criteria). These locations have been highlighted white in Figure 6.10-1. Similarly, the locations where the day/night difference is less than 5dB(A) will be controlled by night time noise emissions. These are highlighted in yellow.

The results show that daytime noise levels will be the controlling criterion at all locations except those in the vicinity of Roe Highway/Kwinana Freeway interchange. At this location, the night time criterion is up to 0.6dB(A) more stringent than the daytime criterion. This may be due to a change in driver behaviour on approach to/departure from the interchange (e.g. acceleration/braking/engine braking); however, the reasons are not clear. It is reasonable to assume the same will be true for the future Roe Highway/Stock Road interchange, given the similarity between the existing Kwinana Freeway interchange and the proposed Stock Road interchange.

Noise assessment has therefore been based on daytime noise emissions, with a 0.6dB(A) night time penalty considered at locations in the vicinity of interchanges at Stock Road and Kwinana Freeway.

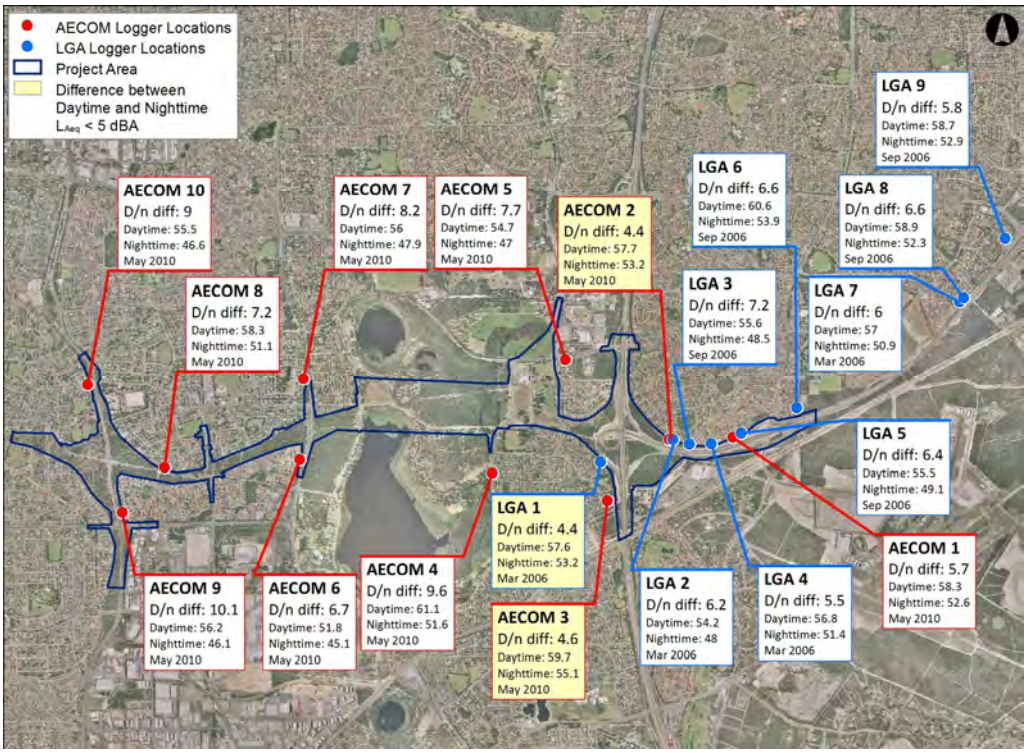


Figure 6.10-1: Baseline pre-construction daytime versus night-time noise levels in the project area

Also in response to concerns raised by DEC (Guo 2011), a traffic planning study has been carried out in order to better understand the diurnal traffic patterns on Roe Highway and their effect on the corresponding night time noise levels.

The hourly traffic profile on Roe Highway Extension (RHE) is expected to be similar to that of Roe Highway. Traffic data were acquired from Main Roads' Asset & Network Information Branch to determine the existing (2008) total traffic and heavy vehicle (Austroads Classes 3-12) hourly profiles for a normal day on Roe Highway at the bridge under Karel Avenue. The total traffic, heavy vehicle and heavy vehicle percentage profiles are shown in Figure 6.10-2 in red, blue and green respectively.

The adjusted forecast 2031 daily total traffic and heavy vehicle traffic for RHE and Roe Highway were determined from the Main Roads Regional Operations Model (ROM), West of Stock Road (WoS) project case. The forecast 2031 daily total traffic and heavy vehicle traffic for Roe Highway (at Karel Avenue) are 107,200 and 10,900 respectively. The corresponding traffic figures from the 2008 data are 41,700 and 9,300. This represents a growth in daily total traffic of 157% and a low growth in daily heavy vehicle traffic of 17%. This low growth in daily heavy vehicle traffic is not considered to be realistic.

According to the Perth Urban Corridor Strategy 2007 (PUCS 2007), 'road freight will continue to increase by between three and four per cent a year to 2018, tailing off to between two and three per cent to 2025'. If this forecast is used, along with the assumption that 2.5% growth will apply from 2025 to 2031, then the growth in heavy vehicle traffic from 2008 to 2031 would be 94%.

From the above, it is suggested that the forecast hourly total traffic and heavy vehicle traffic profiles be determined as follows:

- 2031 Total Traffic Profile = 2008 Total Traffic Profile × 2031 ROM Daily Total/2008 Data Daily Total; and
- 2031 Heavy Vehicle Profile = 2008 Heavy Vehicle Profile × PUCS 2007 Heavy Vehicle Growth.

The total traffic, heavy vehicle traffic and heavy vehicle percentage profiles for 2031, based on the above, are shown in Figure 6.10-2 in light red, light blue and light green respectively. From these 2031 profiles for Roe Highway (at Karel Avenue), the heavy vehicle percentage profile is proposed for use in the noise assessment for RHE. Since Fremantle Ports already operates 24 hours a day, seven days a week, no further adjustments to the heavy vehicle percentage profile are deemed necessary.

The graph shows that currently, heavy vehicle proportion on Roe Highway hovers just above 20% for most of the night time period, with an increase to 30% at 3am and 28% at 4am. It also shows that the number of heavy vehicles throughout the night remains relatively steady, with the increase in %HV caused by a decline in the light vehicle traffic numbers. The %HV returns to its night time levels after 4am as light vehicle numbers increase. The corresponding noise measurement results show that with current light/heavy vehicle distribution, daytime noise emission is the controlling criterion everywhere on Roe Highway except in the vicinity of the interchange with Kwinana Freeway. This may be due to a change in driver behaviour on approach to/departure from the interchange (e.g. acceleration/engine braking), however the reasons are not clear.

Heavy vehicle percentage distribution curves for 2008 and 2031 (dark green and light green respectively) show that the proportion of heavy vehicles is likely to decrease on Roe Highway as a percentage of total traffic by 3 to 6%.

The results support the approach of using daytime noise emissions as the controlling criterion for the proposed project everywhere except for the major interchanges at Kwinana Freeway and Stock Road (Appendix U).

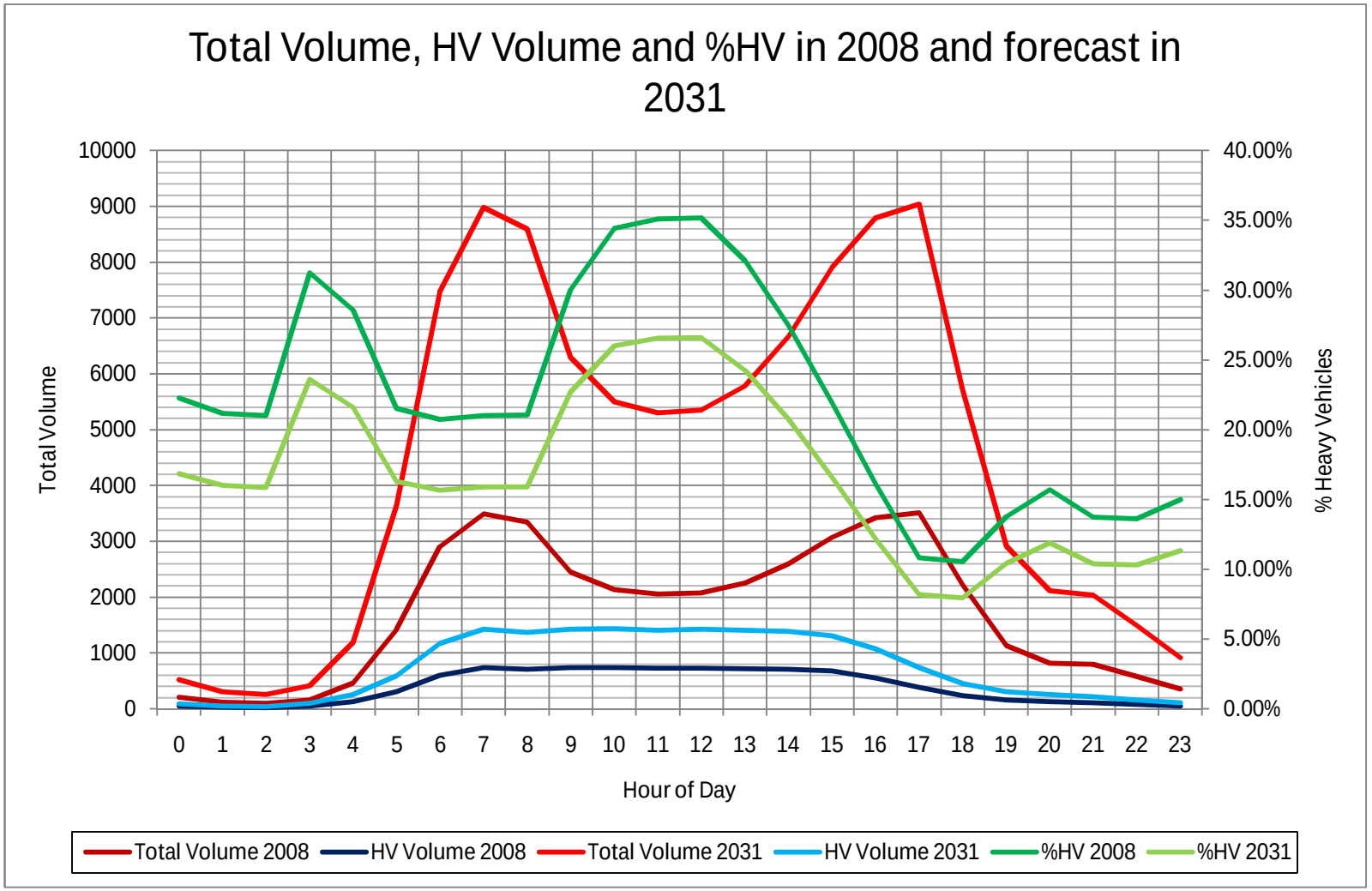


Figure 6.10-2: Hourly road traffic profiles on Roe Highway

6.10.3.4. Assessment Methodology

In accordance with SPP 5.4 assessment methodology, noise criteria are applicable at 1m from the most exposed, habitable façade at ground floor level of the building receiving the noise. For the purpose of this study, all dwellings are assumed to be single storey, and have a height of 3.5m. Noise assessments are based on the noise level predicted at the loudest façade of each dwelling, so noise receivers were placed at 1.5m above ground level and 1m away from dwelling façades at all building façades greater than 3m in length, in order to capture the loudest façade at each dwelling. It is noted that noise levels predicted at the ground floor may not be representative for upper floors of multi storey dwellings, particularly if the ground floor is shielded from the road by a residential boundary fence. Where this is the case, the noise exposure at upper levels will be greater than that predicted at the ground floor.

By way of example, the ground floor of Hamilton Senior High School is shielded from Stock Road by an embankment that is between 2 and 4m high. The noise levels at the first floor of Hamilton Senior High School are 3dB(A) to 5dB(A) greater than at ground level due to the shielding provided by the embankment. When a 1.8m high noise barrier is added to the top of the embankment, the noise level difference increases to between 3dB(A) and 6dB(A). This is the typical worst case difference between ground and first floors expected on this project. Negligible differences are expected in noise levels between ground and first floors where the ground floor is directly exposed to the road (i.e. with no acoustic shielding between the road and ground floor).

6.10.3.5. Noise Model Calibration

A computer noise model (SoundPLAN) of the existing (2010) scenario (based on the existing traffic volumes, posted speed limits, ground topography and existing noise barrier and residential fence locations) has been calibrated against roadside noise measurements. The calibrated model shows good correlation between measured and modelled results, with all modelled receivers being within ±2dB(A) of measured results. Details of the calibration procedure, noise modelling methodology, calibration measurements, modelling inputs and assumptions as well as model accuracy are presented in detail in Appendix U.

6.10.3.6. Noise Modelling Results

Summaries of the predicted daytime noise levels for each of the four future modelling scenarios are presented in Table 6.10-2.

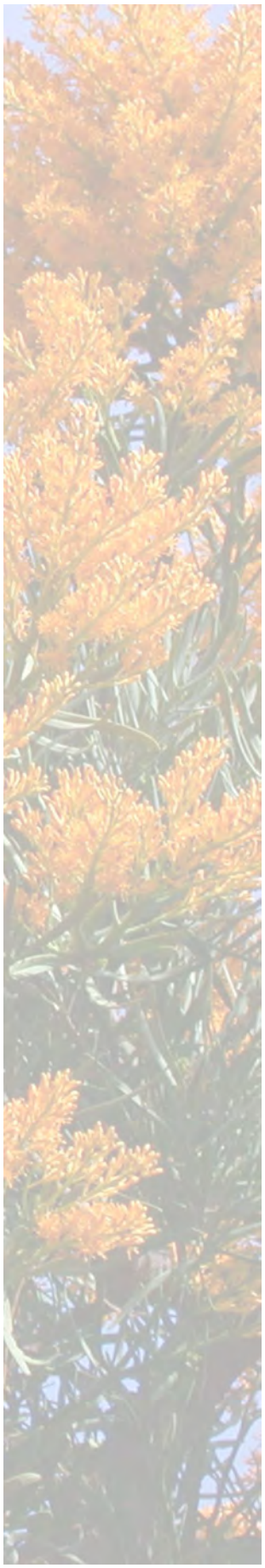


Table 6.10-2: Summary of Predicted Daytime ($L_{Aeq(Day)}$) Noise Levels

Modelled Scenario	Number of Receivers				$L_{Aeq,(Day)}$ (dB(A))	
	Total	> 55 dB(A)	> 60 dB(A)	> 65 dB(A)	Average	Maximum
2016, No-build	1,472	100	0	0	47.1	59.8
2016, Build	1,472	245	5	0	51.8	63.8
2031, No-build	1,472	205	21	0	49.0	63.3
2031, Build	1,472	494	79	0	53.9	64.3

The results indicate that the highest noise levels associated with the build scenarios occur in the design year (2031). Therefore, design year build scenario is the controlling scenario, so compliance with noise criteria in the design year will ensure compliance in the opening year. Noise contour maps and tabulated noise levels at each noise sensitive receiver are presented graphically in Appendix U for the modelled scenarios.

It should be noted that the noise modelling presented in Appendix U is based on a preliminary concept design, which has since had some minor alterations to its alignment. These alterations include a westward shift of the Bibra Drive alignment, and an eastward shift of the Murdoch Drive off ramp. In recognition of the need to revise the entire noise modelling predictions once the detailed design is finalised in order to reconfirm noise mitigation requirements, these minor changes have not been modelled. However, a qualitative assessment of the likely impacts of these changes has been made, and it has been determined that they are unlikely to significantly change noise levels at sensitive receptors.

6.10.3.7. New Roads

Noise impacts on new roads are assessed against the noise target and noise limit criteria of the SPP 5.4 (Appendix U). Build scenario modelling results presented in Table 6.10-2 indicate that, without mitigation, the controlling 2031 build scenario will result in 494 out of 1,472 modelled receivers exceeding the noise target of 55dB(A), with 79 of those receivers also exceeding the noise limit of 60dB(A) (Table 6.10-2).

6.10.3.7.1. Stock Road to Progress Drive

Noise sensitive receivers south-west of the Roe Highway/Stock Road interchange are generally predicted to exceed the noise target at the ground floor, ranging from below 55dB(A) to 58dB(A). Therefore, reasonable and practicable noise mitigation measures have been considered adjacent to the proposed exit ramps, in accordance with SPP 5.4.

The proposed project between Stock Road and Coolbellup Avenue/Sudlow Road overpass is in a cutting, which is up to 10m deep. While the cutting provides a degree of noise shielding for the adjacent sensitive receivers, noise levels at receivers in this portion of the project generally exceed the target criteria of 55dB(A). Reasonable and practicable noise mitigation measures to meet the noise target have been considered for this part of the proposed project, in accordance with SPP 5.4.

A three-dimensional view of the proposed vertical alignment in this portion of the project is shown in Figure 6.10-3. The 3-D figures show 2031 build scenario daytime noise levels against which compliance with criteria is assessed. Black lines represent existing property boundary fences.

Figure 6.10-3: Northerly View of Stock Road to Sudlow Road Showing 2031 Build Noise Levels

Six receivers in this portion of the project are predicted to exceed the noise limit of 60dB(A), with three being adjacent to existing roads (Stock Road) and three adjacent to the proposed road. The elevation of the three receivers adjacent to proposed road relative to their back fences is such that they overlook the road reserve (i.e. little to no shielding is afforded by the back fence). This is shown in Figure 6.10-4. Existing property boundary fences are represented by black lines. Noise mitigation is required to meet the noise limit and reasonable and practicable mitigation measures have been considered to achieve the noise target at these receivers.

Figure 6.10-4: Westerly View of Stock Road and Coolbellup Avenue Showing 2031 Build Noise Levels

The proposed project east of the Coolbellup Avenue/Sudlow Road overpass emerges out of the cutting and runs on fill that is up to 2m above grade. The elevation of the road relative to noise sensitive receivers is shown in Figure 6.10-5, with buildings coloured in accordance with 2031 build scenario noise exposure and property boundary fences indicated by black lines.

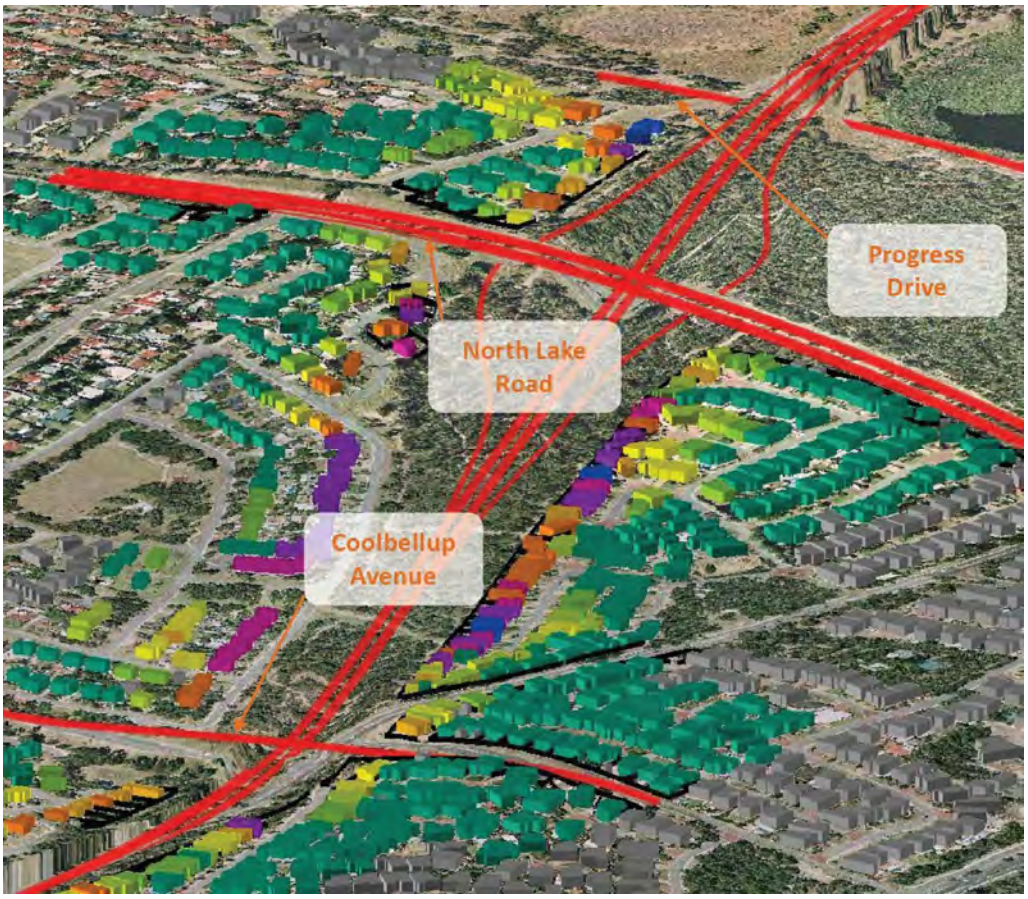


Figure 6.10-5: Easterly View of Coolbellup Avenue/Sudlow Road Overpass to Progress Drive Overpass

Noise sensitive receivers along this portion of the project are generally predicted to exceed the noise limit of 60dB(A) in 2031 as a result of the proposed project. The 2031 build scenario predicted noise levels therefore show that noise mitigation is required in this portion of the project in order to achieve the noise limit and to meet the noise target, where reasonable and practicable, in accordance with SPP 5.4.

6.10.3.7.2. Bibra Drive to Kwinana Freeway

The road alignment along this portion of the project is in a cutting, generally 4m to 6m deep. Dwellings on Hope Road south of the proposed alignment are further shielded by the Murdoch Drive off ramp, which projects up to 6m above grade. The vertical alignment in this portion of the project is shown in Figure 6.10-6, with existing property boundary fences indicated in black.

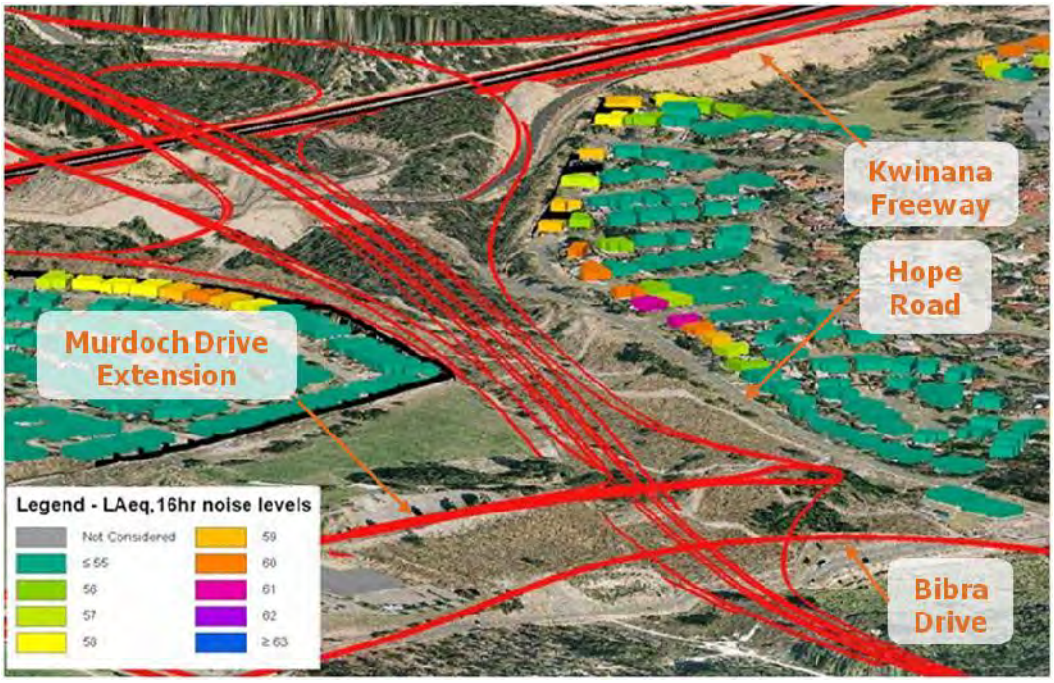


Figure 6.10-6: Easterly View of Bibra Drive to Kwinana Freeway

Noise sensitive receivers on Hope Road east of Lakeview Drive exceed the noise target of 55dB(A) and several receivers also exceed the limit of 60dB(A). Similarly, several receivers north-west of the Kwinana Freeway interchange are also predicted to exceed the noise target of 55dB(A). Accordingly, noise mitigation will be required to meet the noise limit, with reasonable and practicable mitigation measures considered to achieve the noise target at these receivers.

Other receivers adjacent to the proposed project are predicted to be below the noise target of 55dB(A). In accordance with SPP 5.4, no further noise mitigation is necessary for these receivers.

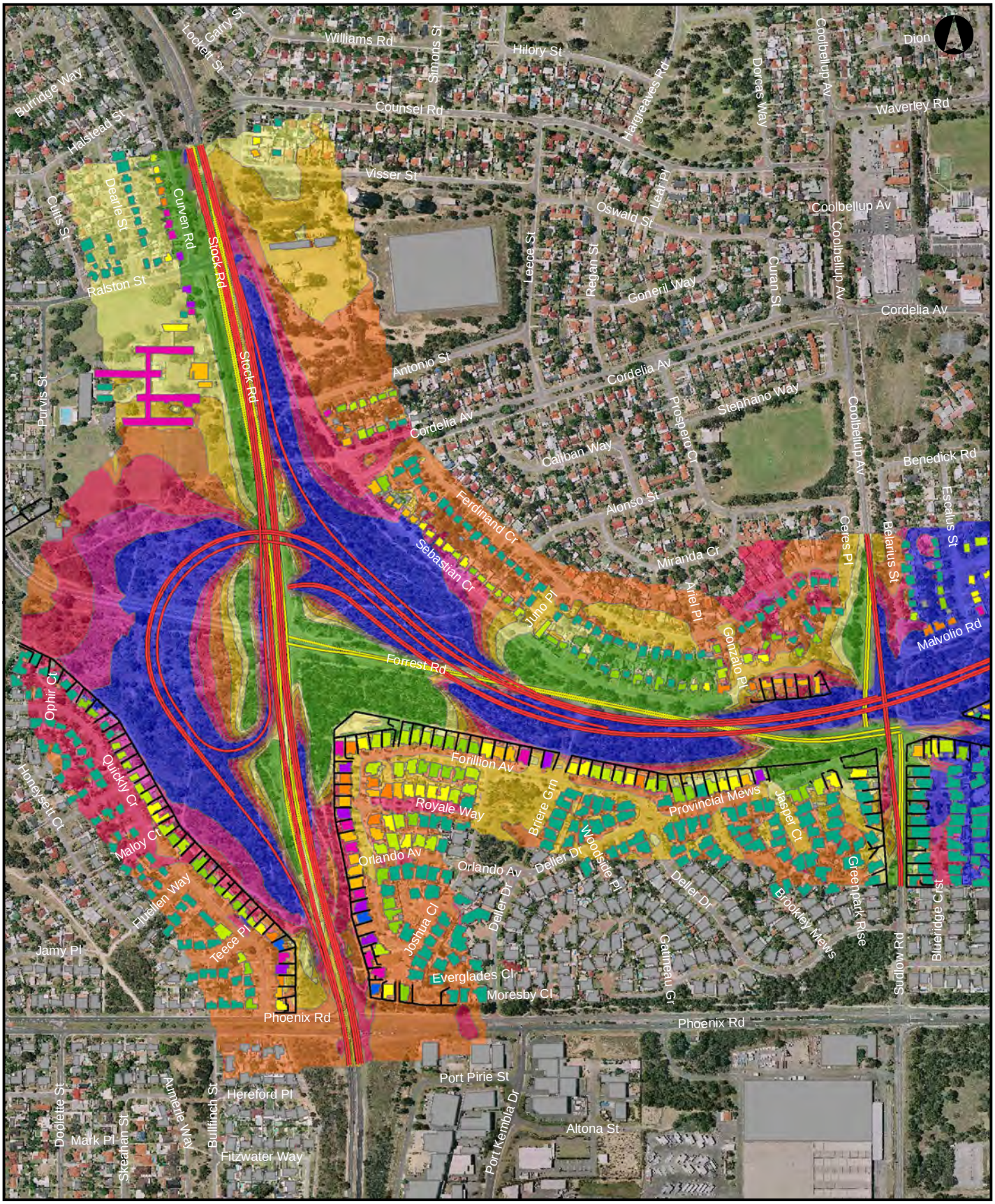
6.10.3.8. Redevelopment of Existing Roads

SPP 5.4 requires that reasonable and practicable noise management and mitigation measures are considered at receivers adjacent to major redevelopments of existing roads, with regard to:

- Existing transport noise levels;
- Likely changes in noise emissions resulting from the proposal; and
- Nature and scale of the works and the potential for noise amelioration.

Noise difference maps (i.e. build – no-build) for the controlling scenario have been prepared, in order to assess predicted changes in noise emissions resulting from the proposed project. These are presented in Figure 6.10-7 and Figure 6.10-8.

Building footprints have been colour-coded to show the controlling 2031 build scenario predicted noise exposure, while contour lines show the predicted increase in noise levels resulting from the proposed project (i.e. 2031 build scenario – 2031 no-build scenario noise level difference).



Controlling (2031) Noise Scenario

Noise Difference Map Showing Predicted Increase in Noise Levels

South Metro Connect

Figure 6.10-7.A

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

House Colour: 2031 Build Scenario Daytime Noise Level

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63

- Existing Fences
- Proposed Roads
- Current Roads

Noise Contour Colour: Noise Increase due to project (dB(A))

- < 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

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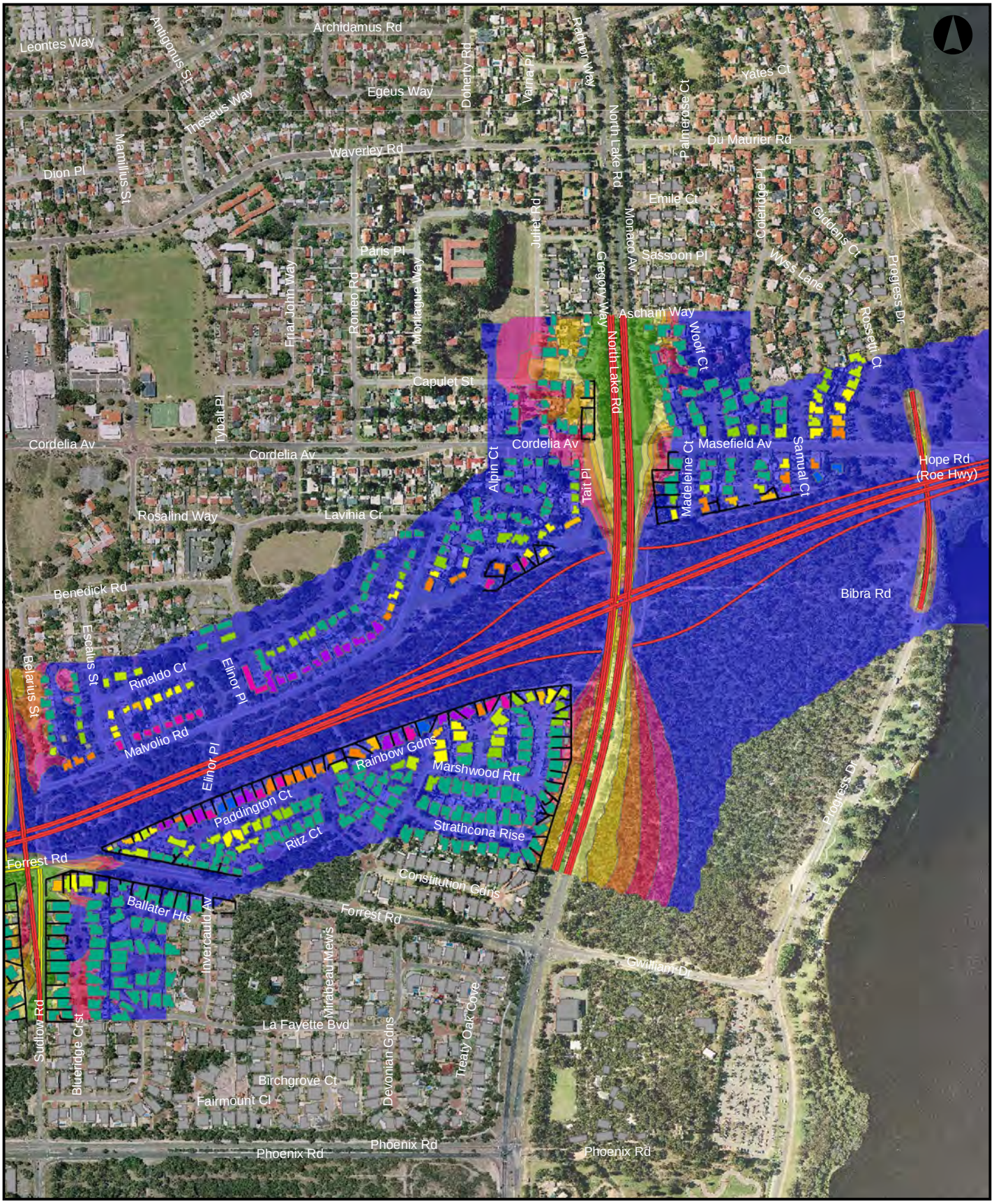

Controlling (2031) Noise Scenario

Noise Difference Map Showing Predicted Increase in Noise Levels

South Metro Connect

Figure 6.10-7.B

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

House Colour: 2031 Build Scenario Daytime Noise Level

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63

- Existing Fences
- Proposed Roads
- Current Roads

Noise Contour Colour: Noise Increase due to project (dB(A))

- < 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

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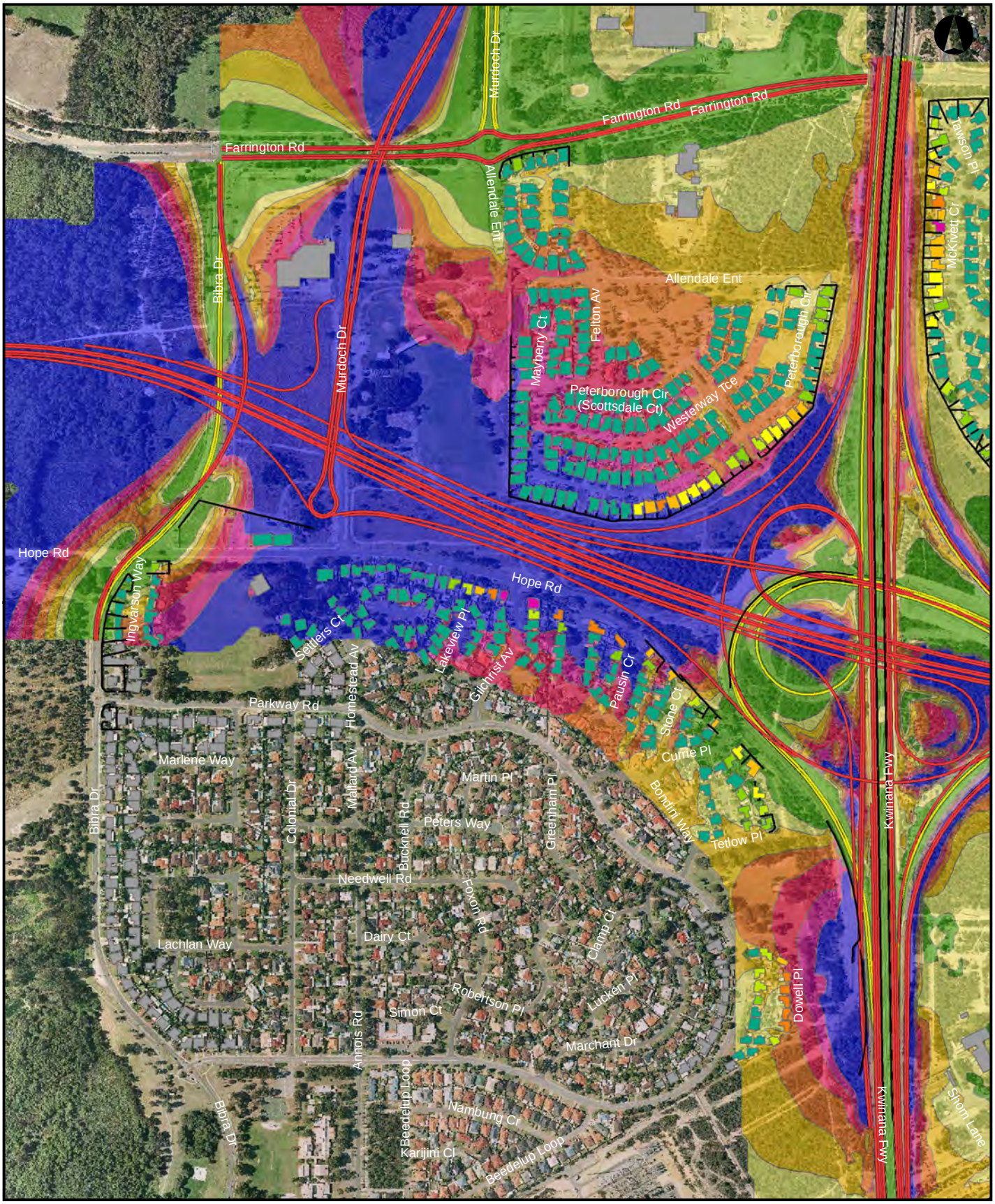

Controlling (2031) Noise Scenario

Noise Difference Map Showing Predicted Increase in Noise Levels

South Metro Connect

Figure 6.10-8.A

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

House Colour: 2031 Build Scenario Daytime Noise Level

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63

- Existing Fences
- Proposed Roads
- Current Roads

Noise Contour Colour: Noise Increase due to project (dB(A))

- < 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

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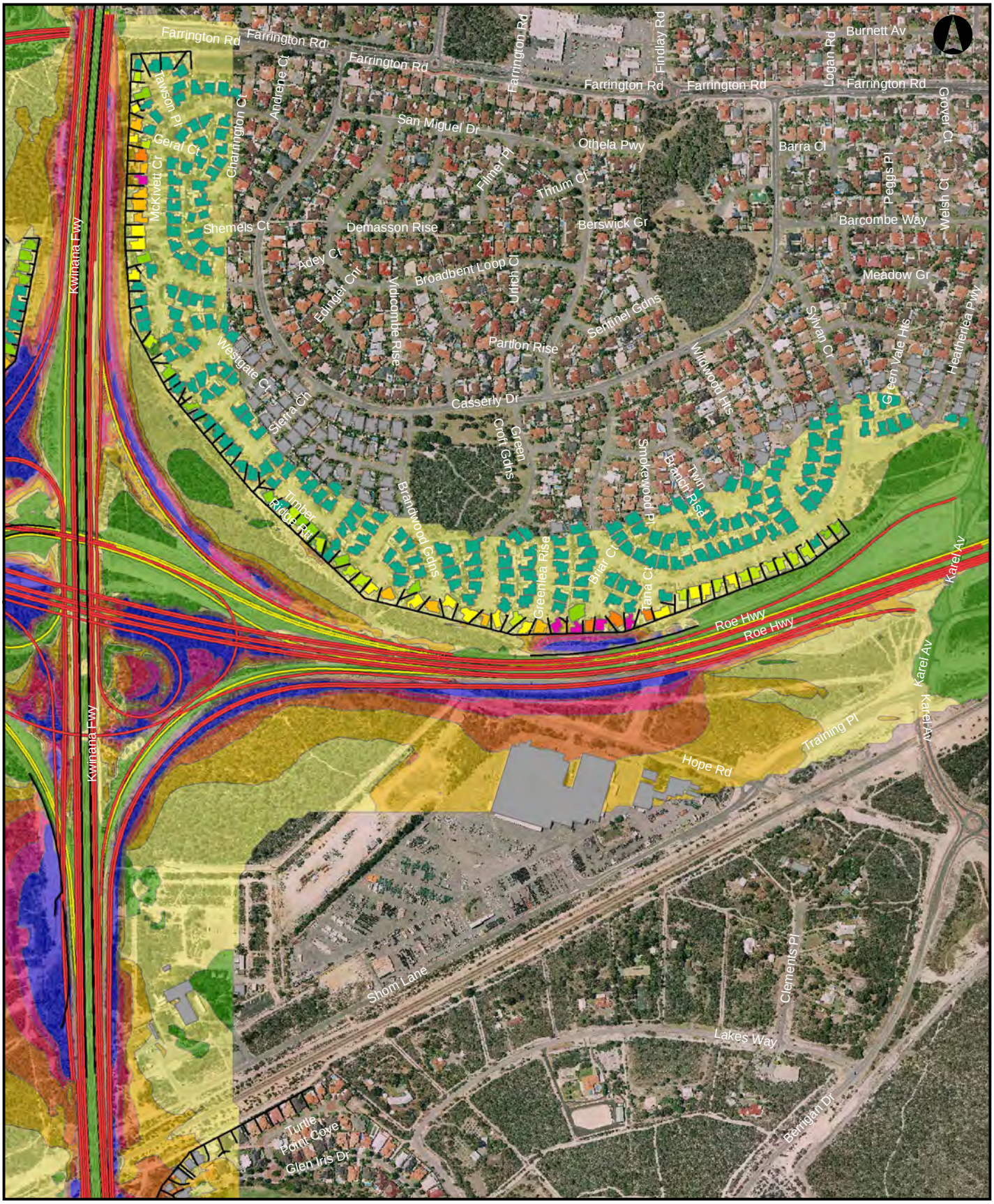

Controlling (2031) Noise Scenario

Noise Difference Map Showing Predicted Increase in Noise Levels

South Metro Connect

Figure 6.10-8.B

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

House Colour: 2031 Build Scenario Daytime Noise Level

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63

- Existing Fences
- Proposed Roads
- Current Roads

Noise Contour Colour: Noise Increase due to project (dB(A))

- < 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

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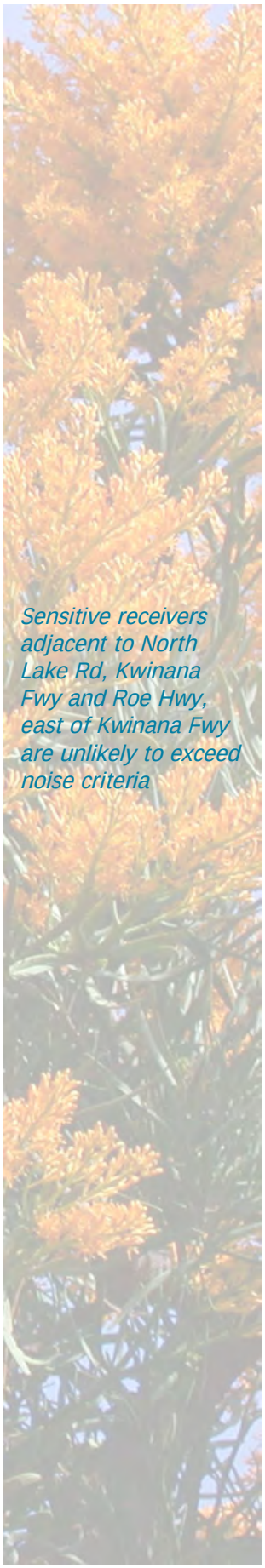


Sensitive receivers adjacent to North Lake Rd, Kwinana Fwy and Roe Hwy, east of Kwinana Fwy are unlikely to exceed noise criteria

6.10.3.8.1. Stock Road

By 2031, the proposed project will result in noise sensitive receivers adjacent to Stock Road being exposed to noise levels ranging between 59–64dB(A), as indicated in Figure 6.10-7. The vertical alignment of Stock Road south of Roe Highway will rise by up to 3m resulting in noise sensitive receivers adjacent to this portion of the project generally exceeding the noise limit of 60dB(A). In addition, the noise levels at these receivers are predicted to increase by between 2–4dB(A). Therefore, reasonable and practicable noise mitigation measures have been considered to meet the noise limit at these receivers.

No significant changes to the vertical alignment of Stock Road are proposed north of Roe Highway. Noise sensitive receivers along this portion of the project comprise private residences (north of Ralston Street) and Hamilton Senior High School. Modelling indicates that, as a result of the proposed project, noise levels at these receivers are generally predicted to exceed the noise limit of 60dB(A) by up to 2dB(A) in 2031, with noise levels at the school predicted to increase by between 1–3dB(A). Reasonable and practicable noise mitigation measures have therefore been considered to meet the noise limit at the school. Noise levels at residential receivers north of Ralston Street are predicted to decrease due to the proposed upgrade. Consequently, noise mitigation has not been considered at these receivers.

Noise modelling indicates that sensitive receivers adjacent to North Lake Road, Kwinana Freeway and Roe Highway, east of Kwinana Freeway are unlikely to exceed noise criteria and are therefore not addressed further in this section. More detailed analysis is presented in Appendix U.

6.10.3.9. Parks and Recreation Areas

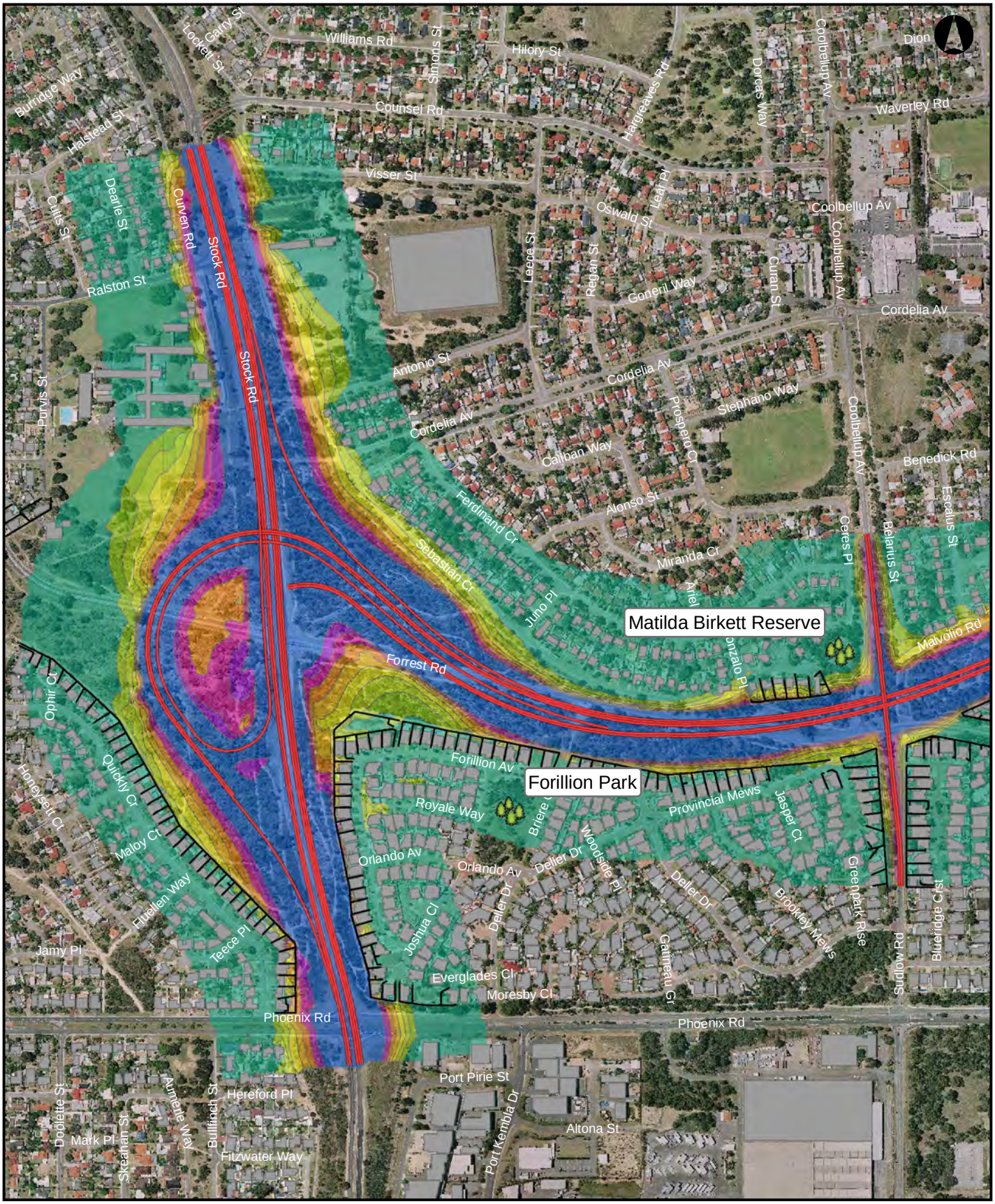
In the absence of noise criteria for parks and recreation areas within the SPP 5.4 noise policy, noise impacts at parks and recreation areas have been assessed against daytime outdoor noise objectives for noise sensitive receivers, with regard to the:

- Size of the park/recreation area and the proportion of area exceeding the noise criteria;
- Location of fixed recreational infrastructure (e.g. playgrounds, picnic tables, barbecue facilities) and compliance with the outdoor noise criteria at these locations; and
- Availability of alternative recreation areas within reasonable distance of areas affected by noise.

The recreation areas potentially affected by the proposed project comprise those surrounding North and Bibra Lakes, as well as Matilda Birkett Reserve, Rinaldo Reserve, Basset Reserve, Meller Park, Aubin Park, Pioneers Park and James Patterson Park. Three additional small playgrounds/recreation areas are located within the study area. These comprise:

- Recreation area in Coolbellup (Elinor Park) – a small park in Coolbellup fronting the MRS road reserve bounded by Elinor Place, Malvolio Road and Rinaldo Crescent;
- Recreation area in Bibra Lake (Forillion Park (refer to Table 6.10-3)) – a small recreation area located approximately 100m from the proposed alignment. It is bounded by Forillion Avenue, Arches Way, Orlando Avenue and Briere Green; and
- Recreation area/playground in Leeming (Sylvan Playground (refer to Table 6.10-3)) – small recreation area with playground infrastructure in Leeming. It is bounded by Sylvan Crescent, Heatherlea Parkway, Karel Avenue and Roe Highway.

Noise contour maps for assessment of noise impacts in parklands and recreation areas are presented in Figure 6.10-9; Figure 6.10-10 and Figure 6.10-11. As noise receivers within recreation areas are located in free-field conditions (i.e. there are no reflective surfaces such as dwelling façades present at receiver locations), the noise contours presented in these figures do not incorporate a façade correction. Therefore, the noise contour map levels shown in the figures are not applicable to residential receivers and, consequently, building noise exposures are not shown. Compliance with the noise criteria is assessed against the (worst case) 2031 build scenario. Therefore, the 2031 build scenario is the controlling scenario, as compliance in the 2031 build scenario will result in compliance in the 2016 build scenario.



Controlling (2031) Noise Scenario

Free Field Noise Contour Map

South Metro Connect

Figure 6.10-9.A

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

LAeq, 16hr Noise Levels

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63
- Existing Fences
- Proposed Roads
- Parklands

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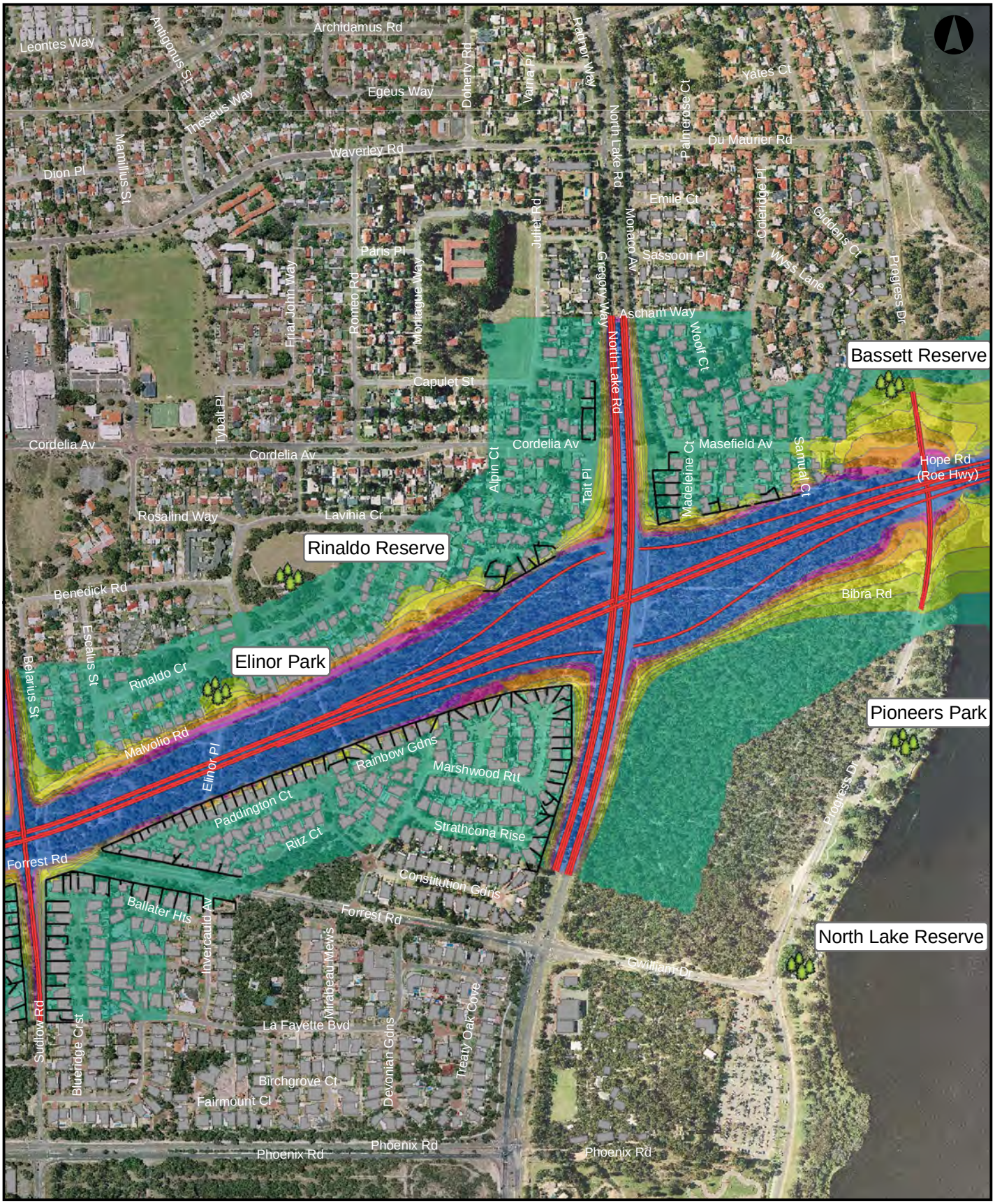

Controlling (2031) Noise Scenario

Free Field Noise Contour Map

South Metro Connect

Figure 6.10-9.B

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

LAeq, 16hr Noise Levels

Not Considered	59	Existing Fences
≤ 55	60	Proposed Roads
56	61	Parklands
57	62	
58	≥ 63	

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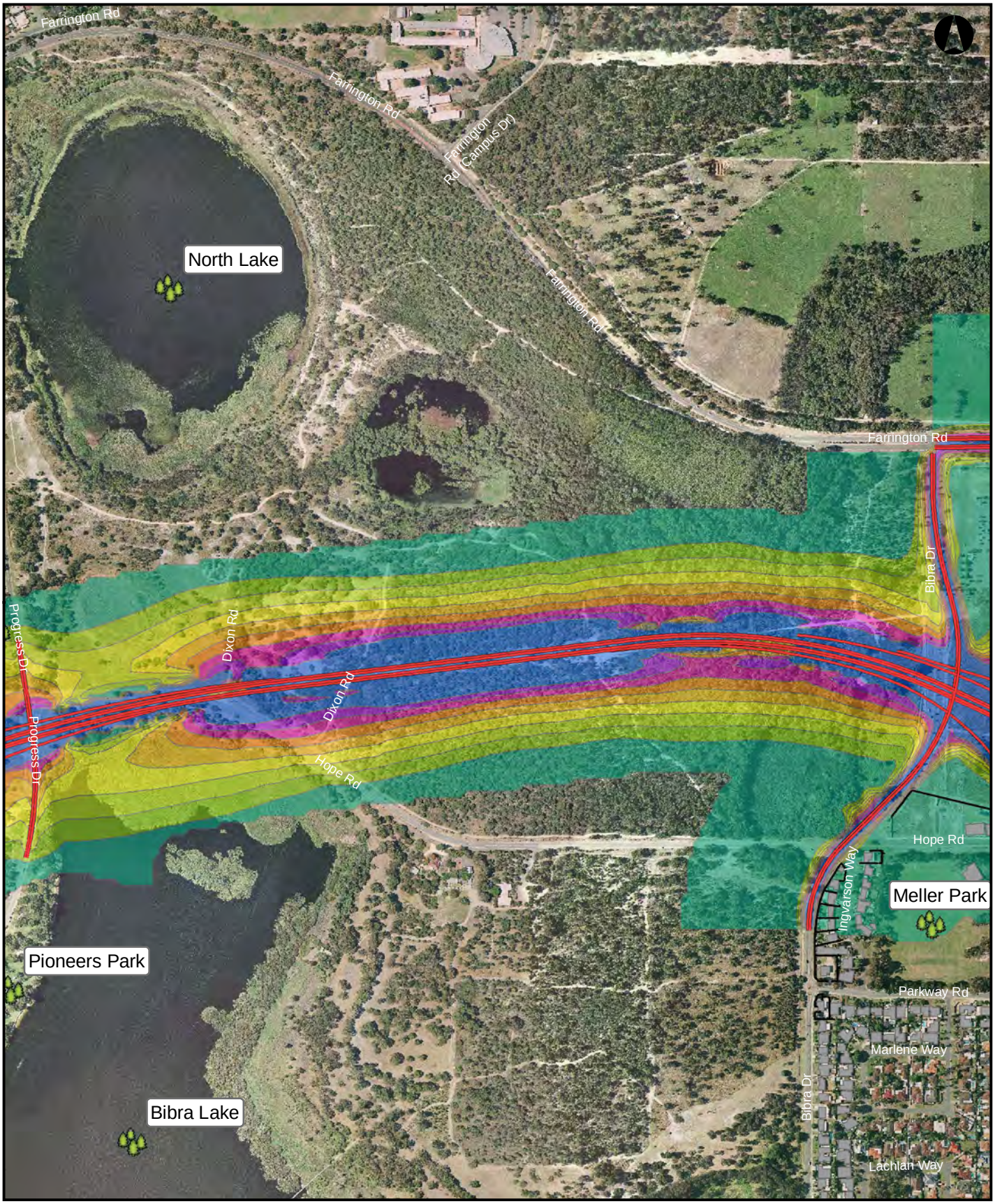

Controlling (2031) Noise Scenario

Free Field Noise Contour Map

South Metro Connect

Figure 6.10-10

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

LAeq, 16hr Noise Levels

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63
- Existing Fences
- Proposed Roads
- Parklands

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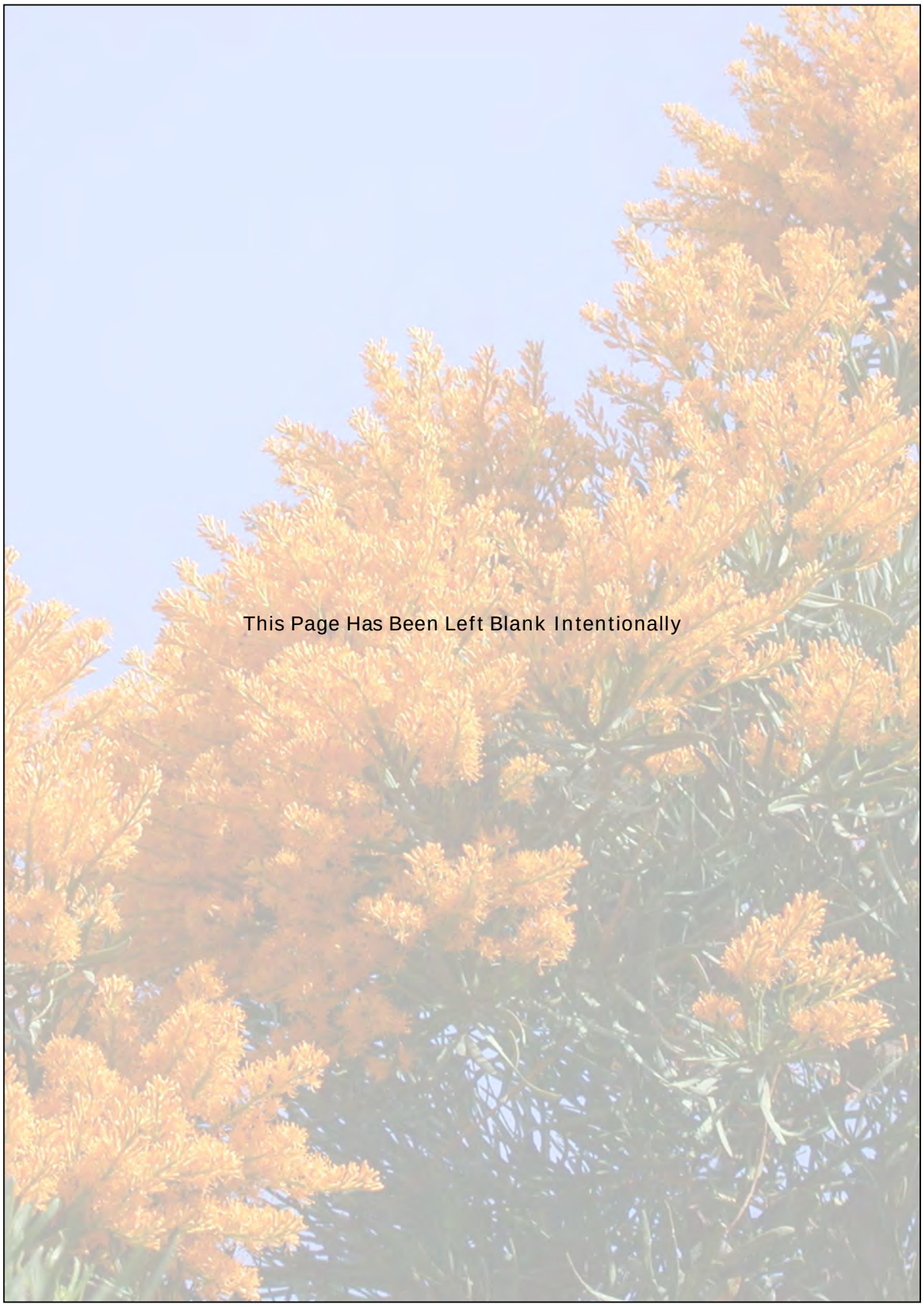
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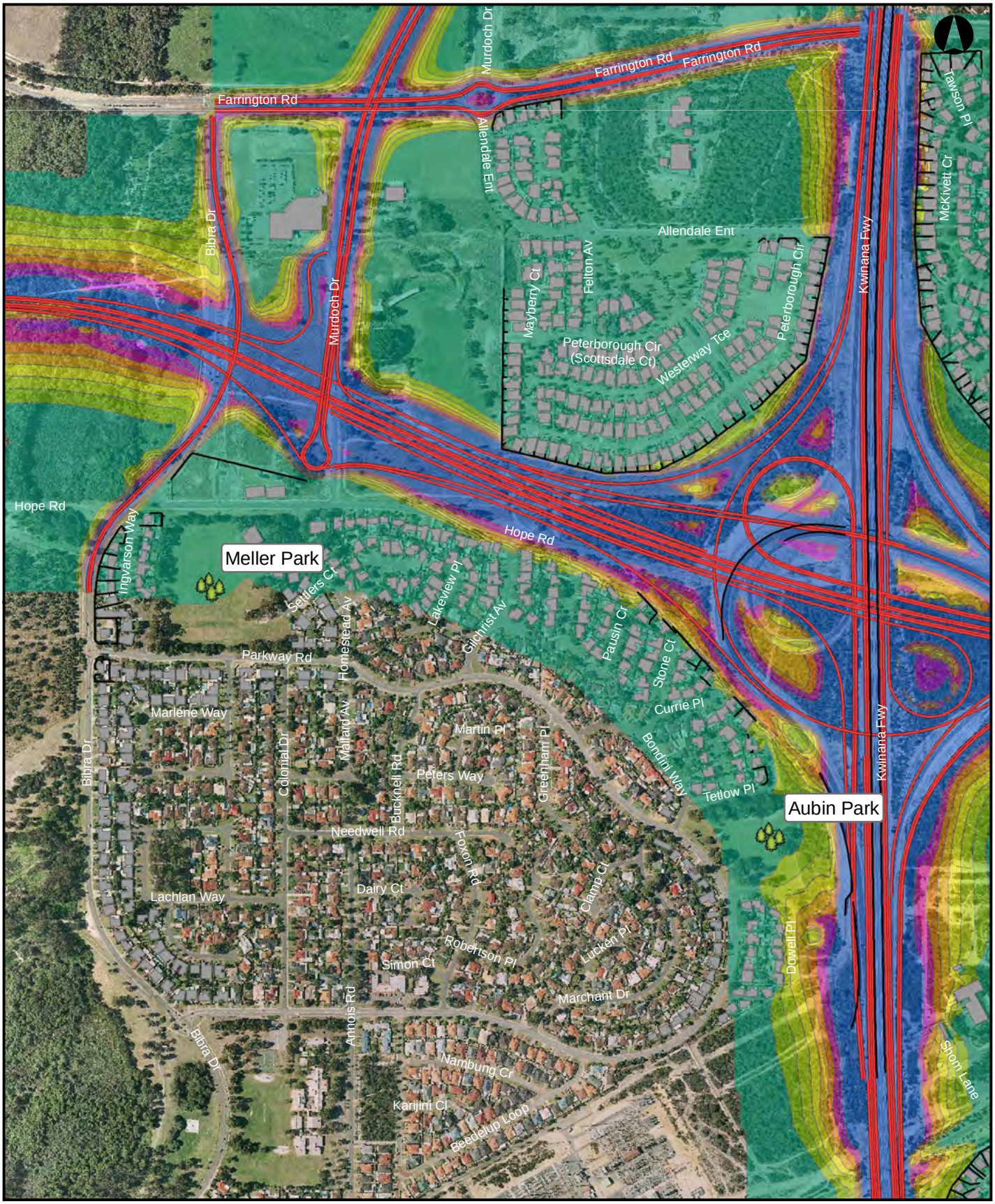

Controlling (2031) Noise Scenario

Free Field Noise Contour Map

South Metro Connect

Figure 6.10-11.A

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

LAeq, 16hr Noise Levels

- Not Considered
- ≤ 55
- 56
- 57
- 58
- 59
- 60
- 61
- 62
- ≥ 63
- Existing Fences
- Proposed Roads
- Parklands

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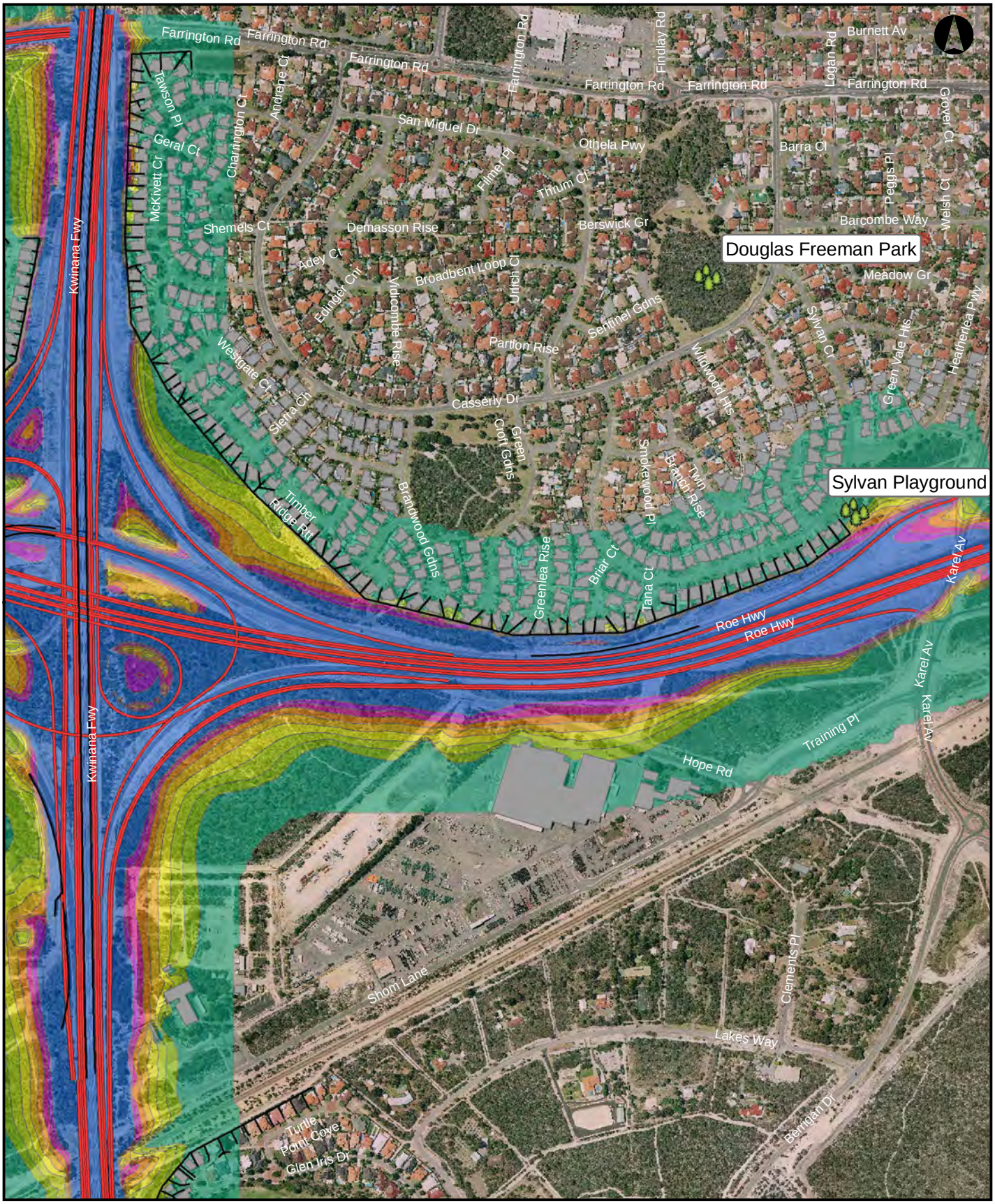

Controlling (2031) Noise Scenario

Free Field Noise Contour Map

South Metro Connect

Figure 6.10-11.B

0 50 100 150 200 250

Metres

Datum: GDA94 Projection: MGA z50

LEGEND

LAeq, 16hr Noise Levels

Not Considered	59	Existing Fences
≤ 55	60	Proposed Roads
56	61	Parklands
57	62	
58	≥ 63	

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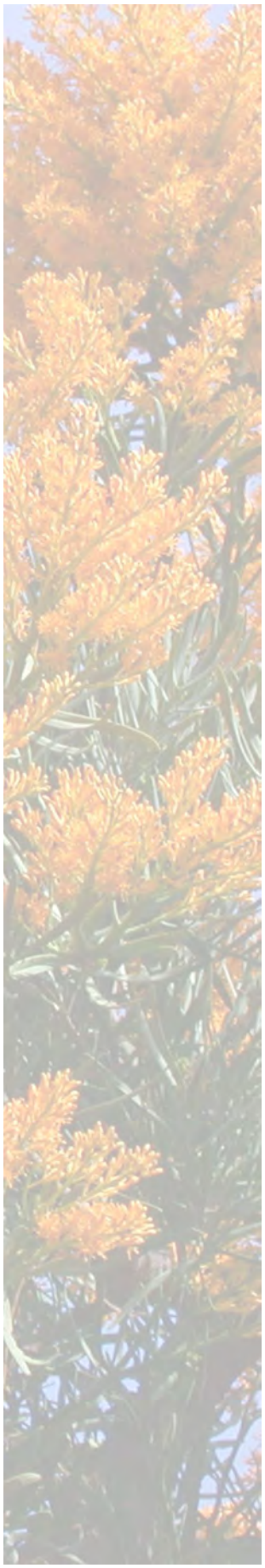


A summary of noise impacts on parks and recreation areas within the study area is presented in Table 6.10-3. Further discussion of noise impacts on individual parks and recreation areas is provided in Appendix U.

Table 6.10-3: 2031 Scenario Noise Impacts on Parks and Recreation Areas

Park/Recreation Area	Approximate % of Park Area Exceeding Noise Criteria		Recreational Infrastructure Exceeds Noise Criteria?	Nearest Alternative Recreation Area (Distance to Nearest Recreation Area)
	Noise Target (55dB(A)	Noise Limit (60dB(A))		
Matilda Birkett Reserve	0%	0%	No	n/a
Rinaldo Reserve	0%	0%	No	n/a
Bassett Reserve	50%	0%	Yes	Pioneers Park (500m)
Meller Park	0%	0%	No	n/a
Aubin Park	15%	0%	No	Meller Park (>1 Km)
James Patterson Park	0%	0%	No	n/a
Parklands (Bibra Lake)	<5%	<1%	No	n/a
Parklands (North Lake)	35%	15%	No	James Patterson Park (100m) Bibra Lake Parklands (500m)
Pioneers Park	10%	0%	No	North Lake Reserve (800m) James Patterson Park (900m)
Elinor Park[1]	50%	10%	Yes	Rinaldo Reserve (200m)
Forillion Park[1]	0%	0%	No	n/a
Sylvan Playground[2]	40%	0%	No[2]	Douglas Freeman Park (400m)

[1]Recreation area named after nearest street for reference only. Actual area may not have name, or one which is different from above.

[2]Sylvan Playground is exposed to noise from existing transport corridors, therefore exceedances are assessed against the noise limit criterion.

6.10.4. Management and Mitigation

Noise mitigation design methodology is discussed in detail in Appendix U and describes the process in which reasonable and practicable noise mitigation measures are proposed that best balance noise benefit, cost, feasibility and amenity impacts, including safety and security.

6.10.4.1. Construction Noise and Vibration

Construction noise and vibration will be managed through best practice construction methods

Construction noise and vibration will be managed through best practice construction methods which include using the quietest reasonably available machinery. Construction plant and equipment operating near noise sensitive locations may be fitted with broadband reversing alarms, which are less intrusive than their traditional (pure tone) counterparts.

Where noise barriers are proposed for property boundaries, they will be installed prior to the commencement of construction works that are likely to affect those properties, acknowledging that some enabling works may be required in order to construct the walls (e.g. vegetation clearing, etc.). Proposed noise barrier locations are discussed in Section 6.10.4.2.

A construction noise and vibration impact assessment will be carried out during the detailed design phase of the project. A noise mitigation and management plan will be prepared to address all the potential impacts associated with the project and submitted to DEC for approval. Community consultations will be carried during the construction phase of the project to inform residents of the likely impacts as well as mitigation and management measures undertaken to minimise their effects. Property condition surveys will be conducted for residences likely to be affected by construction vibration, and monitoring will be carried out during construction. Operators will be alerted to exceedances of vibration limits for human comfort and building damage, as well as to community complaints so they can be appropriately addressed.

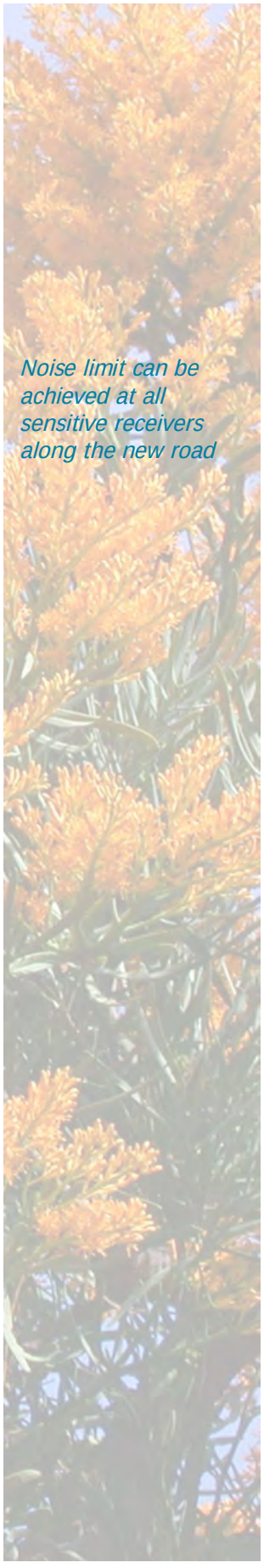
Construction activities required outside of standard construction hours (i.e. 7am and 7pm) will only be undertaken where the works are essential to be completed in this period and only after appropriate consultation with affected residences, DEC and local government.

A construction noise and vibration impact management plan will be prepared following completion of detailed design and submitted to DEC and local government for approval under Noise Regulations 13, prior to commencement of construction.

6.10.4.2. Mitigation to Meet SPP 5.4 Noise Objectives

Noise walls have been designed to meet the noise mitigation criteria

In accordance with SPP 5.4, noise walls have been designed to meet the noise mitigation target and limit criteria at noise sensitive receivers adjacent to the proposed project. A summary of barrier requirements to meet each of the SPP 5.4 objectives is presented in Table 6.10-4.



Noise limit can be achieved at all sensitive receivers along the new road

Table 6.10-4: Theoretical Noise Barrier Configuration Required to Meet Noise Objectives

Theoretical Barrier Configuration	Total Length (m)	Average Height (m)	Maximum Height (m)	Total Barrier Vertical Area (m^2)
Barrier to meet all noise limit	1,962	2.4	3.6	4,611
Barrier to meet all noise target	8,045	3.8	6.2	30,460

6.10.4.2.1. Mitigation to Meet Noise Limit

Noise barriers can be practically applied to meet the noise limit of 60dB(A) along the majority of the proposed project. An exception to this occurs between the Coolbellup Avenue/Sudlow Road overpass and North Lake Road, where the proposed project is up to 2m above grade. Noise barriers of 2.0–3.6m in height are required in portions of this part of the project to meet the noise limit. Details of noise barriers that are required to meet the noise limit are presented in Appendix U.

At upgraded sections of existing roads, only Stock Road requires additional noise barriers to meet the noise limit of 60dB(A). This is because the vertical alignment of Stock Road, south of the interchange is increased by 1–6m to accommodate the Roe Highway/Stock Road north-bound exit ramps. A 2.0–2.6m high noise barrier is required on the property boundary at receivers on the south-east section of Stock Road. The terrain topography on the south-west side is such that receivers are up to 4m below the level of the adjacent road. This makes noise walls on residential boundaries ineffective, due to a significant height difference between the road and adjacent receivers. A 120m barrier located adjacent to the road is therefore required to meet the noise limit of 60dB(A) south-west of the interchange.

Provided that existing noise barriers (that may be removed during construction) adjacent to Kwinana Freeway and Roe Highway are either retained or replaced, noise limit criteria will be met at all noise sensitive receivers within this area.

6.10.4.2.2. Mitigation to Meet Noise Target

A total barrier length of 8,045m at an average height of 3.8m is required to meet the noise target criterion along the proposed new road alignment. The barrier ranges in height from 1.8 to 6.2m. Noise barriers on the residential boundaries south of the proposed project range from 2.4m up to 5.6m in height, which may not be practical due to solar overshadowing, design requirements and cost. Details of noise barrier requirements and targets are presented in Appendix U.

6.10.4.3. Proposed Noise Mitigation Design

Preliminary community preferences have been incorporated into the proposed mitigation where they do not conflict with other planning and transport policies. A total barrier length of 8,270 at an average height of 3.2m has been proposed to demonstrate noise impacts associated with the proposed project can be managed in accordance with SPP 5.4. Noise barriers located on residential boundaries have been limited to 4.4m, whilst those within the road reserve have been limited to 5m in height, providing a balance between noise benefit, cost and visual amenity. The proposed barrier design will achieve the noise target at all but 170 receivers, of which 29 are adjacent to the new road. A summary of the proposed noise barrier is presented in Table 6.10-5.

Noise target can be achieved at the majority of sensitive receivers along the new road

Table 6.10-5: Proposed Noise Barrier Summary

Barrier Configuration	Total Length (m)	Average Height (m)	Maximum Height (m)	Total Barrier Area (m^2)
Proposed noise barrier	8,270	3.2	5	26,331

The layout of the proposed barrier configuration and resulting 2031 build noise levels are presented graphically in Appendix U. A summary of results comparing build scenarios with proposed mitigation versus corresponding no-build scenarios is presented in Table 6.10-6.

Table 6.10-6: Comparison of Build Scenarios with Proposed Mitigation versus No-build Scenarios

Modelled Scenario	Number of Receivers				Daytime $L_{Aeq,16h}$ (dB(A))	
	Total	> 55dB(A)	> 60dB(A)	> 65dB(A)	Average	Maximum
2016 No-build	1,472	100	0	0	47.1	59.8
2016 Mitigation	1,472	61	0	0	50.5	59.8
2031 No-build	1,472	205	21	0	49.0	63.3
2031 Mitigation	1,472	170	5	0	52.6	61.6

The comparison shows that although the average noise exposure across all receivers increases due to the project, the number of receivers exceeding both the target and the limit criteria decreases. The number of receivers exceeding the noise target in 2031 decreases from 205 to 170 due to the project. Similarly, the number of receivers exceeding the noise limit criterion decreases from 21 to five. All five receivers exceeding the noise limit are located adjacent to existing roads and are generally out of the scope of the proposed upgrade.

There will be a net decrease in the number of receivers exceeding the noise target on existing roads

Twenty-nine of the 170 receivers exceeding the noise target are adjacent to the new road (i.e. those previously not exposed to significant noise from road traffic). Of these, seven exceed the target by 2dB(A) and 22 by 1dB(A). The remaining 141 receivers exceeding the target but not the limit are adjacent to existing roads, where the net result of the proposed project is a decrease in the number of receivers exceeding the noise target from 205 to 141 (refer to Table 6.10-6). Proposed mitigation will be subject to refinement, following detailed design and additional consultation and feedback on the proposed noise barriers.

The above assessment is based on noise levels predicted at the ground floor of noise sensitive receivers, in accordance with SPP 5.4 assessment methodology. The noise levels at upper storeys of double storey residences are expected to be between 3 and 6dB(A) greater than those on the ground floor. Although many first floor receivers will exceed the noise target, based on the above, they are generally expected to comply with the noise limit criterion adjacent to the new road. Noise exposure at first storey residences adjacent to existing roads may exceed the noise limit; however, it is noted that many locations will experience a decrease in noise levels as a result of the proposed works, and where the levels do increase, the increase will be marginal.

6.10.5. Conclusion

This section describes the residual impacts associated with noise and addresses the key issues relevant to this factor raised in EPA Bulletin 1088.

6.10.5.1. Residual Impacts

Temporary construction noise and vibration impacts are likely to occur along the length of the proposed project. Although these cannot be assessed until detailed road design and construction planning is finalised, it is expected that these effects are manageable within the requirements of Western Australian *Environmental Protection (Noise) Regulations 1997*.

Operation phase impacts include noise emissions associated with new roads and the redevelopment of existing roads, and noise impacts on parks and recreation areas adjacent to the proposed project. Reasonable and practicable noise mitigation measures are proposed that best balance noise benefit, cost, feasibility, amenity impacts, as well as safety and security.

The outcome of noise modelling of the current concept design indicates that a total barrier length of 8,270m at an average height of 3.2m is required to demonstrate noise impacts associated with the proposed project can be managed in accordance with SPP 5.4. The proposed mitigation achieves compliance with the noise target at all but 170 noise sensitive receivers in the project area, of which 29 are adjacent to the new section of road. Of these, seven exceed the target by 2dB(A) and 22 by 1dB(A). The remaining 141 receivers that exceed the target but not the limit are adjacent to existing roads, where the net result of the proposed project is a decrease in the number of receivers exceeding the noise target from 205 to 141. That is, for the majority of residences currently impacted by noise from the existing road network, there will be an overall improvement in noise levels.

More importantly, the overall number of receivers exceeding the noise target in 2031 decreases from 205 to 170 due to the project, and the number exceeding the noise limit decreases from 21 to five. All five receivers exceeding the noise limit are located adjacent to existing roads and are generally out of the scope of the proposed upgrade.

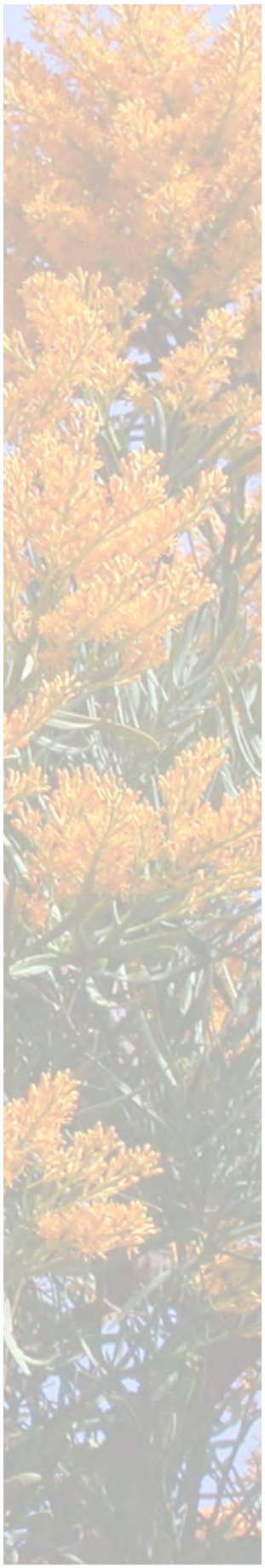
The above assessment is based on noise levels predicted at the ground floor of noise sensitive receivers, in accordance with SPP 5.4 assessment methodology. Noise levels at upper storeys of double storey residences are typically expected to be between 3 and 6dB(A) greater than those on the ground floor. Although many first floor receivers will exceed the noise target, based on the above, they are generally expected to comply with the noise limit criterion at the majority of double storey residences adjacent to the new section of road. Noise exposure at first storey residences adjacent to existing roads may exceed the noise limit; however, it is noted that many locations will experience a decrease in noise levels as a result of the proposed works, and where the levels do increase, the increase will be marginal.

The current concept design is likely to be revised during detailed design. Alterations to the current design may result in different noise levels at sensitive receptors, necessitating a revised barrier design. Accordingly, additional modelling will be required following completion of detailed design in order to determine the exact noise wall configuration required to mitigate noise effects as much as practicable.

A summary of the mitigation, management and residual impacts for project noise emissions is presented in Table 6.10-7.

Table 6.10-7: Residual Impacts Associated with Noise

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Operation and maintenance of plant and machinery (including pile driving)	Temporary disturbance to noise sensitive receivers associated with construction noise and vibration	Managed through best practice construction methods using quietest reasonably available machinery Use of less intrusive reversing alarms Staged installation of permanent noise walls on property boundaries adjacent to noisy construction activities Vibration monitoring at potentially affected locations Property condition surveys at sensitive structures prior to commencement of vibration intensive construction A construction noise and vibration management plan will be prepared in the detail design phase of the project prior to commencement of construction activities	Noise and vibration may be temporarily encountered during the construction phase through different parts of the project area Several recreational areas adjacent to the proposed transport corridor will potentially be affected by the proposed project during construction



Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Operation Phase			
Freight /Private transport	Disturbance of noise sensitive receivers by associated road operations	Noise barriers that best balance noise benefit, cost, feasibility, amenity, community preferences and safety and security (where these do not conflict with other planning and transport policies) will be installed prior to the opening of the road Where noise barriers are to be located on property boundaries, they will be constructed prior to the commencement of adjacent road works, to help minimise construction noise impacts at noise sensitive receivers. Preliminary noise wall mitigations comprise over 8km at an average height of 3.2m (preliminary barrier design subject to confirmation in the detail design phase)	Twenty nine receivers adjacent to the new road are predicted to marginally exceed the noise target criterion (by up to 2dB(A)) at the ground level in 2031 All receivers are predicted to comply with the noise limit criterion at the ground floor in 2031.

6.10.5.2. EPA Bulletin Matters

Table 6.10-8 highlights the EPA concerns for noise from the proposed project as stated in Bulletin 1088 (EPA 2003).

Table 6.10-8: EPA Concerns for Noise as Stated in Bulletin 1088

Bulletin 1088 Statement	Proposed Project Concept Response
The construction of this highway would result in significant changes to the noise environment for residences and sensitive land uses in the vicinity of the corridor... there would also be a significant change in the noise environment for nearby residences and sensitive land uses within the vicinity of Forrest Road	Whilst there will be significant changes in the noise environment in the short term, proposed mitigation achieves compliance at all but 170 noise sensitive receivers in the project area, of which 29 are adjacent to the new section of road. The remaining 141 receivers that exceed the target but not the limit are adjacent to existing roads, where the net result of the proposed project is a decrease in the number of receivers exceeding the noise target from 205 to 141. In addition, the number of residences predicted to exceed the noise limit also reduces from 21 to five (refer Table 6.10-6). The proposed project therefore results in a net decrease in noise levels adjacent to existing roads

6.11. Recreation and Education

The EPA's objective with regards to the protection of recreation is:

To ensure that existing and planned recreational uses are not compromised.

The EPA does not state a specific objective with regards to education; however, EPA Bulletin 1088 (EPA 2003) identified both recreation and education as key environmental values associated with the proposed project. Bulletin 1088 raised the concern that construction of the proposed project, as it was defined at the time, would significantly detract from the recreational and educational values currently provided by the area.

6.11.1. Potential Impacts

A range of potential impacts on recreation and education were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. Design solutions were developed for the following potential impacts:

- Excavation of road cuttings could cause diminished visitor perceptions of amenity and overall recreation experience – construction activities are temporary and will occur over a relatively short time frame;
- Excavation of road cuttings could result in a temporary construction zone, halting movement and access to recreational opportunities – construction activities are temporary and will occur over a relatively short time frame with alternative routes provided; and
- Excavation of road cuttings may cause changes to Lakeside Recreation Centre frontage and access - this will not prevent the centre from performing its functions, as they are indoor and not impacted by the road works.

A detailed assessment of predicted recreation and education impacts is provided in Sections 6.11.2 and 6.11.3.

6.11.2. Construction Phase Impacts

Construction phase impacts on recreation and education are discussed below and include impacts associated with:

- Active recreation facilities;
- Access to recreation; and
- Access to educational pursuits.

Solutions to avoid impacts on the Spanish Club and Murdoch Pines Golf and Recreation Park are being developed in consultation with these stakeholders

Regional access to local recreation facilities will be improved but impacts on local access are anticipated.

Regional cycle access will be improved

6.11.2.1. Active Recreation Facilities

6.11.2.1.1. The Spanish Club

The Murdoch Drive extension south from Farrington Road to Roe Highway (roughly corresponding to the alignment of Baker Court) impacts on the north-west corner of the Spanish Club soccer pitch. Access to the club and car park will also be affected by the works. A solution to modify the pitch, such that playing activities are not disrupted during road construction or operation, is being developed in consultation with the club.

6.11.2.1.2. Murdoch Pines Golf and Recreation Park

The Murdoch Drive extension south from Farrington Road to Roe Highway cuts across the western boundary of the Murdoch Pines Golf and Recreation Park, which will impact current access to and parking at the facility. The proposed project also cuts across the southern end of the site, thereby removing a small portion of the driving range and mini golf areas. The putting green area may also be affected by access and car park modifications. A solution to modify the driving range, mini golf and relocate the putting green area to enable current activities to continue is being developed in consultation with Murdoch Pines Golf and Recreation Park.

6.11.2.1.3. Access to Recreation

The bus route along Forrest Road between Sudlow Road and Stock Road will no longer be available, as this section will be replaced by the proposed highway. This bus route is central to the residential communities on either side of the project corridor.

Local road access to recreation facilities will be affected by creation of a cul-du-sac on Hope Road, west of the wetlands precinct, as a result of the road's partial decommissioning. Local vehicular access will generally be maintained through retention of north-south links across the proposed road corridor.

Local pedestrian paths will generally be retained through reinstatement or supplementing of existing north-south and east-west links. The standard of paths is also likely to be improved. One local pedestrian access that will be removed is currently located from Briere Green, south of Forrest Road between Stock Road and Sudlow Road, across the proposed project to Sebastian Crescent.

The proposed project will, however, result in improved access to recreation facilities in the vicinity of the project area for regional visitors through the provision of a more simplified, free moving and higher speed road environment, as an alternative to the existing road network. Regional cycle access will also be improved through the extension of the PSP and links with the existing Perth bicycle network routes; however, minor local impacts on access to recreation opportunities are anticipated.

6.11.2.2. Access to Educational Pursuits

The most likely construction phase impact on education relates to reduced accessibility. The Cockburn Wetlands Precinct, planned by the City of Cockburn (Section 5.15), will lose vehicular access from the west as a result of the decommissioning of Hope Road; however, access provided via Bibra Drive is considered to be sufficient for the future needs of the Precinct (Avard 2010). Furthermore, the removal of through traffic along Hope Road will improve the overall level of safety for pedestrians and precinct users.

Removal of through traffic from Hope Road will improve overall pedestrian safety

6.11.3. Operation Phase Impacts

The operation phase impacts described in this section relate to the ability of places and facilities to maintain their current:

- Active recreation function;
- Passive recreation function; and
- Educational value.

6.11.3.1. Active Recreation

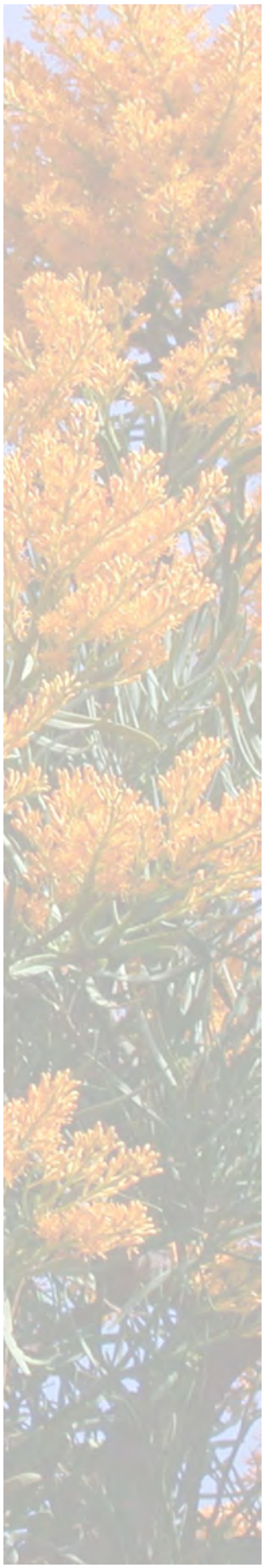
Cycling and general fitness activities (such as walking and jogging) on paths and trails around Beeliar Regional Park will be affected by the proposed project via severance of the route around the northern end of Bibra Lake and north/south routes across the road corridor. This will also impact formal active recreation activities, such as the Bibra Lake Fun Run, organised by the City of Cockburn.

Cyclists and general fitness users of paths and trails around Beeliar Regional Park, who are not directly affected by the proposed project, but are in close proximity to the Roe Highway, could perceive the new road, the traffic on the road and associated noise as a deterrent to their exercise. However, the distance to active recreation facilities in the vicinity of the project area is such that this will not be considered a significant impact.

6.11.3.2. Passive Recreation

Paths and trails are the only passive recreation facilities in Beeliar Regional Park to be directly impacted by the project. Any 'off-path' related passive recreation, such as wildlife observation, occurring within the road corridor through Beeliar Regional Park will also be affected by the proposed project.

Passive recreation (predominantly walking, walking dog(s) and generally accessing the benefits of being outdoors) will be directly impacted by the proposed project along the remainder of the corridor, mostly west of Beeliar Regional Park. They will also be impacted to a lesser degree to the east, based on the opportunities afforded by informal tracks and the attractiveness of the natural environment.



Other impacts on passive recreation areas adjacent to, or nearby, the proposed road corridor relate to visitor perceptions of their amenity and overall recreation experience being diminished by a combination of factors. Some of these factors, such as visual amenity and noise, can be quite clearly defined and are addressed in other sections. However, some experiential factors are more difficult to measure, subjective and may be unique to each person.

6.11.3.3. Educational Pursuits

The majority of local schools, as well as universities and technical colleges, use Beeliar Regional Park, North and Bibra lakes, the Cockburn Wetlands Education Centre and Native ARC as educational resources. Restrictions that prevent these education providers from accessing the park, lakes, Wetlands Centre or Native ARC will have an impact on their ability to use the area for educational purposes. This impact however, is not considered to be significant.

6.11.4. Management and Mitigation

Management and mitigation for recreation and education relates predominantly to accessing active and passive recreation pursuits.

6.11.4.1. Active Recreation

The Spanish Club management committee was consulted throughout the design process. A range of alternative road alignments have been considered, but were deemed to have greater negative impacts on environmental factors or other stakeholders. Main Roads has committed to relocate the Spanish Club's two playing fields to the east, so that the Spanish Club can continue to hold soccer matches. Consultation is ongoing with the Murdoch Pines Golf and Recreation Park on how best to mitigate the impacts on the recreational functions of the site; however, the concept design has limited the extent of impact on this facility to the southern end of the driving range and parking facilities.

The greatest area of impact on active recreation along paths and trails occurs between Bibra Lake and Horse Paddock Swamp/North Lake. The constraints created by existing residential areas to the north of the proposed project, located west of Progress Drive, as well as the environmental values of the lakes and wetlands, provide little scope to adjust the alignment of proposed road corridor in this section to retain existing paths.

The design aims to address the severance of the path around the northern boundary of Bibra Lake by creating a new recreational path between the northern edge of Bibra Lake and the southern side of the new road formation. In addition, two connections will be provided under the new road at the western and eastern ends of the new northern section of shared path. This will provide connections to the path network on the north side of the road corridor, to North Lake and beyond. This is consistent with the intent of the Beeliar Regional Park and Bibra Lake management plans and support has been indicated by the City of Cockburn.

The design addresses severances to the north-south links across the proposed project, by creating a dedicated pedestrian link under the proposed road, which is separate from, but adjacent to, the east side of Progress Drive. Another link will be created under the proposed road, approximately 300 – 400m east of Progress Drive. Both links will provide strong visual and physical connections between North and Bibra Lakes. In addition, the eastern-most link will enable the PSP to connect from the north side of the proposed project to a route along Hope Road. Another underpass will be provided west of Roe Swamp, approximately 200m west of the proposed bridge that coincides with an existing informal track used regularly by park users.

Access to the Cockburn Wetlands Education Centre from the west will need to be redirected along alternative routes including Progress Drive, Farrington Road and Bibra Drive. Appropriate signage and information will be provided, where required.

Pedestrian connectivity to revised bus routes will be provided or improved, if substitute bus routes are created by Transperth north and/or south of the residential area between Stock Road and Sudlow Road/Coolbellup Avenue, to replace the services lost from Forrest Road.

Appropriate detours and temporary routes will be established during the construction period, to maintain adequate access to recreation facilities. Adequate communication to potentially affected drivers, pedestrians and public transport providers will be provided.

6.11.4.2. Passive Recreation

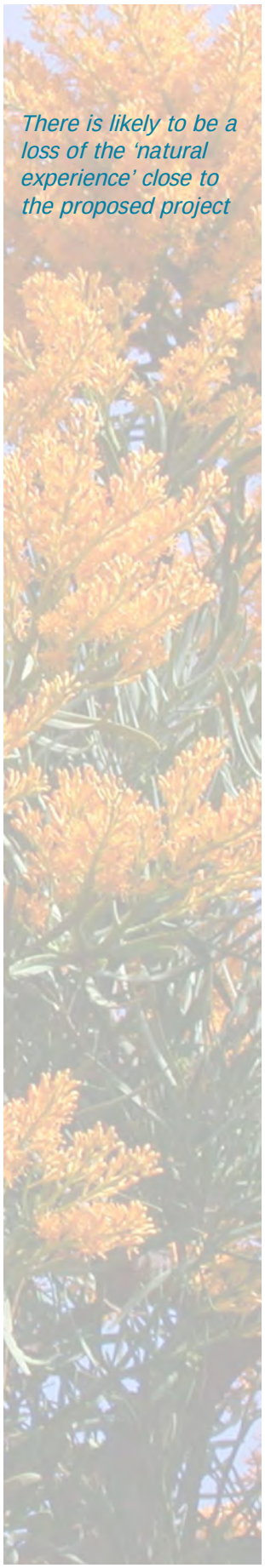
Mitigation of impacts on active recreation users utilising the paths and trail networks in Beeliar Regional Park have been outlined in Section 6.11.4.1. Impacts on those using the remainder of the proposed project corridor are more difficult to mitigate. The project design aims to retain as much remnant vegetation as possible along the corridor, by utilising retaining walls and increasing the gradient of batters. This will enable residents to access natural environment experiences along the edge of the corridor; however, access will be limited. Additional recreation paths (separate to the PSP) are proposed along the edge of the corridor in some locations. Further discussions will be held with the City of Cockburn, as some paths may need to be constructed outside the project area.

6.11.5. Summary and Conclusions

The construction of the proposed project will result in some interruption to recreational and educational pursuits during construction. However, these impacts are expected to be relatively short-term and restricted to the immediate project area.

Over the longer term, the proposed project will result in the removal of local access to and from the west end of Hope Road and via Forest Road. The extent of this impact on access to recreational facilities is considered minimal, with sufficient alternatives available.

The residual impacts of the proposed project on recreation and education are described in Section 6.11.5.1.



There is likely to be a loss of the 'natural experience' close to the proposed project

6.11.5.1. Residual Impacts

The main residual impact will be on the 'natural experience' for visitors who utilise the formal circuit around Bibra Lake and potentially the less formal circuit around North Lake and/or Horse Paddock Swamp. While the current, predominantly intact, intrinsic 'natural experience' is likely to be lost for anyone visiting Beeliar Regional Park in close proximity to the proposed project, the park is quite large and these experiences will still be available at the majority of other locations within the park. To minimise the effect on the local values, access tracks will be retained, with underpasses installed in appropriate locations to minimise the extent of this impact: therefore, it is not expected to significantly compromise the recreational use of the broader project area.

An alteration in local vehicular access and in public transport network routes will occur; however, this will not result in compromised regional recreational or educational values.

Included amongst the residual benefits are:

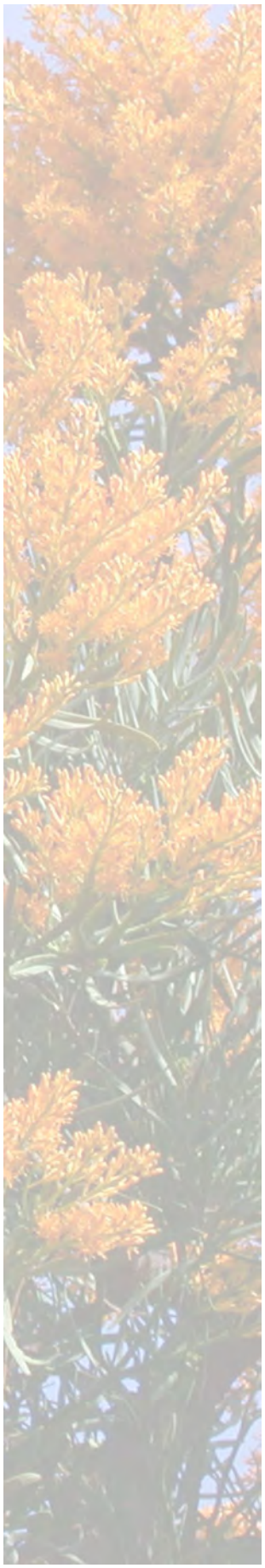
- Improved access to recreation facilities in the vicinity of the project area for regional visitors through the provision of a more simplified, free moving and higher speed road environment;
- Improved access to wetland education values for nearby the Blue Gum Montessori School, through a new underpass at Bibra Drive;
- Improved westward flow from the existing Roe Highway PSP; and
- Improved standard of local pathways and road connections.

Educational values will be altered by the proposed project; however, current education values will continue to exist in most areas. While educational values in the immediate vicinity of the proposed road will change, they will provide new opportunities and will not detract significantly from the recreational and education value that the parkland currently provides. In this regard, the EPA objectives for recreation and education in Bulletin 1088 will be met.

A summary of the management, mitigation and residual impacts on recreation and education is presented in Table 6.11-1.

Table 6.11-1: Residual Impacts on Recreation and Education

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Excavation of road cuttings, placement of fill and other earthworks	Disturbance of the Spanish Club playing fields	Relocation of the Spanish Club's two playing fields to the east	Nil
	Disturbance of Murdoch Pines Golf and Recreation Park	Continued consultation with the Murdoch Pines Golf and Recreation Park on mitigation	Reconfiguration may be required for the: Driving range Car parks Mini golf Putting green
Removal/rehabilitation of existing redundant roads	Loss of local vehicular access along Forrest Road between Sudlow Road and Stock Road	Local vehicular access will be maintained through reinstatement of north-south links across Roe Highway, (such that existing east/west links remain viable): Alignment of Sudlow Road and Coolbellup Avenue to allow for installation of overpass to maintain local connectivity Installation of an underpass at Progress Drive to maintain north/south access Adequate communication to potentially affected drivers, pedestrians and public transport providers will be provided	Alteration of public transport network
	Reduced local road access to recreation facilities via Hope Road through its partial decommissioning	Continued access to facilities will be provided from Bibra Drive Redirection along alternative routes, including Progress Drive, Farrington Road and Bibra Drive Appropriate signage and information will be provided, where required	Alteration of local vehicular routes Improved safety for park users



Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Operation Phase			
Physical Presence of Road	Alteration to cycling, fitness paths and trails	Local pedestrian paths will be improved and retained through reinstatement or replacement of north-south and east-west links Creation of a new shared use path between the existing Roe Highway and Bibra Lake The extension of the PSP will provide greater contact area for exercise along the extended route Three formal passageways for north-south access between Progress Drive and Roe Swamp bridge Additional recreation paths are proposed along the edge of the corridor in some locations	A minor reduction in natural experience will occur Net benefits include: Improved westward flow from the existing Roe Highway PSP Improved standard of local pathways Improved access to wetlands for Blue Gum Montessori School
	Restricted access for providers of educational pursuits	Local pedestrian paths will be improved and retained through reinstatement or replacement of north-south and east-west links Three formal passageways for north-south access between Progress Drive and Roe Swamp bridge	Alteration of educational access routes

6.11.5.2. EPA Bulletin Matters

Table 6.11-2 highlights the EPA concerns for recreation and education from the proposed project as stated in Bulletin 1088 (EPA 2003).

Table 6.11-2: EPA Concerns for Recreation and Education as stated in Bulletin 1088

Bulletin 1088 Statement	Proposed Project Concept Response
Construction within the alignment for Stage 8 of Roe Highway would detract significantly from the recreational and educational values that the area currently provides	The construction of the proposed project will result in some interruption to recreational and educational pursuits in the short term, during construction Educational values in the immediate vicinity of the proposed road will change; however, they will provide new opportunities and will not detract significantly from the recreational and education value that the parkland currently provides

6.12. Visual Amenity

The EPA objective for visual amenity is:

> *To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable.*

This section provides a summary of the extent to which the construction and operation of the proposed project will affect visual amenity. The visual impact assessment used a number of Zones of Theoretical Visibility (ZTVs) and representative viewpoints to describe and determine impacts on visual amenity associated with the proposed project. This preliminary impact assessment assumes no relief for affected visual receptors provided by design mitigation measures through implementation of the Landscape and Urban Design Framework (Appendix X)

6.12.1. Potential Impacts

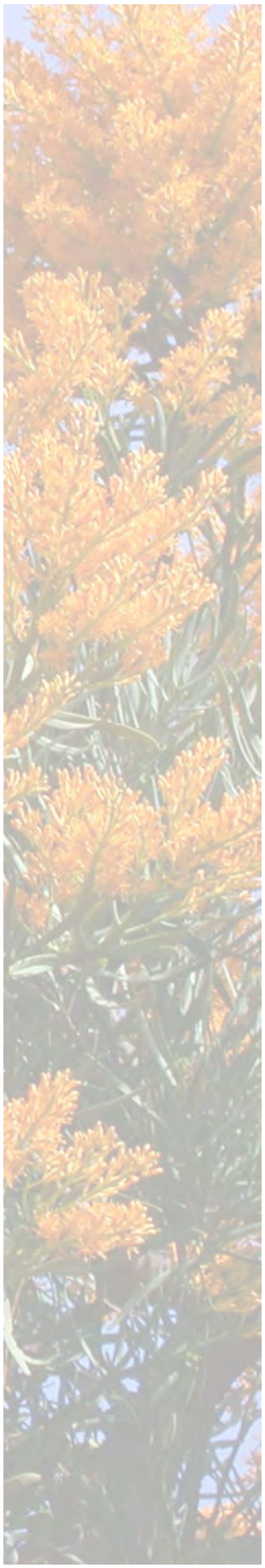
A range of potential impacts on visual amenity were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. Design and planning solutions were developed for the following potential impacts:

- Creation of storage areas for topsoil and mulch may cause views of stockpiles for nearby residents – stock piles will occur during the construction period and are therefore temporary; and
- The physical presence of the road may cause a perceived visual severance of Beeliar Regional Park from the Coolbellup, Bibra Lake and North Lake communities – Landscape Character Units (LCUs) 3 and 4 does not include noise walls and has a number of existing crossing points in the form of Hope Road and Progress Drive. Existing road infrastructure provides current levels of perceived severance.

A detailed assessment of predicted visual amenity impacts is provided in Sections 6.12.2 and 6.12.3.

6.12.2. Construction Phase Impacts

While construction activities are likely to have a significant impact on the visual amenity of the project area, it will be relatively short-term (for approximately two years). Nevertheless, these impacts will result in a decline in the visual amenity of the area, as a result of construction traffic, temporary works compounds and stockpiles, and the removal of tree cover. These activities will contrast with existing suburban, parkland and water/wetland landscape character, as well as the quality and values of the project area and will be seen by sensitive viewers of nearby surrounding suburbs (e.g. residents and recreational users).



The most significant construction impact on visual amenity is the removal of native vegetation. Where possible, clearing will be minimised to ensure cleared areas are less visible from adjacent areas. However, this has not been achieved in constrained locations, such as immediately west of Coolbellup Avenue and in locations where passive recreation takes users close to the alignment. These locations are few and this impact does not require further mitigation at these points.

The construction of the road formation, through the importation and placement of fill, will result in a more visually intrusive landscape element, generally changing it from a natural landscape to an infrastructure landscape. This element will then persist into the operation phase of the project, as the completed road.

6.12.3. Operation Phase Impacts

Operation phase impacts on visual amenity values arise from the physical presence of uncharacteristic road infrastructure in the Beeliar Regional Park and nearby surrounding residential suburbs, such as Coolbellup, North Lake and Bibra Lake. The project area currently contains inherently natural and formal parkland and water and wetland landscapes and areas that have high local and regional recreational values.

Impacts on visual amenity will be a result of the presence of road infrastructure, including embankments, road pavement, noise walls, traffic and lighting. Certain design elements have been proposed to minimise these impacts. In particular, the design objective of retaining a 20m corridor of native vegetation between North Lake Road and Stock Road will block or filter most views of the proposed project from adjacent residential areas.

Noise walls, where required, will be installed either on property boundaries, or adjacent to the edge of the road. Noise barriers located on residential boundaries have been limited to 4.4m, whilst those within the road reserve have been limited to 5m in height, providing a balance between noise benefit, cost and visual amenity (see Section 6.10). Noise walls that are no higher than the current fence line will not have an effect on the current outlook from those properties; however, those that are higher, will reduce views of native vegetation or parkland, where they currently exist. In most circumstances, noise walls that are installed along the edge of the road will be screened by a buffer of existing native vegetation and their impact will be minimal.

For ease of understanding, impacts on visual amenity values have been divided into consideration of impacts on views and impacts on landscape character of the Beeliar Regional Park and the local communities of nearby surrounding suburbs. Consideration of the impacts of lighting on visual amenity values is included.

6.12.3.1. Impacts on Views

The introduction of the transport infrastructure affects views available to sensitive viewers or viewer groups. Key views identified in the assessment that will be affected by the proposed project during daylight hours are:

1) Views across Bibra Lake. The introduction of an elevated road into numerous views looking north from points around Bibra Lake is incongruous with the existing parkland view of the water body;
2) Views in close proximity to the proposed bridge at Progress Drive and the proposed elevated structure between North and Bibra lakes (e.g. from Bassett Reserve and the paths around Bibra Lake);
3) Views in close proximity to the proposed Bibra Drive modifications (e.g. from the Blue Gum Montessori School);
4) Close distance views of the proposed noise walls for residents living around Forillion Close, Provincial Mews, Blue Ridge Crescent, Paddington Crescent, Rainbow Garden, Glasshouse Close, Marshwood Retreat, Madeleine Court, Lygon Court, Samual Court, Hope Road (including Pausin Crescent, Stone Court, Currie Place and Tetlow Place), Peterborough Circle, Greenlea Rise, Briar Court and Tana Court. In many cases, these noise walls will block views of the remaining road infrastructure and parkland or natural areas; and
5) Potentially close distance views of the elevated parts of the Kwinana interchange from Hope Road (including Pausin Crescent, Stone Court, Currie Place and Tetlow Place) and Peterborough Circle.

Most views assessed are of local importance (or sensitivity) and therefore the impact will be largely confined to a local context. There are no designated scenic lookouts in the study area, and hence no regionally significant viewpoints. However, key viewpoints do exist that could be designated as lookout points in the future (e.g. key views across Bibra Lake, such as that from Bibra Lake reserve (Viewpoint 12), illustrated in Figure 6.12-1).

For the purpose of the assessment, this and similar views are considered to be 'regionally' significant, as they are of a wetland within a regional park and are obtained by local viewers and visitors. These viewers have a proprietary, and in many cases, prolonged interest in the surrounding landscape; as opposed to a fleeting interest such as users of Stock Road or Kwinana Freeway. Figure 6.12-2 illustrates the view of the proposed project from Viewpoint 12 upon completion of construction. Figure 6.12-3 illustrates the view once screening vegetation has had an opportunity to establish alongside the works.

Figure 6.12-1: Viewpoint 12 – Existing View From Footpath by Bibra Lake Reserve

Figure 6.12-2: Viewpoint 12 – Photo Simulation Illustrating 'Unmitigated' Proposed Project

Figure 6.12-3: Viewpoint 12 – Photo Simulation Illustrating Landscape Mitigations of Proposed Project

This assessment indicated that the most significant impact will result from changing part of the existing inherently natural and formal parkland and water/wetland landscapes into transport infrastructure. A range of adverse visual impacts have been identified from a high to low level of significance. The significance of this impact will vary depending on where the road infrastructure is being viewed from, who the viewer is, what the viewer will see and how long after completion it remains in view. In most cases, the most significant level of impact will be experienced at a close distance (e.g. views from paths around Bibra Lake that are close to the proposed project), from the Blue Gum Montessori School and from Bassett Reserve.

6.12.3.2. Impacts on Character

The road infrastructure will affect the character of the natural and formal parkland, and water/wetland landscapes in the project area. Parts of this perceived and actual recreational open space landscape will be replaced with previously uncharacteristic or unprecedented transport infrastructure. This will entail the permanent loss of tall trees throughout the project, such as the *Eucalyptus* trees growing between Stock Road and Progress Drive in Landscape Character Units LCU1 and LCU2 (Figure 5.14-3).

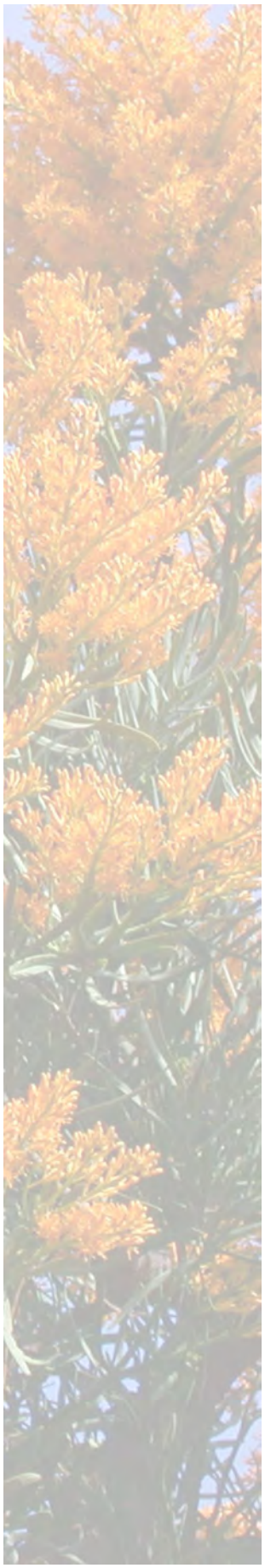
Even though LCU1, LCU2 and LCU5 are not designated as public open space, they function as locally important open, green spaces that divide the suburbs and provide informal recreational use. The introduction of the road into these LCUs, will remove a large portion of the bush/vegetation quality and value, as well as the informal recreational use.

Impacts on the landscape character of Beeliar Regional Park through LCU3 and LCU4 will result in only a small portion of the park being replaced by the new transport infrastructure. Therefore, existing parkland and wetland character and values will be maintained.

The areas immediately around the park will maintain recreational function. The inherent character of this landscape will be retained. However, the introduction of the proposed project has the potential to diminish visual amenity values of LCU3 and LCU4 parkland, as well as reduced values associated with potential weed incursion. LCU6 has limited regional or local visual amenity value. The impact will be an intensification of transport infrastructure land use and is therefore negligible.

6.12.3.3. Visual Impacts of Proposed Lighting

There is expected to be an intensification of night time light levels in close proximity to the proposed project. Night lighting can be divided into light glow, which is effectively the glow of night lighting off air particles, and light spill, which refers to those areas from which light sources are visible. This increase in night time light levels is predicted to impact views for a number of residents in close proximity to the project. These are located between Stock Road and Progress Drive, and for those residents around Peterborough Circle and Hope Road (including Pausin Crescent, Stone Court, Currie Place and Tetlow Place).



6.12.4. Mitigation of Construction Phase Impacts

The following mitigation and management measures will be implemented to reduce impacts on visual amenity during the construction of the proposed project:

- The number and size of temporary works compounds will be minimised and located as far as practicable from sensitive viewer groups, or in localities where views from residential areas are more difficult to achieve;
- An access protocol that limits the use of local streets and maximises the use of the construction corridor will be developed and implemented;
- A vegetation clearing plan will clearly delineate vegetation to be retained, which will be tagged prior to commencement of clearing activities;
- Hoardings that display art work and/or project information will be attached to construction fences in well-used locations, such as near the Cockburn Wetlands Education Centre; and
- Progressive landscaping and rehabilitation will be undertaken during construction to enable early plant establishment.

6.12.5. Mitigation of Operation Phase Impacts

The following mitigation and management measures will be applied to reduce impacts of the operation phase of the proposed project on visual amenity:

- Detailed landscape, revegetation and urban design guidelines will be developed and incorporated into the detailed design. Both the Department of Environment and Conservation and Heritage Council of Western Australia will be invited to comment on these guidelines;
- A rehabilitation programme will be implemented to establish native vegetation, with particular focus on screening the proposed project from sensitive viewers, such as residential receptors, where appropriate;
- Where noise walls are required at property boundaries, they will be offset from the existing boundary and will replace the boundary fence, by agreement with property owners;
- Where space permits, landscape strips will be established between road infrastructure (retaining walls, noise walls, barriers, etc) and adjacent residents to soften the impact of the road infrastructure noise wall for adjacent residents, provide shade for path users and assist in preventing graffiti;
- The following strategies will be undertaken in order to minimise the impacts of light spill:
    - Lighting design will be in line with best practice and Australian Standards;
    - The use of low level and/or directional Light Emitting Diode (LED) lighting, to focus light upon the area to be illuminated and away from properties, will be applied in sensitive locations and where it meets safety and lighting requirements; and
    - Aesthetic lighting will be used in locations that are away from sensitive receptors (e.g. concentrated at key nodes, such as the Kwinana Freeway interchange).

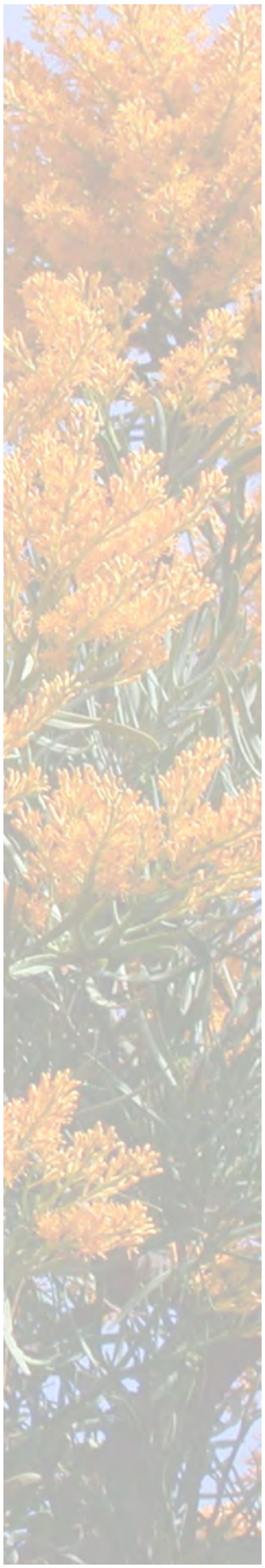
- The proposed pedestrian/cycle underpasses will comply with best practice Crime Prevention Through Environmental Design (CPTED) principles, create a positive and attractive setting, and be safe to use; and
- Methods to ensure intervisibility (i.e. views 'through' and 'under' the proposed road) between North Lake/Horse Paddock Swamp and Bibra Lake will be incorporated into detailed design, where appropriate.

6.12.6. Summary and Conclusions

This section contains a summary of the residual impacts and the consequences of the implementation of effective mitigation efforts for visual amenity. A summary of the mitigation, management and residual impacts for visual amenity is presented in Table 6.12-1.

Table 6.12-1: Residual Impacts on Visual Amenity

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Vegetation removal	Impacts on landscape character	Visual impacts will be mitigated through the retention of native vegetation to ensure screening of project works and new planting introduced to supplement existing vegetation, as much as practicable	Some vegetation clearing will remain visible from residences and recreational areas
Placement of fill, compaction of embankments and other earthworks	Views of earthworks and other construction activities	Establishment of an access protocol will ensure that construction traffic avoids public areas, as much as practicable Hoardings with project information and artwork will screen construction activities from high visibility locations Progressive landscaping and rehabilitation will be undertaken during construction	There will be limited views from parklands and private residences of construction activities adjacent to wetland and bushland landscapes for a limited period of time
Physical presence of road	Impacts on views	A landscape, revegetation and urban design will be incorporated into detailed design Views of the proposed project will be screened by noise walls and vegetation Urban design elements will blend the highway into the existing setting, as much as practicable Landscaping will endeavour to soften the hard edges of the infrastructure	Views of infrastructure and traffic from parklands and private residences adjacent to wetland and bushland landscapes will persist



Aspect	Predicted Impact	Management and Mitigation	Residual Impact
	Impacts on landscape character	Vegetation and urban design elements will be applied to blend the fringes of the proposed project into the existing environment All disturbed areas adjacent to the proposed project will be rehabilitated Urban design will attempt to integrate with the local character to engender a sense of place	Loss of intact native vegetation Over time, impacts on landscape character will diminish, due to the growth of vegetation in strategic rehabilitated locations
	Impacts of noise walls	Noise wall options will be discussed with relevant residents, where appropriate Vegetation will be used to screen noise walls where sufficient space allows. Reflective materials on noise walls will be avoided and recessive colours, materials and surface treatments used on structures within the Bibra Lake LCU Public art will be encouraged, where appropriate, to improve appearance and engender community ownership	Although noise walls will provide some screening benefits (i.e. reduced visibility of traffic and road), they will block existing views of the natural landscape
Street lighting	Intensification of night time light levels	Street and path lighting design will ensure light spill and glow are minimised, commensurate with the requirements of lighting standards	Some light spill and sky glow will occur in areas that are not currently subject to artificial lighting

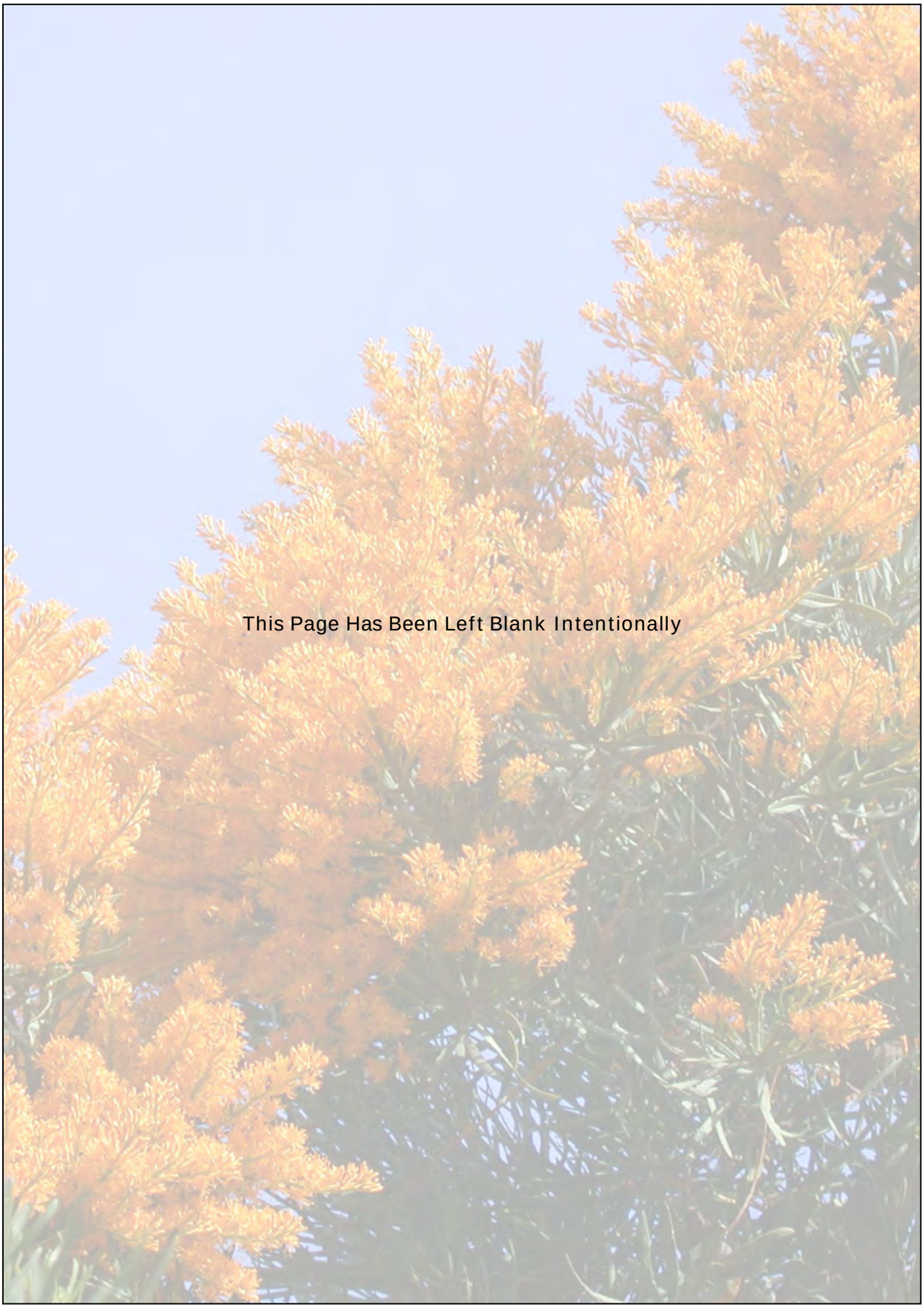
The visual impact assessment has used a number of ZTVs, representative viewpoints and photo simulations to describe and determine impacts on visual amenity associated with the proposed project. This assessment has been conducted in two parts. Firstly a preliminary impact assessment was carried out, which assumed no relief for affected visual receptors. The second part of the assessment considered the effectiveness of the proposed landscape and urban design treatments in the residual impacts assessment.

The residual impact assessment clearly illustrates that the application of the key mitigation measures identified and implementation of the Landscape and Urban Design Framework can, in many instances, reduce the level of adverse visual impact and, if carried out sensitively and to a high quality, can actually reverse the type of impact from adverse to beneficial for some affected viewers.

There are still a number of situations, where the residual impact assessment illustrates that significant impacts and effects will occur on visual amenity values (i.e. those adverse impacts over moderate/major significance) both during the day and night.

However, the visual impact assessment does determine the Visual Management Objectives defined for each of the LCUs are predominantly being met by the proposed project mitigations.

This indicates that the aesthetic values of the project area and its surrounds have been comprehensively considered, with a variety of measures proposed for adoption during detailed design, to reduce visual impacts on the landscape. In this regard, it is considered that the EPA's objectives for visual amenity have been met.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6.13. Air Quality

The EPA's objective with regard to air quality is:

> *To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.*

During construction of the proposed project, potential atmospheric emissions will include products of fuel combustion from construction fleet vehicles and equipment, as well as dust and odour emissions from construction activities. Fuel combustion emissions of concern include:

- Particulate matter;
- Carbon monoxide (CO);
- Nitrogen dioxide (NO_2);
- Organic compounds, such as volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs); and
- Heavy metals.

During operation of the proposed project, potential atmospheric emissions will include products of fuel combustion from vehicles and dust (i.e. particulate matter) generated by vehicle movement. The main air pollutants of concern associated with traffic include a selection of criteria pollutants (i.e. carbon monoxide, nitrogen dioxide and particulate matter), and five air toxics (i.e. benzene, toluene, xylenes, formaldehyde and benzo(a)pyrene).

6.13.1. Potential Impacts

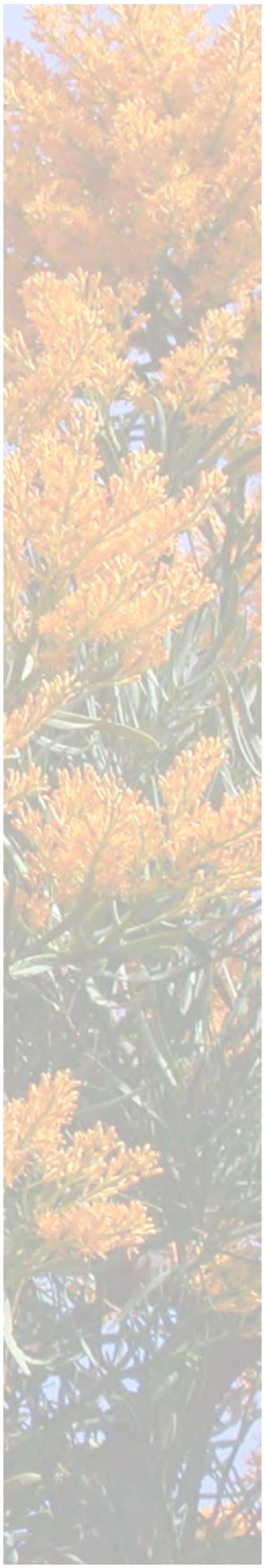
A range of potential impacts on air quality were raised during the community and stakeholder engagement programme, design meetings and internal risk assessment workshops. The following potential impacts are considered negligible:

- Construction activities, including the operation of plant and machinery and laying of asphalt may result in increased odour during construction – this impact is considered temporary and highly localised (negligible); and
- Construction activities such as above may result in an increase in air pollutants – this impact is considered temporary and negligible.

6.13.2. Construction Phase Impacts

Construction activities will result in the release of fugitive dust from earthworks and release of emissions from vehicle exhausts. During construction of the proposed project, potential atmospheric emissions include:

- Products of fuel combustion from vehicles and equipment used in construction activities; and
- Dust and odour emissions from clearing and construction activities.



Discharges to air from fuel emissions and dust during construction are primarily a management issue and can be minimised with best management practices. Predicted short-term construction impacts are based on the use of conventional construction equipment.

6.13.2.1. Fuel Combustion Emissions

Emissions from fuel combustion by vehicles and equipment will be predominantly diesel engine based and depend on the grade and composition of the fuel and the status of equipment maintenance. Fuel combustion emissions of concern include:

- Particulate matter;
- CO;
- NO_2;
- Sulphur dioxide (SO_2);
- Organic compounds, such as VOCs and PAHs; and
- Heavy metals.

The sources of fuel combustion emissions during construction operations are small, transient and widely dispersed over an extended period of time. Therefore, they are unlikely to generate significant concentrations of the criteria pollutants at sensitive receptors.

6.13.2.2. Dust Emissions

Fugitive dust arises from the mechanical disturbance of granular material exposed to the air. Common sources of fugitive dust include unpaved roads, aggregate storage piles and heavy construction operations. The dust-generation process is caused by two basic physical phenomena:

- Pulverisation and abrasion of surface materials by application of mechanical force with implements (wheels, blades, etc.); and
- Entrainment of dust particles by the action of turbulent air currents, such as wind erosion of an exposed surface by wind speeds over 19km/h (~5.3m/s).

Dust emissions comprise two components: suspended and deposited particulate matter. Deposited particulate matter refers to the mostly larger fractions that fall from the air close to emission sources. In general terms, most deposited particles have aerodynamic diameters greater than approximately 20µm. The main adverse effect associated with this material is dust nuisance, primarily due to soiling of clothes or building surfaces. Depending on the physical or chemical characteristics of the dust, it may cause surface deterioration of materials due to its abrasive or corrosive properties.

Suspended particulate matter refers to the fraction of particles that remain suspended in the atmosphere for relatively long periods and have diameters typically smaller than 20µm. Since particulate matter greater than 10µm in diameter cannot be inhaled, these particles do not penetrate further than the mouth and nose. Particulate matter smaller than 10µm in diameter (PM_{10}) can be inhaled; while fractions with particulate matter smaller than 2.5µm in diameter ($PM_{2.5}$) can enter the respiratory system.

Discharges to air (in particular, dust) during the construction phase are primarily a management issue and can be minimised with good management practices, so are not typically modelled. Accordingly, fugitive dust emissions during construction have not been quantified, but they are expected to be minimal, localised, temporary and manageable.

6.13.2.3. Air Pollutants from Potentially Contaminated Sites

Where construction activities disturb historically contaminated ground, there is a risk that pollutants such as VOCs, vapour phase PAHs and acidic aerosols may be suspended by ground disturbing construction activities. The chemical composition of these has the potential to further exacerbate potential short-term and long-term health effects associated with inhalation of particles. A preliminary site investigation indicated that the proposed project is unlikely to encounter such contaminants during construction and the proposed management of potential contaminated site issues will ensure this impact does not occur (refer to Sections 5.4 and 5.6).

6.13.3. Operation Phase Impacts

Computer-based dispersion modelling (CAL3QHCR) has been used to predict ground-level concentrations of CO, NO_2, particulate matter (i.e. $PM_{2.5}$ and PM_{10}) and the five air toxics based on traffic forecasts for 2016 (the year of opening) and 2031 (approximately 15 years after opening). Generally, CAL3QHCR modelling is used to assess air quality impacts close to roadways resulting from changes in lane configurations and traffic volumes. The details of the atmospheric dispersion modelling input data (e.g. meteorology, traffic volumes, emission estimates and sensitive receptors) and results used in this study are outlined in Appendix V.

Potential impacts have been assessed by comparing predicted concentrations against relevant regulatory air quality criteria for CO, NO_x, $PM_{2.5}$, PM_{10} and five air toxics at the nine air sensitive receptors, 12 residential receptors and the surrounding environment.

The predicted concentrations of CO, NO_2, PM_{10} and air toxics are within relevant NEPM criteria

The maximum predicted concentration of $PM_{2.5}$ is higher than the annual NEPM criteria

Compared to the existing background levels for $PM_{2.5}$, the contribution of the proposed project will be minor

Table 6.13-1 summarises the maximum predicted ground level concentrations of CO, NO_2, PM_{10}, $PM_{2.5}$ and five air toxics, including background at the worst affected of the 21 receptors for both 2016 and 2031. The predicted ground level concentrations of CO, NO_2, PM_{10}, and the five air toxics are within relevant National Environment Protection Measure (NEPM) ambient air criteria. In addition, the 24 hour average NEPM criterion of 25µg/m^3 is met for $PM_{2.5}$. However, the maximum predicted ground level concentration of $PM_{2.5}$ during both operating years is higher than the annual NEPM criteria (8µg/m^3). As discussed in Section 5.12, the annual average $PM_{2.5}$ concentration (8.7µg/m^3) measured at the South Lake monitoring station in 2006 used as background for the assessment is already above the NEPM goal of 8µg/m^3, most likely as a result of heavy industry to the south of the project area.

The contribution of the proposed project to the $PM_{2.5}$ concentration levels predicted by modelling at the 21 sensitive receptors is minor (maximum 1.5µg/m^3 in 2016 and 2.1µg/m^3 in 2031) compared to the recorded existing background of 8.7µg/m^3 used in the assessment. Furthermore, the NEPM goals set for $PM_{2.5}$ are advisory reporting standards, designed to assist in gathering sufficient data nationally on fine particle levels.

Table 6.13-1: Maximum Predicted Ground Level Concentrations of Pollutants at the Sensitive Receptors From Proposed Project Operation

Pollutant	Averaging Period	Maximum Predicted Concentration Including Background (µg/m^3)		NEPM Ambient Air Quality Criteria (µg/m^3)
		2016	2031	
CO	8 Hour	1,847	2,314	11,250
NO_2	1 Hour Annual	139 36	225 50	246 62
PM_{10}	24 Hour	33	36	50[a]
$PM_{2.5}$	24 Hour Annual	15 9.5	16 10.1	25[b] 8[b]
Benzene	Annual	2.3	2.8	10
Toluene	24 Hour Annual	16 3.5	19 4.2	4,100 410
Formaldehyde	24 Hour	6.9	7.3	50
Xylenes	24 Hour Annual	10 2.4	11.4 2.9	1,200 950
Benzo(a)pyrene	Annual	0.053	0.094	0.3

[a] no more than five exceedances per year

[b] advisory standard

6.13.4. Management and Mitigation Measures

Controlling dust and air emissions from construction activities is essentially a management exercise. The following management measures will be applied to minimise emissions of dust and other pollutants during construction activities:

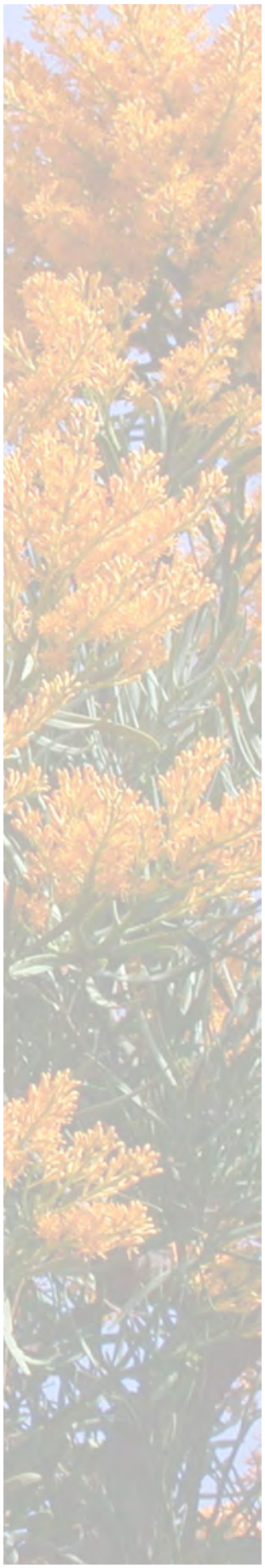
- Vehicle running times will be minimised, as much as practicable;
- An appropriate maintenance regime will be implemented to manage exhaust quality;
- Exposed soil surfaces will be treated to minimise the risk of dust lift, including dampening, chemical and/or mechanical stabilisation, wind breaks, etc.;
- Atmospheric conditions (wind) and ambient dust levels will be monitored and work practices modified to suit conditions; and
- A complaints management procedure will be established.

6.13.5. Summary and Conclusions

On the basis of the dispersion modelling results discussed above, an air quality monitoring programme is not considered a requirement during operation of the proposed project. A summary of the mitigation, management and residual impacts for air quality is presented in Table 6.13-2.

Table 6.13-2: Residual Impacts on Air Quality

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Earthworks	Elevated dust levels	Turn engines off while parked on-site Regular maintenance Modify work practices to suit atmospheric and ambient conditions Application of control procedures Complaints management system in place	Temporary, minimal levels of fugitive dust
Operation of plant and machinery	Elevated dust levels	As above	Temporary, minimal levels of fugitive dust
Transport	Predicted ground level concentrations of CO, NO_2, PM_{10}, and five air toxics below NEPM ambient air criteria $PM_{2.5}$ will make a minor contribution to current ambient levels that already exceed the NEPM advisory reporting criteria	No mitigation required	Predicted concentrations of CO, NO_2, PM_{10}, and five air toxics will be below NEPM ambient air criteria $PM_{2.5}$ will exceed advisory reporting criteria



The application of appropriate management procedures will ensure that dust and air pollutant emissions during construction will be minimised. Furthermore, the implementation of a wind and dust monitoring programme and complaints procedure will ensure that detrimental effects are recognised and responded to quickly.

Modelling indicates that air quality criteria are achieved during operation of the proposed highway, except for $PM_{2.5}$. The maximum predicted ground level concentration of $PM_{2.5}$ during operation is higher than the annual NEPM criteria ($8\mu g/m^3$). However, the contribution of the proposed project to the $PM_{2.5}$ concentration levels predicted by modelling at the 21 sensitive receptors is minor compared to the recorded existing background that is already above the NEPM criteria. Furthermore, the NEPM goals set for $PM_{2.5}$ are advisory reporting standards, designed to assist in gathering sufficient data nationally on fine particle levels. This small increase in background levels is not assessed as significant.

Accordingly, the EPA's objective for air quality can be met.

6.14. Greenhouse Gas Emissions

The EPA's objective with regards to greenhouse gases (GHGs) is:

> *To minimise emissions to levels as low as practicable on an on-going basis and consider offsets to further reduce cumulative emissions*.

6.14.1. Potential Impacts

A range of potential impacts associated with greenhouse gas emissions were raised during the community and stakeholder engagement programme, as well as during design meetings and internal risk assessments. The following impacts were determined to be of low significance or have been addressed by design solutions, which are described in detail in Appendix W:

- Freight and private transport will cause GHG emissions – the quantities of these emissions are low on a regional scale. In addition, it has been calculated that the proposed project will reduce GHG emissions across the road network by improving the efficiency of the Perth southern metropolitan road network, providing a more direct route to various destinations and reducing time spent on the road; and
- The presence of the proposed road could exacerbate the impacts of climate change on the surrounding wetland environment (e.g. reduced rainfall entering project area wetlands may be even further reduced by presence of the road) – the drainage design incorporates vegetated bioretention basins to recharge treated water captured from stormwater back into the project area wetland system.

A detailed assessment of predicted greenhouse gas impacts is provided in Sections 6.14.2 and 6.14.3.

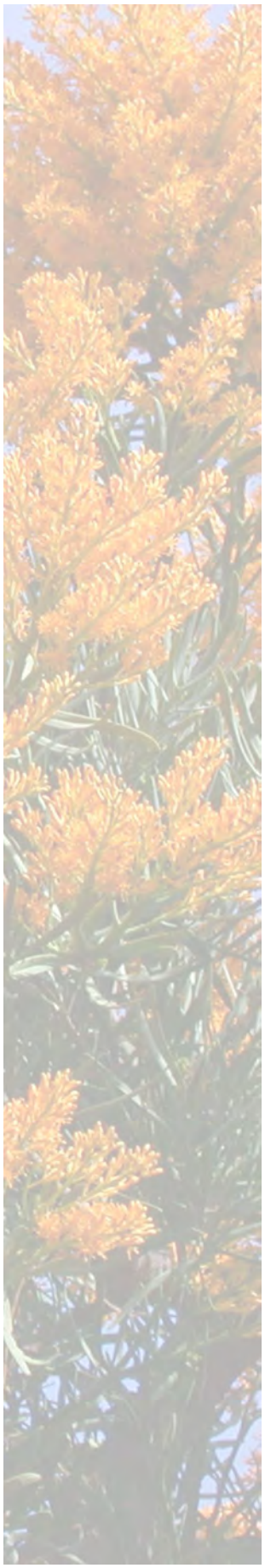
6.14.2. Construction Phase Impacts

Construction phase impacts for the proposed project are a result of the emissions associated with:

- Vegetation clearing;
- Embodied energy of materials used for construction; and
- Operation of construction plant and machinery.

6.14.2.1. GHG Emissions from Vegetation Clearing

A portion of atmospheric carbon dioxide (CO_2) absorbed by trees and other vegetation during the process of growth and photosynthesis is stored, in exchange for oxygen, as woody biomass. Clearing of vegetation results in the release of this carbon as CO_2 to the atmosphere, along with small amounts of methane (CH_4) and nitrous oxide (N_2O), caused by decomposition and soil disturbance. The quantity of the emissions associated with the clearing of vegetation (e.g. site preparation and construction earthworks) includes emissions associated with the removal of below ground carbon contained in roots.



A detailed estimation of the volume of GHG predicted to be released, as a result of clearing for the project, was undertaken with specific consideration of the existing vegetation types, condition and extent (Appendix W). The calculated total emissions predicted from this source were 3,479t CO_2-eq (carbon dioxide equivalent units), ±50%. The large margin of error is a function of difficulties in accurately estimating plant biomass and CO_2 conversion potential.

6.14.2.2. GHG Emissions from Embodied Energy

Seventy-five percent of emissions generated by the project are associated with the embodied energy of materials used in construction (i.e. total amount of energy required to produce and transport a material). Embodied emissions associated with construction materials on the proposed project are estimated at 142.5 tonnes CO_2-eq per lane per kilometre. This equates to a total of 3,468 tonnes CO_2-eq based on the construction of 6,084m of road. Table 6.14-1 presents a summary of GHG emissions expected from the construction of the proposed project.

Project construction emissions that arise as a result of energy consumed as fuel in the operation of machinery, construction plant, vehicles and electricity in the running of project and site offices are not considered to be significant.

Table 6.14-1: Summary of Greenhouse Gas Emissions Associated with Construction

Emissions Area/Source	Direct GHG (t CO_2-eq) ±50%	Indirect GHG (t CO_2-eq) ±50%
Vegetation clearing	3,479	-
Construction emissions-(onsite)	1,156	-
Embodied energy emissions	-	3,468
Total emissions	4,635	3,468

Source: Appendix W

6.14.3. Operation Phase Impacts

The operational phase impacts of the proposed project include:

- Emissions created through the production of energy to operate the asset; and
- Atmospheric emissions of GHGs through the use of the road by vehicles.

6.14.3.1. GHG Emissions from Lighting

The only significant ongoing source of GHG emissions associated with the proposed infrastructure that is within the control of Main Roads is the consumption of electricity to provide lighting for the road and associated infrastructure, including the Principal Shared Path (PSP). Electricity consumption is classified as a Scope 2 emission under the *National Greenhouse and Energy Reporting Act 2007* (*NGER Act*) guidelines, as the emissions are released to the atmosphere outside of the project area. However, this has been considered a direct emission, as the consumption of electricity is in direct control of Main Roads.

Estimated emissions have been based on the installation of traditional 250W high pressure sodium (orange) lighting, as used on major roads within the road network, representing the 'business as usual' solution. Table 6.14-2 presents a summary of GHG emissions expected from the operation of the proposed project.

Table 6.14-2: Summary of Greenhouse Gas Emissions Associated with Operation

Emissions Area/Source	Direct Annual GHG (t CO_2-eq)
Street lighting - road	128
Street lighting - path	64
Total emissions	192

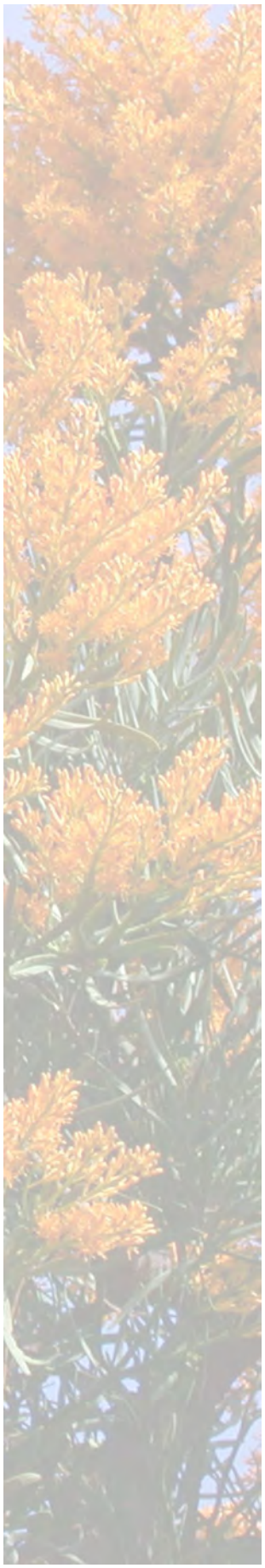
Emissions produced during the operation of the proposed project will be captured under the WA System for Accounting and Reporting Government Emissions (SARGE) scheme, but will not be reported under the *NGER Act* emissions.

6.14.3.2. GHG Emissions from Vehicles

The primary purpose of the proposed project is to improve vehicle mobility within the region. As a result, the proposed project is likely to change available travel routes, times and speeds by facilitating a faster, shorter and more direct route. As has been observed on other major road projects, increased vehicle traffic is expected to use the proposed road that otherwise might currently use alternative routes. When calculated across the road network, GHG emissions from vehicles resulting from the increased traffic flow were modelled to be approximately the same (0.4 percent with an accuracy of ± 50 percent) as compared to the 'no-build' scenario.

The assessment of the greenhouse gas emissions resulting from vehicular movements associated with both the no-build base case and the proposed project are detailed in Appendix W. This includes the standards, calculation of emissions associated with vehicle travel and estimation of emissions associated with idle time.

When emissions associated with vehicles idling at intersections and traffic lights is considered, the net daily impact of GHG emissions associated with vehicles using major roads in the metropolitan area will be less, as a result of the construction of the proposed project. Based on a conservative estimate of idle time (Appendix W), the construction of the proposed project will result in a net saving of 171 t CO_2-eq daily (62,415 tonnes of CO_2-eq annually) across the road network.



6.14.4. Impacts of Climate Change on Infrastructure

The proposed project is extremely unlikely to have a measurable impact on climate change at a local or regional level, beyond what would be experienced as a result of unassociated land use change. In contrast, the collective global impact associated with increases in GHG in the atmosphere are likely to increase the magnitude of climate changes experienced in the Perth metropolitan region, including the project area. The indirect impact of climate change on the planning, design and operation of the proposed infrastructure is discussed in detail in Appendix W. Also detailed is the discussion regarding the indirect impact of climate change that may occur on land surrounding the road and supporting infrastructure.

6.14.5. Management and Mitigation

Management strategies of climate change impacts are divided into climate change mitigation strategies (i.e. minimising GHG emissions) and climate change adaptation strategies (i.e. minimising the effects of climate change on the asset), which are terms used to describe human responses to the changing climate.

Climate change mitigation, also known as GHG management, refers to actions that reduce GHG emissions from entering the atmosphere (sequestration). Climate change adaptation refers to the way humans respond to the changed climate, including the consideration of the impacts (e.g. on infrastructure) of projected future climate and opportunities created by changed conditions.

6.14.5.1. Climate Change Adaptation

The predicted impacts of climate change on the proposed project are not significant enough to warrant specific design measures to be included. As a result of a changing climate, ongoing monitoring and maintenance will be required to ensure the life of the asset is prolonged.

6.14.5.2. Climate Change Mitigation

Greenhouse gas emissions as a result of vegetation clearing are mitigated through the implementation of measures outlined in Section 6.6. Residual impacts on factors, such as significant fauna, wetlands and vegetation loss, will be mitigated through the implementation of a proposed offsets package (Section 10). This will serve the additional function of ensuring that some carbon emissions during the life of the project are offset.

In addition to the above, specific initiatives aimed at minimising energy consumption include the use of low carbon fuels (biofuels), energy efficient lighting and recycled construction materials. Such initiatives are currently under consideration and will be implemented during the detailed design phase, where applicable.

Minimising energy consumption will reduce the total GHG emissions of the project, although, without specific strategies identified, it is not possible to quantify the extent of these reductions at this stage. Benchmark energy consumption levels are not currently available, which makes commitments to absolute savings difficult. Main Roads will monitor all energy consumption for the life of the construction period and commits to reporting the consumption results at the completion of the construction phase.

These commitments support Main Roads' existing initiatives outlined in their Carbon Response Plan, which aspires to a 5 percent minimum reduction below 2010 levels by 2020. In addition, it sets a best practice target of 15 percent reduction for emissions associated with corporate activities and those resulting from the operation of the road network, including road lighting and traffic signals.

6.14.6. Conclusion

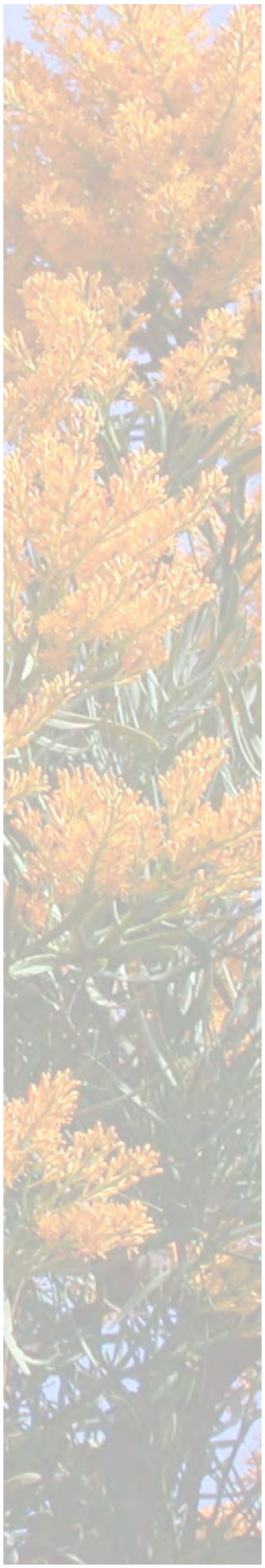
The construction of Roe Highway Extension will result in the emission of greenhouse gases, both during the construction and operation phases of the project. However, based on projected traffic movements throughout the Main Roads network, the construction of the proposed project will result in total savings of 62.4kt of CO_2-eq annually by 2031, as compared to the no-build scenario (Appendix W).

A summary of the management, mitigation and residual impacts associated with greenhouse gases is presented in Table 6.14-3.

Table 6.14-3: Residual Impacts associated with Greenhouse Gases

Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Construction Phase			
Vegetation removal	Emission of 3,479 t CO_2-eq (±50%) GHGs	Vegetation clearing will be minimised as much as practicable. Residual clearing will be offset in accordance with the proposed Offsets Package (Section 10)	Nil
Use and transport of construction materials	3,468t CO_2-eq (±50%) embodied energy emissions of materials used for construction	Provide a benchmark carbon emissions value against which to drive improvements in efficiencies for the proposed and future projects Implement specific initiatives aimed at minimising energy consumption including: Low carbon fuels (bio-fuels) Energy efficient lighting Recycled construction materials Implement a procurement policy that includes consideration of embodied energy, including transport distances	GHG emissions will be offset through a more efficient road network during operations

Improved transport efficiency will result in a net reduction of GHG emissions



Aspect	Predicted Impact	Management and Mitigation	Residual Impact
Operation Phase			
Street/PSP lighting	Emission of 192t CO_2-eq GHGs annually (energy usage)	Where possible (commensurate with road safety standards) utilise energy efficient lighting, in accordance with street and path lighting standards, to minimise energy consumption Provide a report supporting lighting standard decisions	GHG emissions as a result of energy efficient lighting strategies may be reduced Residual emissions will be offset as a result of improved transport efficiencies during operations
Freight/private transport	Reduction of 62,415t CO_2-eq emissions annually across the road network	To reduce GHG emissions across the road network by improving the efficiency of the Perth southern metropolitan road network, providing a more direct route to various destinations and reducing time spent on the road	A residual benefit will occur, as the project results in a net reduction of GHG emissions

Main Roads will provide a benchmark carbon emissions value against which to drive improvements in efficiencies for the proposed and future projects. Monitoring of all energy consumption will be undertaken for the life of the construction period, in line with Main Roads construction practices. Subsequent to this, the results of all monitoring will be submitted to the Office of the Environmental Protection Authority (OEPA) following the completion of construction.

These commitments, in conjunction with management and mitigation, will minimise emissions to levels as low as reasonably practicable on an ongoing basis, to ensure the EPA's objective for greenhouse gas emissions will be met.

7. Summary of Environmental Impact Assessment

This section provides a summary of the Environmental Impact Assessment for the proposed project. Table 7-1 summarises the existing conditions and presents the main predicted impacts, proposed management and residual impacts for each of the key factors.

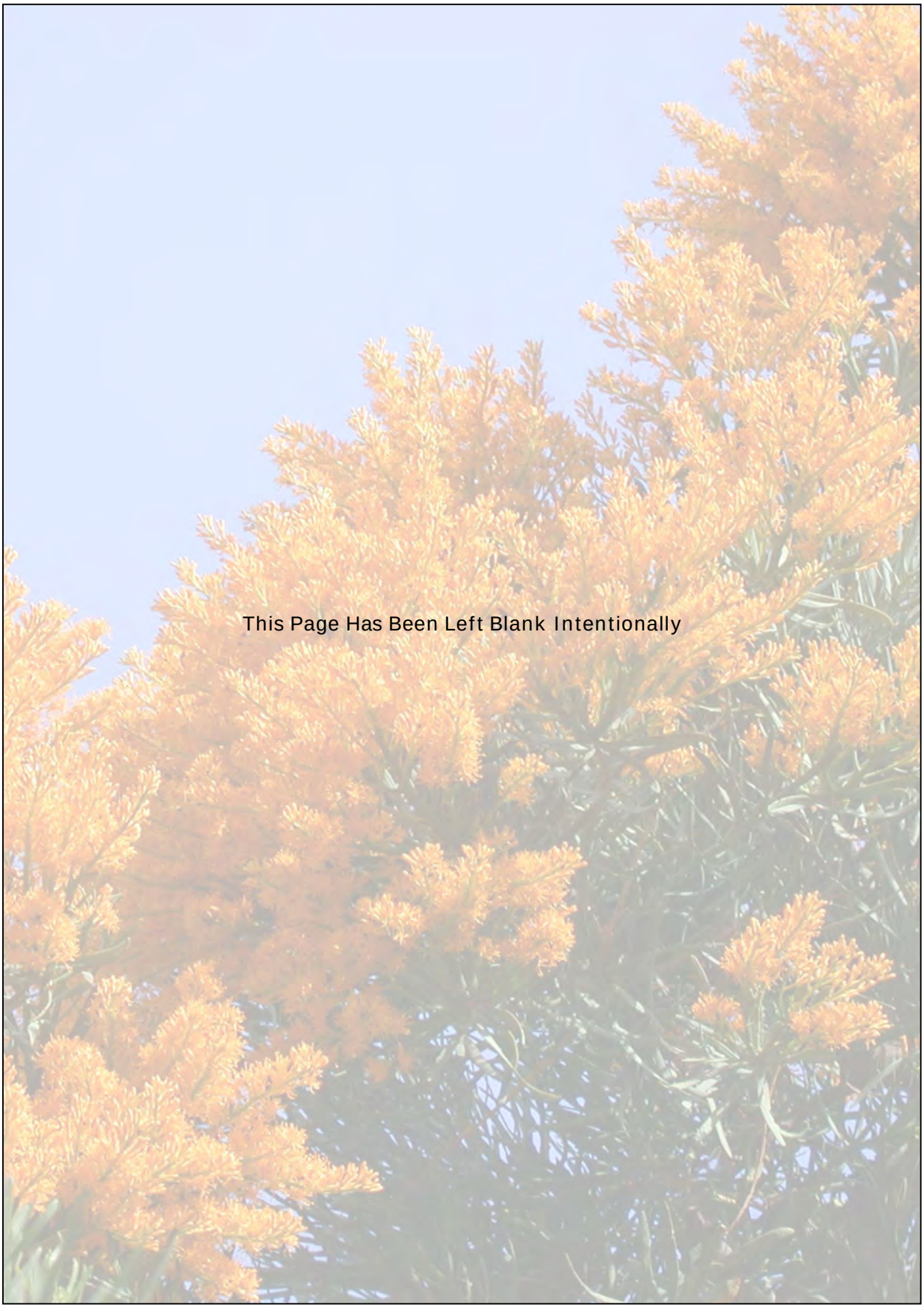

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Table 7-1: Summary of Environmental Impact Assessment

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
Wetlands	To maintain existing ecological functions and environmental values.	Project situated within the Eastern Chain of the Beeliar Wetlands, which comprises part of the Beeliar Regional park Project area divided into three hydrological zones: delivery, wetland and impoundment zones Project area encompasses two Lakes EPP wetlands (Horse Paddock Swamp and Bibra Lake), two CCW (Roe Swamp and Horse Paddock Swamp), one REW (part of Bibra Lake) and one MUW (part of Bibra Lake) Roe Swamp exhibits values commensurate with its CCW classification Horse Paddock Swamp is heavily weed infested and completely devoid of native vegetation Project area supports Groundwater Dependent Ecosystem (GDE) vegetation	Vegetation removal	Loss of fauna habitat function of the wetland resulting in alteration of species composition and abundance Loss of approximately 2.1ha of intact native vegetation within Roe Swamp CCW boundary	Relocate Murdoch Drive Extension interchange to the east Align road along cleared transmission corridor Rehabilitate secondary disturbed areas, offset loss of vegetation Strict dust management utilising water from outside project area	Reduction in extent of existing GDE vegetation communities (13.3ha) Reduction in area of intact native vegetation within Roe Swamp CCW boundary
			Excavation of road cuttings; placement of fill and other earthworks	Loss of 5.3ha of mapped CCW area (Roe Swamp and Horse Paddock Swamp), excluding 0.5ha clearing for Murdoch Drain relocation Loss of 1.0ha of mapped EPP area (Bibra Lake) Fragmentation of habitat for faunal utilisation	'Best balance' of road design to situate apertures at Roe Swamp and through formation between Progress and Bibra Drives Road alignment to avoid fragmentation of Bibra Lake and Horse Paddock Swamp Stormwater treatment basins to retain runoff, remove pollutants and infiltrate to groundwater for conveyance through wetlands Locate construction laydown areas and stockpiles outside wetland boundaries Create bioretention basin (1.7ha) between Roe and Horse Paddock swamps	Reduction in 'continuity' of Roe Swamp Filling of part of a CCW
				Localised alterations in groundwater distribution and surface water drainage patterns Temporary loss of 0.50ha of Roe Swamp CCW values with the relocation of Murdoch Drain	Install bridges at Roe Swamp and south-east of Horse Paddock Swamp Purposeful placement of culverts and openings beneath embankments along the Progress – Bibra Drive section during detailed design	
				Erosion and sedimentation of surface waters Effects on macro invertebrate communities as well as other fauna within the food web due to changes in water quality	Construction Environmental Management Plan to include best management practices to prevent emissions from project construction footprint	
				Alteration in groundwater distribution (mounding and shadowing) in response to altered water availability Localised shift in hydraulic gradient in relation to re-location of a portion of Murdoch Drain	Bioretention and/or infiltration basins to capture and treat road runoff at slow percolation rates Direct stormwater flows to basins Bioretention and other basins designed to capture and treat road runoff	
				ASS-related impacts resulting from dewatering activities	Complete detailed geological investigation Avoid deep cuts into ASS laden soils Develop and implement ASS management plan including treatment and disposal procedures	
			Presence of road	Solar shading of 0.4ha of vegetation beneath the bridge at Roe Swamp Presence of infrastructure within wetland affects amenity values and aesthetics	Reduction in total clearing footprint via design measures Vegetation rehabilitation including screen trees and sensitive lighting as required Use texture and colour on abutments, piles and walls to blend with recessive colours into natural landscape	A reduction in amenity and aesthetics
				Introduction of pollutants from road runoff or direct spills above existing background	Design to direct flows to central basins. Bioretention and/or infiltration processes to capture and treat road runoff	Drainage basins improve water quality delivered wetland areas

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
Vegetation and Flora	To maintain abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge	A total of 434 species from 244 genera and 80 families were recorded within the project area No State listed DRF nor Commonwealth listed Threatened flora recorded within the project area 6 species of naturally occurring State Priority Flora recorded within the project area A total of 40 vegetation communities were recorded in the study area consisting of 25 woodlands, two shrublands, two herbland/sedgelands and 11 other classifications 45% of the vegetation within the project area is classified as intact native vegetation ('Degraded-Good' or better condition rating) 129 introduced or non-endemic species were recorded including 3 species listed as Declared Plants No infestations of *P. cinnamomi* were identified within the project area. The majority of the project area was unmappable due to major areas of disturbance and a lack of indicator species; or areas were uninterpretable because of the presence of the Spearwood Dune association west of Progress Drive No listed TECs or PECs occur within project area The 258ha project area includes 61ha of Bush Forever Site 244 A total of 70 GDE sub-communities are present, as indicated by 29 GDE indicator species within the project area	Vegetation clearing	Loss of 37.5ha intact native flora and vegetation and associated floral biodiversity	Adjustments to the final level of the carriageways to reduce road profiles and volumes for embankments Inclusion of environmental design features resulting in the reduction in clearing requirements by 7ha Bridge structure over Roe Swamp axis to minimise clearing of functional wetland vegetation Alignment on formerly disturbed access tracks with existing clearing and lower vegetation value Incremental top-down construction methodology that avoids the need for continuous clearing and access tracks Incorporation of retaining walls (in lieu of batters) to reduce width of the footprint Restoration of existing degraded areas in the project area through revegetation and landscaping programme, including creation of bioretention basins	Loss of a total of 37.5ha of intact native flora and vegetation, including 7ha of GDE sub-communities Loss of BahS vegetation community type from project area (total of 2ha of Low Open Woodland) Loss of 7ha of Bush Forever, including 4ha of intact native vegetation Loss of 15 sub-populations of Priority Flora, consisting of approximately 7,000 individual plants (most of which are of one small herb species that is locally abundant) Successional shift from the current GDE association of species to a different community type for 12 of the 70 mapped GDE sub-communities within a 50m zone of effect
			Modified localised recharge due to infrastructure and localised concentration of infiltration at bio-retention/infiltration basins	Alteration in vegetation composition and distribution in response to altered water availability	Restoration and creation of constructed wetland areas as bio-retention basins in locations where drainage will be collected/retained/infiltrated	
			Placement of fill, compaction of embankment foundations and other earthworks	Alteration in GDE vegetation composition and distribution Alteration to distribution of groundwater dependent species	Design features included to maintain surface water movements and minimise risk of groundwater impedance Refer to management and mitigation measure described in surface and groundwater flow and wetland sections	
			Presence of infrastructure causes indirect edge effects (including weed invasion, light intrusion and desiccation)	Increased weed invasion along new project edges	Conduct annual weed control activities in accordance with a Weed Management Plan	
			Herbicide use	Inappropriate use of herbicides causing death of native flora	Weed treatments to be conducted by accredited contractors in accordance with the Weed Management Plan	
			Operation of plant and machinery	Increased risk of fire, spread of weeds and pathogens and accidental spills	Management of vehicle and plant hygiene in accordance with a Site Vehicle Hygiene Plan for the construction phase Implementing fire risk management and response procedures for construction and operational phases Soil Hygiene Management Plan will be prepared and implemented for construction phase Strict protocols regarding location of and requirements for maintenance and refuelling of construction machinery Refer to management and mitigation measures identified in the contaminant spills section.	

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
			Construction of bridges and retaining walls	Shading impacts on vegetation	Rehabilitation of areas with shade tolerant vegetation as required	
			Introduction of pollutants from road runoff or direct spills above existing background	Reduced vegetation health	Design of road corridor drainage and stormwater treatment basins to capture spills and treat stormwater flows	
			Dust from construction		Dust control measures during construction	
Fauna	To maintain abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge	Vertebrate fauna Vertebrate fauna assemblages recorded in the project area include: 8 amphibians; 88 birds; 8 native mammals; 21 reptiles; and 5 introduced mammals Fauna habitat includes: *Banksia* woodland, *Xanthorrhoea* Woodland, *Melaleuca* Woodland, *Kunzea* shrublands, sedgeland, riparian vegetation, parkland and previously rehabilitated areas Two conservation significant species recorded include: Carnaby's and Forest Red-tailed Black Cockatoo. No actual nesting or roosting sites were recorded within the project area Two DEC priority species recorded include: Perth Lined Lerista (P3) and Southern Brown Bandicoot (P5) Invertebrate Fauna No SRE taxa recorded in the project area One conservation significant species recorded (Graceful Sun-moth). 8.7ha of confirmed habitat Aquatic macroinvertebrate assemblages across the five wetlands (incl. South Lake) were dominated by: 59 insects; 23 crustaceans; 9 Arachnids; and 8 worms and leeches None of the wetlands are considered particularly significant in terms of diversity of taxa or iconic species within the macroinvertebrate assemblages	Vegetation removal	Loss 112ha of fauna habitat Removal of 249 significant trees for potential black cockatoo nesting (note, nesting is not known to occur within or near the project area) Assuming that each significant tree occupies an area of 100m^2 for potential nesting, an area of 2.5ha will be cleared of potential future nesting habitat Reduction in available black cockatoo foraging habitat	Avoidance measures implemented through design development phase Revegetation of 52ha of fauna habitat (comprising rehabilitation of 37.5ha of native vegetation cleared during construction and restoration of an additional 14ha) Monitor Graceful Sun-moth population in impact area	78.3ha loss of foraging habitat for Carnaby's Black Cockatoo 73.2ha loss of foraging habitat for Forest Red-tailed Black Cockatoo 2.5ha loss of potential future nesting habitat based on the 249 significant trees that will be impacted with an area of 100m^2 applied 72.5ha loss of habitat for Southern Brown Bandicoot 91.4ha habitat loss for Perth Lined Lerista Loss of confirmed non-viable Graceful Sun-moth population Reduction in potential habitat for future Graceful Sun-moth populations
				Fragmentation of fauna habitats	Inclusion of bridges, pedestrian underpasses and fauna underpasses throughout alignment during detailed design	Connectivity within wetland area will be available over a total of 200m at regular intervals between Bibra and Progress drives
				Injury or mortality of fauna resulting from fauna strike with plant and construction equipment. In addition, if fauna are not adequately evacuated from trees to be cleared, fauna may be injured or killed during clearing	Installation of fauna-proof fencing to contain construction machinery Translocation of fauna from construction zone	Minimal fauna strike during construction
			Operation and maintenance of plant and machinery	Increased noise produced by construction machinery will lead to temporary displacement of fauna	Noise management will be in accordance with SPP5.4 requirements and as per Section 6.10	Some displacement and behavioural changes of fauna will occur Fauna may become habituated over time
				Accidental lighting of fire as a result of careless behaviour or sparks created by construction activities. Fires cause habitat loss,	Development and implementation of a CEMP Prohibition of fire lighting during construction	Reduced risk of fire

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
		Migratory, Wetland and Shore Birds Conservation significant species recorded within the project area (those occurring in North Lake, Bibra Lake, Horse Paddock Swamp or Lower Swamp) are as follows: 14 conservation significant 1; one conservation significant 2; and seven conservation significant 3 Project area encompasses a small area of riparian vegetation on the northern edge of Bibra Lake and the southern edge of Horse Paddock Swamp which may support small numbers of wetland birds Project area supports breeding population of Rainbow Bee-eater		fragmentation and loss of sufficient area of suitable habitat to maintain viable populations	Provision of designated cigarette butt disposal containers Construction machinery fitted with spark arresters Personnel and vehicles fitted with fire fighting equipment Communication of fire management procedures to personnel via site inductions	
			Freight and private vehicle transport	Traffic using the proposed highway extension will cause some fauna mortalities as a result of direct strike with vehicles	Installation of visual barriers at critical locations (Section 6.7.4.2)to encourage birds to fly over the height of traffic Creation of dual use underpasses (fauna and pedestrian) and dedicated fauna underpasses Maintenance of permanent ground-level fencing throughout alignment Avoidance of creating foraging habitat immediately adjacent to highway	Very low rates of vehicle strike on flighted birds/other fauna
				Temporary displacement of wetland birds in some areas as a result of traffic noise, resulting in reduced survivability and reproduction	Use of quiet road surfacing materials	Some displacement and behavioural changes of fauna will occur. Fauna may become habituated over time
			Physical presence of road	Potential localised degradation/loss of fauna habitat as a result of changes in altered hydrological conditions	Maintenance of natural vegetation in drainage basin near Stock Road interchange Off-site abstraction of construction water Bridge over portion of Roe Swamp Refer to Section 6.3 for more detailed mitigation measures	Proposed mitigation measures will minimise potential for altered hydrological conditions and consequent degradation of fauna habitat
				Creation of new edges leading to altered conditions will increase the risk of competition, predation and degradation of habitat	Examination of some existing and newly created edges for their potential to be restored, revegetated or regenerated, to enable reintegration of these areas with intact vegetation and habitat Closure of Hope Road near the entrance to Native Animal Rehabilitation Centre (ARC) and the rehabilitation/revegetation of the area west of this point Ongoing post-construction monitoring of retained and rehabilitated vegetation as part of a weed control programme Preparation and implementation of Soil Hygiene Plan	Proposed mitigation measures will minimise the extent of edge effects over time
Ecological Linkages	Maintain ecological linkages and corridors between, within and across the Beeliar Regional Park in order to maintain the diversity and vigour of the Park's ecological systems	The project area is located within an urban area that has undergone fragmentation by development and associated infrastructure Existing severances of Regional and Local Ecological Linkages include: Hope Road; North Lake Road; Stock Road; Farrington Road; Kwinana Freeway The project area supports portions	Removal of vegetation	Decline in functionality of linkages	Rehabilitate disturbed roadside areas (with vehicle safety pre-requisites) Minimise clearing of existing vegetation Restoration of degraded remnants using local provenance native plants	A temporary impact on fauna linkages that require vegetation cover and leaf litter for movement (e.g. *Lerista* and Southern Brown Bandicoot)
			Earthworks and construction fencing	Reduced in connectivity for terrestrial fauna	Fauna proof fencing is essential to prevent harm to native fauna during construction and cannot be avoided	A short-term impact on fauna movement during construction until linkages can be re-established via fauna underpasses

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
		of four regional (i.e. EL1, EL2, EL3 and EL4) and two local (i.e. EL5 and EL6) ecological linkages Six regional habitat areas within or proximal to the project area are connected by ecological linkages	Physical presence of road and transmission line	Decline in connectivity	Retain natural hydrological conveyance and fauna migration pathways by providing constructed fauna and hydrology passages beneath the road alignment with opening under the road (e.g. culverts and fauna underpasses) Provide bridge and other openings (culverts/underpasses) across swamp, other natural low topographic areas and between habitats of 'good' (or better) vegetation condition ratings Provide bridge at Coolbellup Avenue/Sudlow Road and North Lake Road Replacement power lines fitted with high visibility reflectors Installation of visual barriers to encourage birds to fly over the height of traffic	Partial fragmentation of north-south EL5 and DL6 linkages Reduction in size of the east-west EL1 linkage
Noise	To protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards	Noise measurements were taken at ten sites chosen to represent noise emissions from all major and several minor roads proximal to the project corridor Major noise sources include existing transport corridors; Kwinana Freeway, North Lake Road, Stock Road and Roe Highway Minor roads comprise Murdoch Drive, Bibra Dr, Forrest Road, Farrington Road, Coolbellup Avenue, Sudlow Rd and Progress Drive. Noise sensitive receivers comprise of residential dwellings, and non-residential noise sensitive receivers comprising Blue Gum Montessori School and Hamilton Hill Senior High School	Construction activities including earthworks, road formation and pile driving	Temporary disturbance to nearby sensitive receivers associated with construction noise and vibration	Managed through best practice construction methods using quietest reasonably available machinery Use of less intrusive reversing alarms Staged installation of permanent noise walls on property boundaries adjacent to noisy construction activities Vibration monitoring may be carried out during construction to alert operators of exceedances of safe vibration limits for building damage Property condition surveys at sensitive structures prior to commencement of vibration intensive construction A construction noise and vibration management plan will be prepared in the detail design phase	Noise and vibration may be temporarily encountered during the construction phase through different parts of the project area Several recreational areas adjacent to the proposed transport corridor will potentially be affected by the proposed project during construction
			Disturbance of noise sensitive receivers by associated road operations	Noise sensitive receivers adjacent to the proposed corridor may exceed the applicable noise criteria as specified in State Planning Policy 5.4 Several recreational areas adjacent to the proposed transport corridor will potentially be affected by the proposed project	Noise barriers that best balance noise benefit, cost, feasibility, amenity, community preferences and safety and security (where these do not conflict with other planning and transport policies) will be installed prior to the opening of the road Where noise barriers are to be located on property boundaries, they will be constructed prior to the commencement of road construction, to help minimise construction noise impacts at adjacent noise sensitive receivers Preliminary noise wall mitigations comprise over 8 kilometres at an average height of 3.2m (preliminary barrier design subject to confirmation in the detail design phase)	Twenty nine receivers adjacent to the new road are predicted to marginally exceed the noise target criterion (by up to 2 dB(A)) at the ground level in 2031. All receivers are predicted to comply with the noise limit criterion at the ground floor in 2031
Aboriginal Heritage	To ensure that changes to the biophysical environment do not result in a significant adverse effect on historical and cultural associations	Aboriginal heritage is assessed under two concurrent processes; the *Aboriginal Heritage Act (AH Act) 1972* and the *Environmental Protection Act 1986 (EP Act)* Six recorded Aboriginal heritage sites under *AH Act* exist within the project area. Four sites are registered on the permanent register, one as stored data and one with insufficient information	Vegetation removal	Loss of habitat associated with Nyungar faunal values, specifically 73ha of Red-tailed Black Cockatoo foraging habitat Nyungar botanical values include: • 1.7ha of *Kunzea glabrescens* dominated vegetation communities require removal • Removal of 33.4ha of vegetation communities containing *Xanthorrea preissii* Removal of 4.18ha of vegetation communities dominated by *Melaleuca spp*	Management measures and mitigation for impacts of the proposed project on specific flora values are discussed above and within Section 6.6	Reduction in *Xanthorrhoea* numbers Reduction in *Kunzea* spearwood numbers

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
		Nyungar environmental values include; Botanical, Fauna and Water Values under the *EP Act* Botanical values include; food source, material for tools and utilitarian objects and ceremonial values Fauna values include; traditional food sources and associations Water values include; mythological values, traditional food source, traditional cultural practice and a sense of place A direct relationship exists between flora, fauna and wetlands of the project area and relative environmental values held by Nyungar people		Nyungar mythological associations include the removal of 41 individual *Nuytsia floribunda* trees	Management measures and mitigation for impacts of the proposed project on specific flora values are discussed above and within Section 6.6 A selection of *Nuytsia floribunda* trees will be translocated to suitably prominent positions to highlight Nyungar cultural values	Loss of non-iconic *Nuytsia* trees
			Excavation of road cuttings, placement of fill and other earthworks	Reduction of the integrity of mythological values, particularly with regard to perceived effects on the Waugal, through localised alterations in groundwater distribution and surface water drainage patterns	Management measures and mitigation for impacts of the proposed project on hydrology and its effects on flora and fauna are discussed above and within Sections 6.2, 6.3, 6.6 and 6.7	Reduction in area of intact native vegetation within Roe Swamp CCW boundary
				Reduction of the 'sense of place' associated with changes in hydrological regimes through localised alterations in groundwater distribution and surface water drainage patterns	Management measures and mitigation for impacts of the proposed project on hydrology and its effects on flora and fauna are discussed above and within Sections 6.2, 6.3, 6.6 and 6.7	
				Reduction of the potential for traditional cultural practices, such as fishing and hunting or the reduction of the availability of traditional food sources associated with changes in hydrological regimes: • Localised alterations in groundwater distribution and surface water drainage patterns • Loss of habitat features may result in alteration of fauna species composition, diversity and abundances	Management measures and mitigation for impacts of the proposed project on specific water, flora, and fauna values are discussed above and within their respective sections in the PER	
Visual Amenity	To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable	The project area is represented by six separate landscape character units (LCUs) Sensitive visual receptors identified within and surrounding the project area include: Residential communities Schools and local parks Recreational users of North and Bibra Lakes Anticipated landscape changes within the area also include: Jandakot Development Murdoch Activity Centre O'Connor Industrial Estate Cockburn Coast Increased urban density	Vegetation Removal	Impacts on landscape character	Visual impacts will be mitigated through the retention of native vegetation to ensure screening of project works and new planting introduced to supplement existing vegetation, as much as practicable	Some vegetation clearing will remain visible from residences and recreational areas
			Placement of fill, compaction of embankments and other earthworks	Views of earthworks and other construction activities	Establishment of access protocols to ensure construction traffic avoids public areas where practicable Hoardings with project information and artwork Progressive landscaping and rehabilitation	Limited views from parklands and private residences of construction activities adjacent to wetland and bushland landscapes for a limited time period
			Physical presence of road	Impacts on views	A landscape, revegetation and urban design will be incorporated into detailed design Views of the proposed project will be screened by noise walls and vegetation Urban design elements will blend the highway into the existing setting as much as practicable Landscaping to soften the hard edges of infrastructure	Views of infrastructure and traffic from parklands and private residences adjacent to wetland and bushland landscapes will persist
				Impacts on landscape character	Vegetation and urban design elements will be applied to blend fringes of the proposed project into the existing environment Rehabilitation of disturbed areas adjacent to the proposed project Urban design will attempt to integrate with the local character to engender a sense of place	Loss of intact native vegetation Over time, impacts on landscape character will diminish, due to the growth of vegetation in strategic rehabilitated locations
				Impacts of noise walls	Discussion of noise wall options with relevant residents where appropriate	Noise walls will provide some

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
					Vegetation screening of noise walls where space allows Reflective materials on noise walls will be avoided and recessive colours, materials and surface treatments used on structures within the Bibra Lake LCU Public art will be encouraged where appropriate to improve appearance and engender community ownership	screening benefits (i.e. reduced visibility of traffic and road) but will also block existing views of the natural landscape
			Street lighting	Intensification of night time light levels	Street and Path lighting design will ensure light spill and glow are minimised, commensurate with the requirements of lighting standards	Some light spill and sky glow will occur in areas that are not currently subject to artificial lighting
Recreation and Education	To ensure that existing and planned recreational uses are not compromised The proposed project should not detract from the educational values that the area currently provides	Passive and active recreation occurs within parks proximal to the project area Passive recreation areas include; local park recreation, North and Bibra lakes and surrounding natural areas, road reserve recreation Active recreation areas includes; Tempest Park, Len Packham Park, Meller Park Other recreational areas include; Adventure World, located west of Bibra Lake to the south of the project area Access is provided for regionally and locally by: The existing regional road network District roads Local distributor roads The Perth to Mandurah commuter train service A local footpath network Beeliar Regional Park provides an educational resource for at least 19 community organisations, primary schools, secondary schools and tertiary institutions in the local, metropolitan and state areas Education pursuits include; conservation and land management; ecosystem assessment; macroinvertebrate studies; vegetation mapping; and wetland ecology	Physical presence of road infrastructure	Alteration of local road and pathway community connections	Improved westward flow from existing Roe Highway PSP Creation of a new shared use path between the existing Roe Highway and Bibra Lake The extension of the Principal Shared Path (PSP) will provide greater contact area for exercise along the extended route Two connections will be provided under the new road at the western and eastern ends of the new northern section of shared path Three formal passageways for north-south access between Progress Drive and Roe Swamp bridge Additional recreation paths are proposed along the edge of the corridor in some locations	Alternation of public transport network Alteration of local vehicular routes Improved safety for park users A minor reduction in natural experience will occur Net benefits include: improved westward flow from the existing Roe Highway PSP; and improved standard of local pathways improved access to wetlands for Montessori School
			Excavation of road cuttings; placement of fill and other earthworks	Disturbance to the Spanish Club's playing fields Minor changes to Lakeside Recreation Centre frontage Disturbance to Murdoch Pines Golf and Recreation Park driving range, access and car parking Alteration to cycling, fitness paths and trails around the northern end of Bibra Lake and north/south routes across the road corridor Alteration of local vehicular routes North-south access will continue to occur during the road operations phase	Relocation of the Spanish Club's two playing fields Creation of a new shared use path between Roe Highway and Bibra Lake Continued consultation with the Murdoch Pines Golf and Recreation Park The extension of the Principal Shared Path (PSP) will provide greater contact area for exercise along the extended route Three formal people passageways for north-south access between Progress Drive and Roe Swamp bridge	Reconfiguration may be required for driving range, car parks, mini golf and putting green at Murdoch Pines Golf and Recreation Park
				Potential net reduction in access to local park facilities for residents in the vicinity of Gilchrist Avenue and Pausin Crescent	Improved access to recreation facilities in the vicinity of the project area for regional visitors through the provision of a more simplified, free moving and higher speed road environment Redirection along alternative routes including Progress Drive, Farrington Road and Bibra Drive Appropriate signage and information will be provided where required	
			Removal of Forrest Road between Sudlow Road and Stock Road	Loss of access route along Forrest Road between Sudlow Road and Stock Road Reduction in transport network coverage for	Local vehicular access will be maintained through reinstatement of north-south links across Roe Highway (such that existing east/west links remain viable): Alignment of Sudlow Road and Coolbellup Avenue to allow for installation of	Alteration of public transport network

Factor	Objective	Summary of Existing Conditions	Project Aspects and Associated Impact Pathways	Predicted Impacts	Key Management/Mitigations	Residual Impact
				nearby for residents	overpass to maintain local connectivity Installation of an underpass at Progress Drive to maintain north/south access Local pedestrian paths will be improved and retained through reinstatement or replacement of north-south and east-west links Adequate communication to potentially affected drivers, pedestrians and public transport providers will be provided Pedestrian connectivity to revised bus routes required/improved if substitute bus routes are created by Transperth north and/or south adjacent residential areas	
			Removal/rehabilitation of existing redundant roads (Hope Road)	Reduced local road access to recreation facilities via Hope road through its partial decommissioning	Continued access to facilities will be provided from Bibra Drive Redirection along alternative routes including Progress Drive, Farrington Road and Bibra Drive Appropriate signage and information will be provided where required	Alteration of local vehicular routes Improved safety for park users

8. Matters of National Environmental Significance

This section has been prepared specifically for DSEWPaC

The *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*, administered by the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places, which are referred to as Matters of National Environmental Significance (NES) (DSEWPaC 2009). Specifically, *the EPBC Act* governs the following eight Matters of NES:

- World Heritage;
- National Heritage;
- Wetlands of international importance (Ramsar wetlands);
- Listed threatened species and communities;
- Listed migratory species;
- Nuclear actions;
- Great Barrier Reef; and
- Commonwealth marine areas.

In accordance with the *EPBC Act*, a proposed action that will or is likely to have a significant impact on the above Matters of NES requires approval from the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities. Pursuant to Section 45 of the *EPBC Act*, the proposed project will be assessed under the bilateral agreement established between the Commonwealth and the State of Western Australia. Under this agreement, DSEWPaC will review the State-determined project conditions and assess their suitability with respect to Matters of NES. DSEWPaC may liaise with the State Office of Environmental Protection Authority (OEPA) to potentially supplement necessary conditions. The Minister for Sustainability, Environment, Water, Populations and Communities will then make a separate project approval decision.

The online protected matters search tool (Appendix Y) indicates that the proposed project has the potential to affect several Matters of NES. Accordingly, the proposal was referred to the Commonwealth (at the time, Department of Environment, Water, Heritage and the Arts) in July 2009. In September 2009, the proposed project was determined to be a 'controlled action' under the *EPBC Act*, requiring formal assessment and approval by DSEWPaC. Controlling provisions were identified as:

- Listed threatened species and communities; and
- Listed migratory species.

The purpose of this section is to provide a summary of the issues pertaining to Matters of NES relevant to the proposed project as depicted in a series of maps provided in Section 3.5 (Figure 3.5-1to Figure 3.5-6). Table 8.1-1 summarises these matters and, where necessary, refers to relevant sections within this Public Environmental Review (PER) that provide additional detail.

No Commonwealth listed flora was recorded within the project area

8.1. Impacts on Matters of National Environmental Significance

Threatened fauna and flora may be listed in the following categories, as defined in Section 179 of the *EPBC Act*:

- Extinct – there is no reasonable doubt that the last member of the species has died;
- Extinct in the Wild – it is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form;
- Critically Endangered – it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria;
- Endangered – it is not critically endangered and it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria;
- Vulnerable – it is not critically endangered or endangered and it is facing a high risk of extinction in the wild in the medium term future, as determined in accordance with the prescribed criteria; and
- Conservation Dependent – the species is the focus of a specific conservation programme the cessation of which would result in the species becoming vulnerable, endangered or critically endangered, or is a species of fish, or is the focus of a plan of management (in force under a law of the Commonwealth or of a State or Territory) that provides for management actions necessary to stop the decline of, and support the recovery of, the species.

Once a species is listed under the *EPBC Act*, its recovery is promoted using conservation advice, recovery plans and the Act's assessment and approval provisions.

This section details the species listed on the EPBC Threatened Species and Communities list that have been recorded within the project area. The information has been summarised from the EPBC online search tool (Appendix Y) and should be referred to online for citations and references. Potential impacts on listed Matters of NES include:

- Habitat loss;
- Road mortalities;
- Increased noise;
- Artificial night lighting; and
- Fire.

Collision with powerlines is an existing impact on listed migratory terrestrial birds, which may be reduced as a result of project development and implementation by installing additional reflective discs and raising the height of the lines.

Table 8.1-1: Summary of Matters Protected under the *EPBC Act*

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
World Heritage Properties						
The *EPBC Act* Protected Matters Search Tool did not return results for World Heritage Properties within or related to the project area. Therefore, no impact will occur on World Heritage Properties						
National Heritage Places						
Neither the *EPBC Act* Protected Matters Search Tool nor the Australian Heritage Council online database identified National Heritage Places within or related to the project area. Therefore, no impact will occur on National Heritage Places						
Wetlands of International Importance (Ramsar Sites)						
Becher Point Wetlands; Forrestdale Lake & Thomsons Lake; and Peel-Yalgorup System	Project area is located within the same catchment as the Becher Point Wetlands and Peel-Yalgorup System Becher Point Wetlands are approximately 35 km south-west of the project area Forrestdale Lake and Thomsons Lake are approximately 12km south-east and 7km south, respectively	No impact on the Becher Point Wetlands is predicted No impacts on Forrestdale Lake and Thomsons Lake are predicted	No mitigation or management measures are proposed	Yes	No	Impacts on and management of these sites are not discussed further
Listed Threatened Species and Communities						
Birds						
Calyptorhynchus banksii naso (Forest Red-tailed	This species was recorded during spring 2009 and autumn 2010 surveys in several locations in the study area	Vegetation clearing will result in a total loss of 73.2ha (45 percent) of available Red-tail Black Cockatoo	Design features to reduce the width of the footprint and therefore amount of *Eucalyptus* and *Banksia* woodland	Yes	Yes	Section 5.9 and Section 6.7

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Black Cockatoo) Vulnerable	Several records of this species foraging were made during project surveys Targeted surveys did not record evidence of breeding by Forest Red-tailed Black Cockatoos within the project area. The closest breeding record for this species is at Stake Hill, which is located 47km south of the project area (Kirkby 2010) No known roost locations occur in the project footprint Closest roost site is 150m from project area	foraging habitat within the project area. As animals forage over large areas, this equates to approximately 0.85% in a regional context Clearing of 249 significant trees (DBH >500mm), 20 of which contain hollows of sufficient size for potential future nesting Fragmentation of known and potential habitat, leading to a possible decline in habitat condition from edge effects Loss of sufficient area of suitable habitat to maintain viable populations (carrying capacity) in the context of cumulative habitat loss	habitats to be disturbed have been adopted Avoid or minimise habitat loss, degradation and fragmentation by: Avoiding clearing or disturbance outside the defined project footprint boundaries Implementing a soil hygiene and weed control programme Revegetating or rehabilitating edges to minimise edge effects Install visual barriers, such as 3m vertical (diversion) poles to discourage flight into path of vehicles at sensitive locations (See Section 8.2.2) Fit replacement powerlines with high visibility reflectors Implementing fire management procedures			
Calyptorhynchus baudinii (Baudin's Black Cockatoo) Vulnerable	Avifauna surveys did not record sightings within the project area Desktop assessment determined it unlikely that Baudin's Black Cockatoo occurs in the project area	No impact on *Calyptorhynchus baudinii* is predicted	No management measures are specifically proposed for *Calyptorhynchus baudinii*; however, management measures for black cockatoos will be implemented	Yes	No	Impacts on and management of this species are not further discussed

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Calyptorhynchus latirostris (Carnaby's Black Cockatoo) Endangered	Carnaby's Black Cockatoo was recorded at several locations in the study area, including in flocks of up to 70 individuals Several records exist from previous surveys in the vicinity of the project area Extensive foraging records were documented throughout the study area during the surveys Project area surveys did not record evidence of roosting; however, the Great Cocky Count recorded 12 known roost sites within 6km Project area surveys did not record the use of nesting hollows. The closest nesting site of Carnaby's Black Cockatoo has been recorded at Baldivis, 27km south of the project area In recent decades there has been a noticeable shift in the breeding range for this species, moving into the Jarrah/Marri forests of the Darling Scarp and the Tuart forests of the Swan Coastal Plain	Vegetation clearing will result in a loss of 78.3 (44%) of available Carnaby's Black Cockatoo foraging habitat within the project area (0.85% in a regional context) The clearing of 20 trees in the project area that are potentially suitable for nesting (i.e. currently contain hollows) Fragmentation of known and potential habitat, leading to a possible decline in habitat condition from edge effects Loss of sufficient area of suitable habitat to maintain viable populations (carrying capacity) in the context of cumulative habitat loss	Design features to reduce the width of the footprint and therefore amount of *Banksia* and *Eucalyptus* woodland habitat to be disturbed have been adopted Avoid or minimise habitat loss, degradation and fragmentation by: Avoiding clearing or disturbance outside the defined project footprint boundaries Implementing a soil hygiene and weed control programme Revegetating or rehabilitating edges to minimise edge effects Install visual barriers, such as 3m vertical (diversion) poles to discourage flight into path of vehicles at sensitive locations (See Section 8.2.2) Fitting replacement powerlines with high visibility reflectors Implementing fire management procedures	Yes	Yes	Section 5.9 and Section 6.7
Insects						
Synemon gratiosa (Graceful Sun-moth)	Six individuals of this species were recorded at the north-western side of the Stock Road and Forrest Road intersection; and additional records	Loss of 5.6ha of known and 60.5ha of potential habitat due to the clearing of vegetation; 64% of	Monitor Graceful Sun-moth population in impact area Contributing funding to a Graceful Sun-	Yes	Yes	Section 5.9 and Section 6.7

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Endangered	were made in the north-east quadrant Suitable habitat exists elsewhere in the project area, but field surveys did not yield additional records of the Graceful Sun-moth in these locations Due to the short adult life span and subsequent variation in flight periods of the adult moths during the target months, the project surveys record of several individuals suggests that they were collected from an isolated population limited in abundance Another population (three individuals) was recorded during surveys of the Wandi Nature Reserve and Jandakot Regional Park bushland in March-April 2010	confirmed habitat for this population will be disturbed The clearing of habitat during construction will result in mortality of individuals (at the larval development stage) in a known population Loss of known and potential habitat (vegetation communities known to support or potentially support *L. hermaphrodita)* Although the recorded population is already unlikely to be viable, the proposed project will further disrupt this population by lowering the level of breeding	moth research programme (as an approved offset)			
Mammals						
Dasyurus geoffroii (Chuditch, Western Quoll) Vulnerable	*Dasyurus geoffroii* has a patchy distribution throughout the Jarrah forest and mixed Karri/Marri/Jarrah forest of south-west WA and has been determined unlikely to occur in the project area *Dasyurus geoffroii* was not recorded in the project area during systematic vertebrate surveys	No impacts on *Dasyurus geoffroii* are predicted	No management measures are proposed, as *Dasyurus geoffroii* was not recorded in the project area	Yes	No	Impacts on and management of this species are not discussed further
Phascogale calura (Red-tailed	*Phascogale calura* populations are currently known from several isolated nature reserves in the south-west of WA, from the wheatbelt to the	No impacts on *Phascogale calura* are predicted	No management measures are proposed as *Phascogale calura* was not	Yes	No	Impacts on and management

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Phascogale) Endangered	south coast It has been determined unlikely to occur in the project area and was not recorded in the project area during systematic vertebrate surveys		recorded in the project area			of this species are not discussed further
Setonix brachyurus (Quokka) Vulnerable	The current distribution of the *Setonix brachyurus* includes Rottnest and Bald Islands, as well as some mainland sites It has been determined unlikely to occur in the project area and was not recorded in the project area during systematic vertebrate surveys	No impacts on *Setonix brachyurus* are predicted	No management measures are proposed as *Setonix brachyurus* was not recorded in the project area	Yes	No	Impacts on and management of this species are not discussed further
Plants						
Caladenia huegelii (Grand Spider-orchid) Endangered	Habitat preferences, location and previous records indicate that *C. huegelii* has the potential to be supported by the project area *C. huegelii* was not recorded during the 2009/2010 targeted field surveys	No impacts on *C. huegelii* are predicted	No management measures are proposed as *C. huegelii* was not recorded in the project area	Yes	No	Section 5.8 and Section 6.6 Impacts on and management of this species are not discussed further
Darwinia sp. Muchea (B.J. Keighery 2458) (Muchea	Habitat preferences, location and previous records indicate that *Darwinia sp. Muchea* is unlikely to occur in the project area *Darwinia sp. Muchea* was not recorded during	No impacts on *Darwinia sp. Muchea* are predicted	No management measures are proposed as *Darwinia sp. Muchea* was not recorded in the project area	Yes	No	Impacts on and management of this species are not

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Bell) Critically Endangered	the 2009/2010 targeted field surveys					discussed further
Drakaea elastica (Glossy-leafed Hammer Orchid) Endangered	Habitat preferences, location and previous records indicate that *D. elastica* has the potential to be supported by the project area *D. elastica* was not recorded during the 2009/2010 targeted field surveys	No impacts on *D. elastica* are predicted	No management measures are proposed as *D. elastica* was not recorded in the project area	No	No	Impacts on and management of this species are not discussed further
Drakaea micrantha (Dwarf Hammer Orchid) Vulnerable	Habitat preferences, location and previous records indicate that *D. micrantha* is unlikely to occur in the project area *D. micrantha* was not recorded during 2009/2010 targeted field surveys	No impacts on *Drakaea micrantha* are predicted	No management measures are proposed as *Drakaea micrantha* was not recorded in the project area	No	No	Impacts on and management of this species are not discussed further
Lepidosperma rostratum (Beaked Lepidosperma) Endangered	Habitat preferences, location and previous records indicate that *L. rostratum* has the potential to be supported by the project area *L. rostratum* was not recorded during comprehensive 2009/2010 field surveys	No impacts on *L. rostratum* have been identified as this species are predicted	No management measures are proposed as *L. rostratum* was not recorded in the project area	Yes	No	Impacts on and management of this species are not discussed further
Listed Migratory Species						

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Migratory Birds Twenty-one avifauna species listed as migratory under the *EPBC Act* may occur, or are known to occur, within one or more of the 13 wetlands surveyed (Appendix O)						
Terrestrial Species						
Haliaeetus leucogaster (White-bellied Sea-eagle)	*Haliaeetus leucogaster* has been recorded at Bibra Lake and North Lake It is generally a coastal species that has been recorded at some wetlands during the 2009/2010 water birds survey	*Haliaeetus leucogaster* will not be directly affected by habitat loss, fragmentation or edge effects as there will be no loss of shoreline or lakebed habitats within the project area	No species specific management measures are proposed as its habitat will not be directly impacted by the proposed project	Yes	Yes	Section 5.9 and Section 6.7
Merops ornatus (Rainbow Bee-eater)	*Merops ornatus* is considered common in most areas it inhabits and is a habitat generalist (in terms of both foraging and nesting) *Merops ornatus* utilises most habitats for foraging throughout the project area It was recorded nesting in open sandy areas/tracks within the project area and is widely recorded in surrounding areas *Merops ornatus* is known to use disturbed sandy areas for nest building	Vegetation clearing and ground disturbance will result in a loss of 90ha of potentially suitable habitat Nesting sites are occasionally reused; disturbance will occur at the location of a previously recorded nesting site The scale of impact on *M. ornatus* is considered to be negligible, given its lack of specific habitat preferences Ground disturbance is likely to increase the available nesting habitat, but will attract nesting pairs closer to traffic	Minimise the design width of the proposed project Rehabilitate disturbed areas Use directional lighting to minimise the extent of light spill Install visual barriers, such as 3m vertical (diversion) poles to discourage flight into path of vehicles at sensitive locations (See Section 8.2.2) Consider noise attenuation methods Proposed impact management strategies for noise, lighting and road mortality are detailed in Section 6.7	Yes	Yes	Section 5.9 and Section 6.7
Plegadis falcinellus (Glossy Ibis)	*Plegadis falcinellus* has been recorded at North and Bibra lakes	*Plegadis falcinellus* will not be directly affected by habitat loss,	Use of directional lighting to minimise the extent of light spill	No	Yes	Section 5.9 and Section

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
	This species occurs as a non-breeding summer visitor on some of the wetlands adjacent to the project area	fragmentation or edge effects as there will be no loss of shoreline or lakebed habitats within the project area Increased traffic noise may affect bird communication Road mortality may occur where suitable habitat is available on both sides of the proposed alignment Artificial night lighting may result in a decline of migratory birds frequenting the northern portion of Bibra Lake	Install visual barriers, such as 3m vertical (diversion) poles to discourage flight into path of vehicles at sensitive locations (See Section 8.2.2) Consideration of noise attenuation methods Proposed impact management strategies for noise, lighting and road mortality are detailed in Section 6.7			6.7
Wetland Species						
Ardea alba (Great Egret, White Egret)	This species has since undergone taxonomic revision since the generation of the EPBC search report. The Australasian population is a separate species, *Ardea modesta*. Refer to *Ardea modesta* for potential impacts and mitigation	Refer to *Ardea modesta*	Refer to *Ardea modesta*	Australasian species is *Ardea modesta*	No	Not discussed further as occurrence and impact unlikely
Ardea modesta (Eastern Great Egret)	*Ardea modesta* was recorded in the wetland bird and shorebird study area	*Ardea modesta* will not be directly affected by habitat loss, fragmentation or edge effects as there will be no loss of shoreline or lakebed habitats within the project area Increased traffic noise may affect bird communication	Proposed impact management strategies for noise, lighting and road mortality are outlined in Section 6.7	No	Yes	Section 5.9 and Section 6.7

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
		Road mortality where suitable habitat is available on both sides of the proposed alignment Artificial night lighting may result in a decline of migratory birds frequenting the North and Bibra lakes				
Ardea ibis (Cattle Egret)	*Ardea ibis* was recorded at North Lake adjacent to the project area Globally, *Ardea ibis* has a very large range and population, and the population seems to be increasing	*Ardea ibis* will not be directly affected by habitat loss, fragmentation or edge effects as there will be no loss of shoreline or lakebed habitats within the project area Increased traffic noise may affect bird communication Road mortality may occur where suitable habitat is available on both sides of the project area Artificial night lighting may result in a decline of migratory birds frequenting the northern portion of Bibra Lake	No management measures are proposed as *Ardea ibis* was not recorded, and is not expect to occur, in the project area	Yes	Yes	Not discussed further as occurrence and impact unlikely
Botaurus poiciloptilus (Australasian Bittern)	The *Botaurus poiciloptilus* is unlikely to occur within the project area due to the small area of suitable habitat intersecting the project area and was not recorded in the project area during project surveys The nearest recording is at Thomsons Lake	No impacts on *Botaurus poiciloptilus* are predicted	No management measures are proposed as *Botaurus poiciloptilus* was not recorded in the project area	No	No	Not discussed further as occurrence and impact unlikely
Marine Species						

Matter of NES	Existing Environment	Predicted Impacts	Management/Mitigation	Recorded in		Section in PER
				EPBC Act Search Tool	Survey	
Apus pacificus (Fork-tailed Swift)	*Apus pacificus* is unlikely to use near-coastal wetlands (including those adjacent to the project area), except as occasional vagrants *Apus pacificus* was not recorded in the project area during project surveys	No impacts on *Apus pacificus* are predicted	No management measures are proposed as *Apus pacificus* was not recorded in the project area	Yes	No	Not discussed further as occurrence and impact unlikely
Ardea alba (Great Egret)	See above – Wetland Species	-	-	-	-	-
Ardea ibis (Cattle Egret)	See above – Wetland Species	-	-	-	-	-
Nuclear Actions						
The proposed project does not involve nuclear actions						
The Commonwealth Marine Environment						
The proposed project will not take place in proximity to a marine area						
Other Matters Protected by the EPBC Act (*not previously discussed*)						
Limnodromus semipalmatus (Asian Dowitcher)	*Limnodromus semipalmatus* is unlikely to use project area wetlands except as occasional vagrants *Limnodromus semipalmatus* was not recorded in the project area during project surveys	No impacts on *Limnodromus semipalmatus* are predicted	No management measures are proposed as *Limnodromus semipalmatus* was not recorded in the project area	Yes	No	Not discussed further as occurrence and impact unlikely

8.1.1. Listed Threatened Birds

An extensive survey and monitoring programme was undertaken to determine the current extent and types of use of the project area by black cockatoos (Appendix M). Aspects that give rise to potential impacts on Forest Red-tailed Black Cockatoos and Carnaby's Black Cockatoos within the project area include:

- Removal of vegetation;
- Operation of construction machinery;
- Interruptions to ground and surface water hydrology as a result of ground compaction and earthworks;
- Movement of traffic during operation; and
- Use of artificial night lighting.

As a result of the above aspects, the following impacts are predicted:

- Habitat loss and fragmentation;
- Road mortalities; and
- Displacement.

Black cockatoos in the project area are currently at risk of mortality due to collisions with powerlines. It is proposed to reduce this risk through the installation of reflective discs while relocating the power line.

For detailed information on these potential impacts, refer to Section 6.7.

8.1.1.1. Calyptorhynchus banksii naso (Forest Red-tailed Black Cockatoo) - Vulnerable

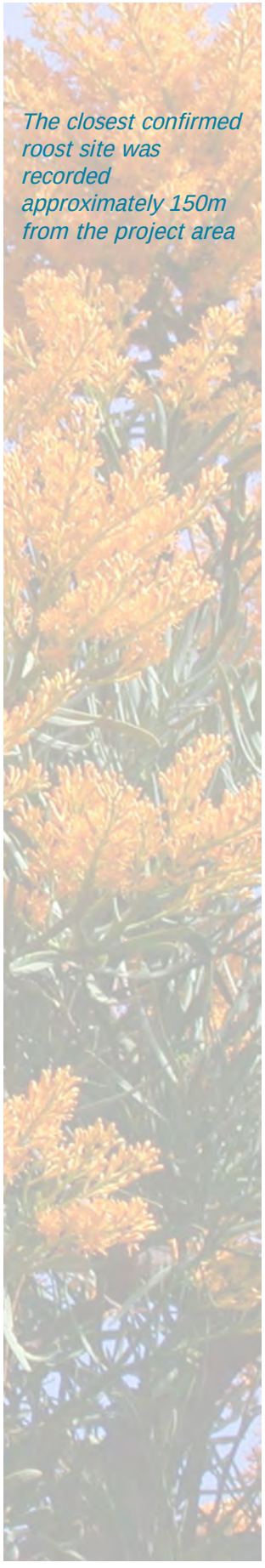
The Forest Red-tailed Black Cockatoo is listed as Vulnerable under the *EPBC Act* and Schedule 1 under the *Wildlife Conservation Act 1950* (*WC Act*). This subspecies is endemic to the south-west of Western Australia and is under threat due to habitat loss, illegal shooting and competition with introduced bees for nest hollows. It displays erratic breeding activity in the summer and winter seasons (Kirkby 2010). These birds primarily nest in large hollows of Marri (*Corymbia calophylla*), Jarrah (*Eucalyptus marginata*), Wandoo (*Eucalyptus wandoo*), Bullich (*Eucalyptus megacarpa*), Tuart (*Eucalyptus gomphocephala*) and Karri (*Eucalyptus diversicolor*) (Johnstone and Kirkby 2009). The closest breeding record to the project area is at Stake Hill, which is located 47km south of the project area (Kirkby 2010). The diet of the Forest Red-tailed Black Cockatoo primarily consists of seeds of Marri, Jarrah, Blackbutt, Karri, Sheoak (*Allocasuarina fraseriana*), Snottygobble (*Persoonia longifolia*) and, in recent times, the seeds of Cape Lilac (Johnstone and Kirkby 2009).

The closest confirmed nesting for the two cockatoos is approximately 27km south of the project area

This species was recorded during spring 2009 and autumn 2010 surveys in several locations within the study area. Several foraging records of this species were collected during project surveys.

There are no known roost locations within the project area; however, the black cockatoo survey identified four known Forest Red-tailed Black Cockatoo roost sites located between 150m and 1.5km from the project area.

The closest confirmed roost site was recorded approximately 150m from the project area



8.1.1.2. Calyptorhynchus latirostris (Carnaby's Black Cockatoo) - Endangered

Carnaby's Black Cockatoo is listed as endangered under the *EPBC Act* and Schedule 1 under the *WC Act*. The species is endemic to the south-west of Western Australia. Its range and abundance has significantly declined due to land clearing for agriculture, forestry and urban development. It faces continuing threats on the Swan Coastal Plain as important feeding habitat is cleared (DEWHA 2010a).

Carnaby's Black Cockatoos breed in eucalypt woodlands between the Stirling Range and Three Springs. Numerous records also exist for the Swan Coastal Plain and the northern Darling Scarp (Higgins 1999; Johnstone and Kirkby 2009). The closest breeding record is at Baldivis, 27km south of the project area (Kirkby 2010). Individuals nest mainly in hollows of smooth-barked eucalypts, especially Salmon Gum (*Eucalyptus salmonophloia*) and Wandoo. On the Swan Coastal Plain, nests are mostly recorded in Tuart. There has been a shift in the breeding range of this species further west and south since the middle of last century. A more rapid transgression in the past 10 to 30 years has shown their range to be moving into the Jarrah/Marri forests of the Darling Scarp and the Tuart forests of the Swan Coastal Plain (Johnstone and Kirkby 2009).

Breeding success for Carnaby's Black Cockatoo is largely dependent on suitable feeding habitat adjacent to the nest site to provide the necessary food for the survival of the chick. Breeding individuals forage no more than approximately 20km from their nesting hollows (ENV 2009), so having sufficient foraging resources close to breeding areas (particularly within a 12km radius) is critical to its breeding success (ENV 2009). Non-breeding birds visit the Swan Coastal Plain (including the Perth Metropolitan Region) from December to July. On the Swan Coastal Plain, important foraging species consist of *Banksia attenuata*, *B. menziesii*, *B. grandis*, *B. ilicifolia*, *B. sessilis*, *B. prionotes*, *Corymbia callophyla*, *Eucalyptus marginata* and non-native *Pinus* species (Valentine and Stock 2008, Higgins 1999).

Carnaby's Black Cockatoo was recorded at several locations in the study area including flocks of up to 70 individuals. Several records exist from previous surveys in the vicinity of the project area (DEC 2010c). Foraging records were documented throughout the study area during the latest surveys.

There was no roost sites recorded within the project area for Carnaby's Black Cockatoo. Six known and up to 16 potential roost sites have been recorded for Carnaby's Black Cockatoo within 6km of the project area. It is likely that indications of foraging within the project area are from individuals originating from these locations (Appendix M).

8.1.1.3. Calyptorhynchus baudinii (Baudin's Black Cockatoo) - Vulnerable

Baudin's Black Cockatoo is found only in the extreme south-west of Western Australia. The range of the species extends from Albany northward to Gidgegannup and Mundaring (east of Perth), and inland to the Stirling Ranges and near Boyup Brook. Breeding has been recorded in the far south of the range, in an area extending from Nornalup northward to near Bridgetown, or sometimes further north to Lowden and Harvey.

Baudin's Black Cockatoo occurs in high-rainfall areas, usually at sites that are heavily forested and dominated by Marri and *Eucalyptus* species, Karri and Jarrah. However, it also occurs in Wandoo woodland and in orchards, and is occasionally recorded in farmland and grasslands. Their diet also consists mainly of the seeds of eucalypts, supplemented with insect larvae and the seeds of other plants such as *Banksia, Dryandra*, *Erodium, Hakea, Malus sylvestris* (apple) and *Pyrus communis* (pear), and occasionally nectar from Marri or other plants. They nest in the hollows of large trees, predominantly of the species described above. Preferred roosts are in areas with a dense canopy that provide birds protection from weather conditions close to permanent sources of water (Johnstone and Kirkby 2008).

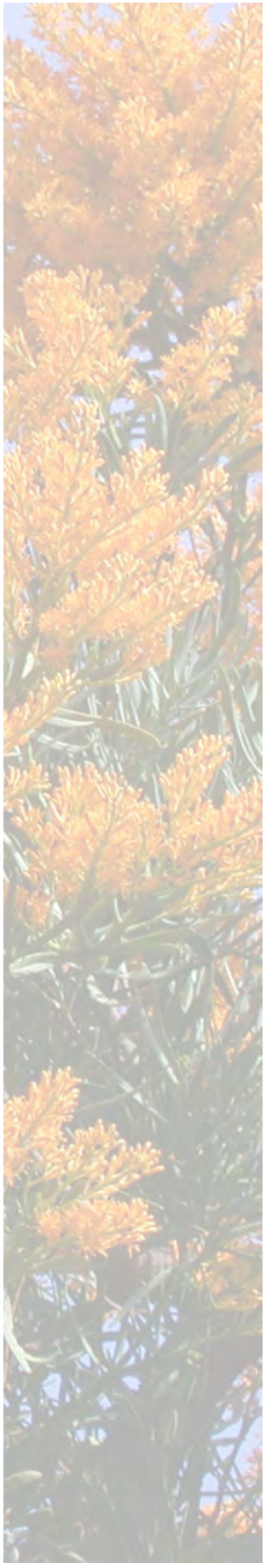
At least some birds undertake post-breeding dispersal between May and September. Therefore, they could potentially be encountered in largest numbers in the project area at that time. However, surveys to date have not recorded evidence of this species occurring within the project area.

8.1.1.4. Assessment against Significant Impact Threshold Values

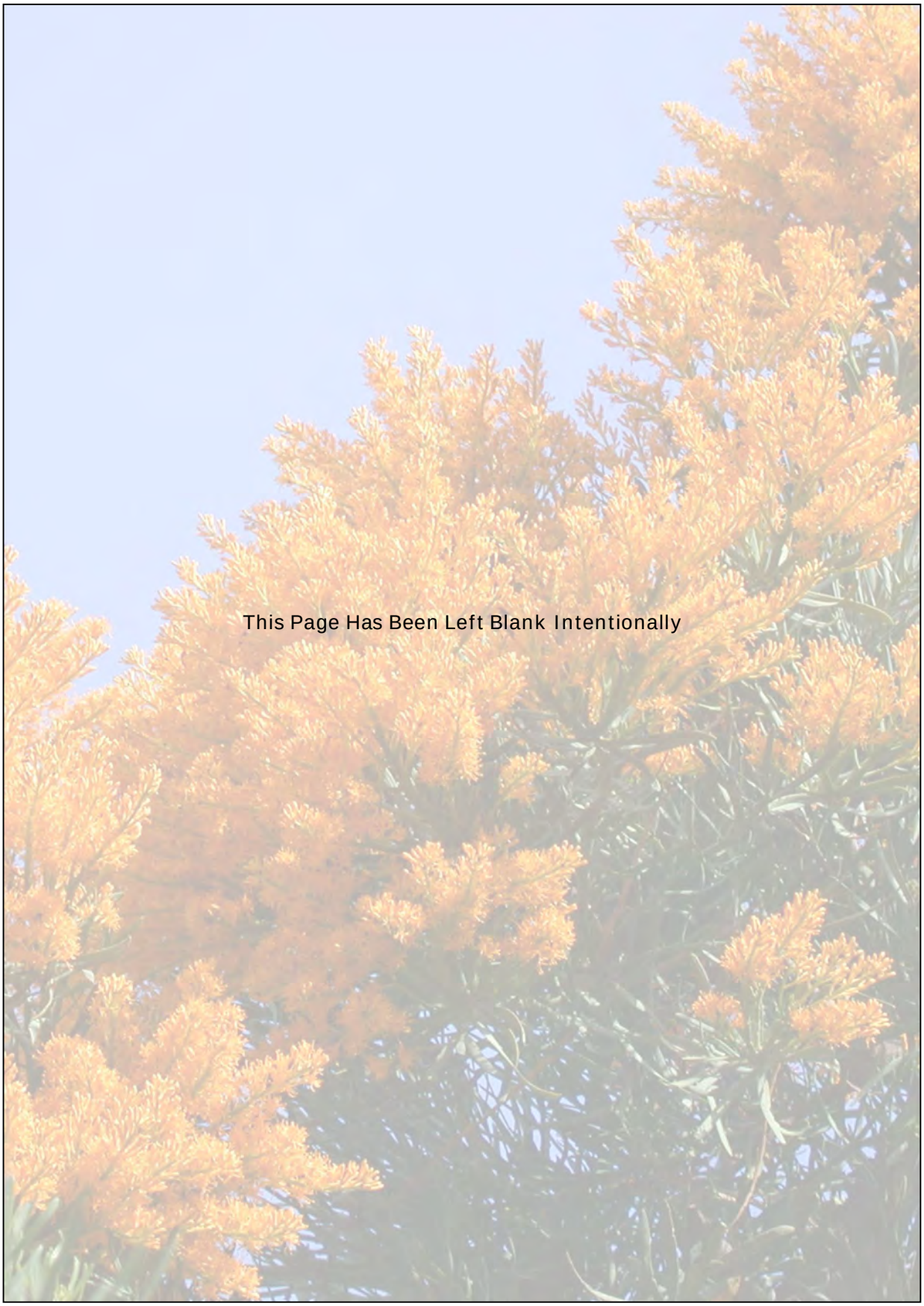
Impacts on Carnaby's and Forest Red-tailed Black Cockatoos have been considered against 'Significant Impact Threshold Values', which broadly relate to various forms and mechanisms of habitat loss. A summary of these impacts is presented in Table 8.1-2 and presented graphically in Figure 8.1-1 and Figure 8.1-2.

Targeted surveys did not record evidence of breeding or use of potential nesting hollows by either Carnaby's or Forest Red-tailed black Cockatoos within the project area. However, targeted surveys identified 68 trees that contain hollows of suitable size for nesting, should the species ever require nesting habitat in this area. The proposed project will result in the removal of 20 of these trees. Surveys also identified 605 trees with a diameter at breast height (DBH) of greater than 500mm within the project area, of which 249 (41 percent) will be removed.

In order to assign a spatial value to the number of significant trees being removed, an area of 100m^2 has been applied to each tree. That is, each significant tree is considered to occupy an area of approximately 10m x 10m. No reduction in overall spatial extent has been made to account for overlap, ensuring the total area used is on the conservative side. Based on this method, the total area of potential nesting habitat to be removed is approximately 2.5ha.



Potential alterations in hydrology will not impact habitat for either species. Section 6.7.3.3 concludes that the risk of hydrological alterations as a result of the project is low, effects will be local and changes in groundwater levels will be minimal. Whilst shallow rooted species may remain at risk, deep rooted species, such as *Eucalyptus* and *Banksia* species that black cockatoos depend upon for foraging and potential nesting habitat, will remain unaffected.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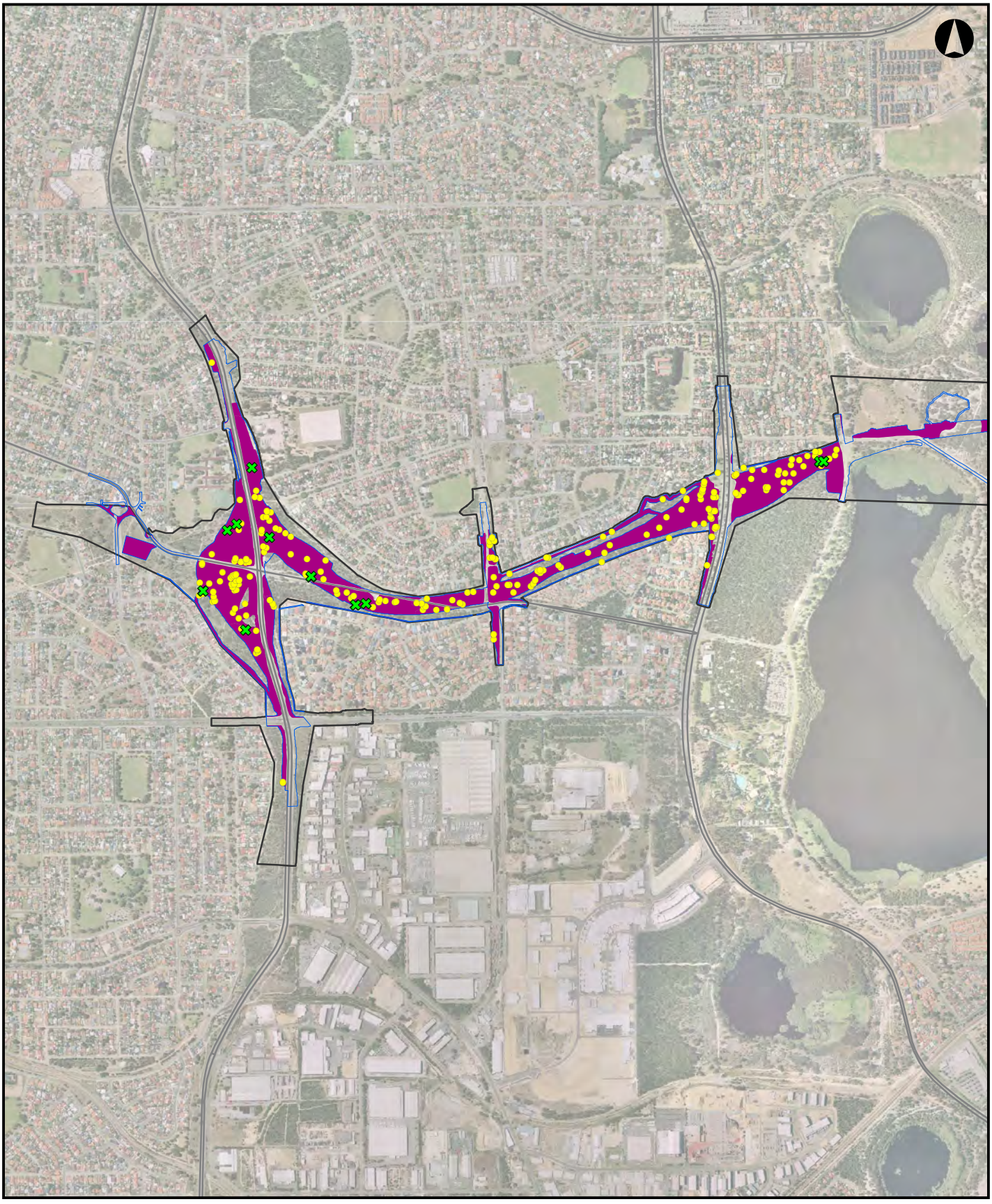

Impacts on Forest Red-Tailed Black-Cockatoo Habitat

South Metro Connect

Figure 8.1-1a

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Forest Red-Tailed Black Cockatoo Habitat Impacted by Construction Footprint
- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos Impacted by Construction Footprint
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos Impacted by Construction Footprint (DBH > 500mm)
- Construction Footprint
- Project Area

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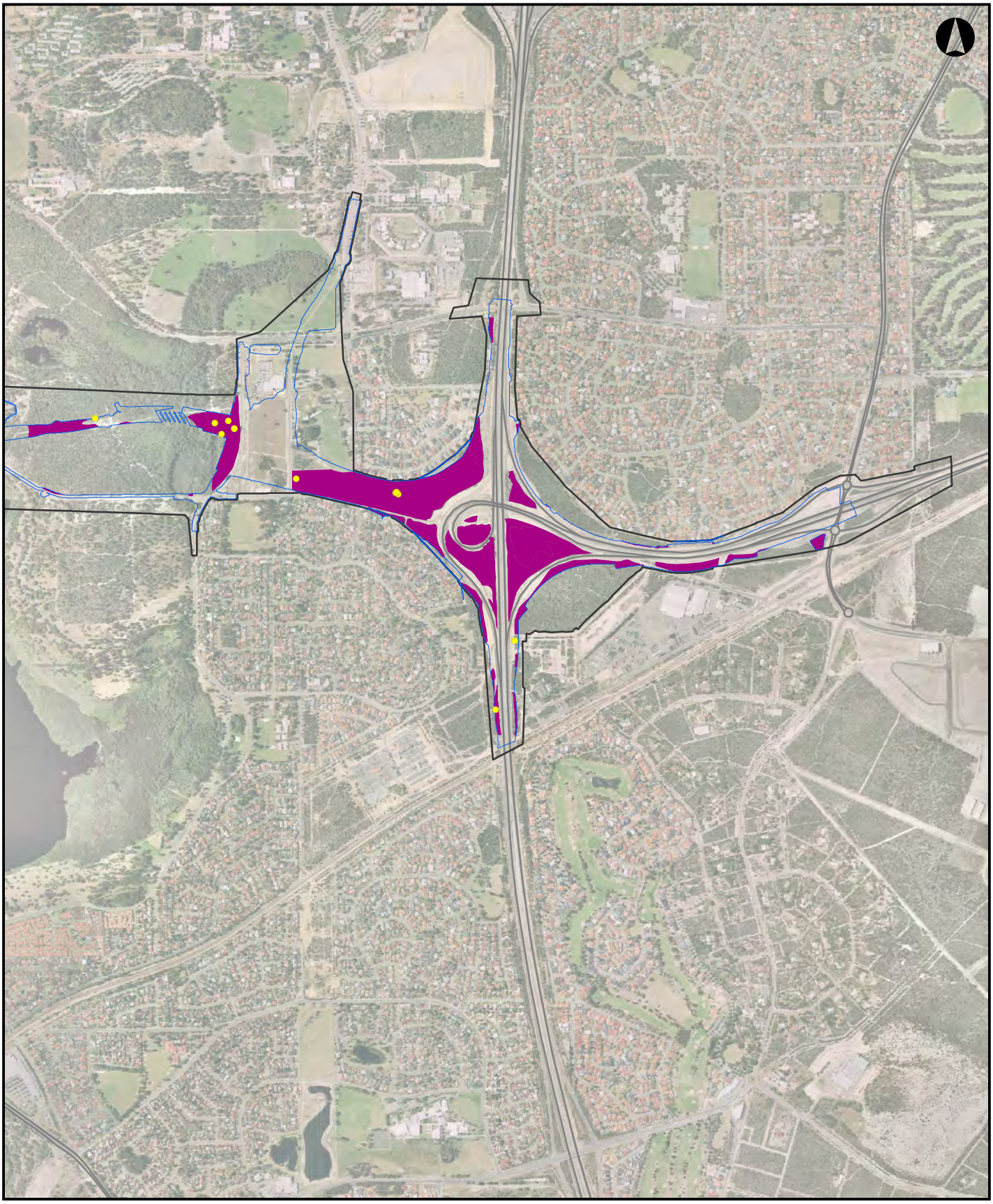

Impacts on Forest Red-Tailed Black-Cockatoo Habitat

South Metro Connect

Figure 8.1-1b

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Forest Red-Tailed Black Cockatoo Habitat Impacted by Construction Footprint
- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos Impacted by ConstructionFootprint
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos Impacted by Construction Footprint (DBH > 500mm)
- Construction Footprint
- Project Area

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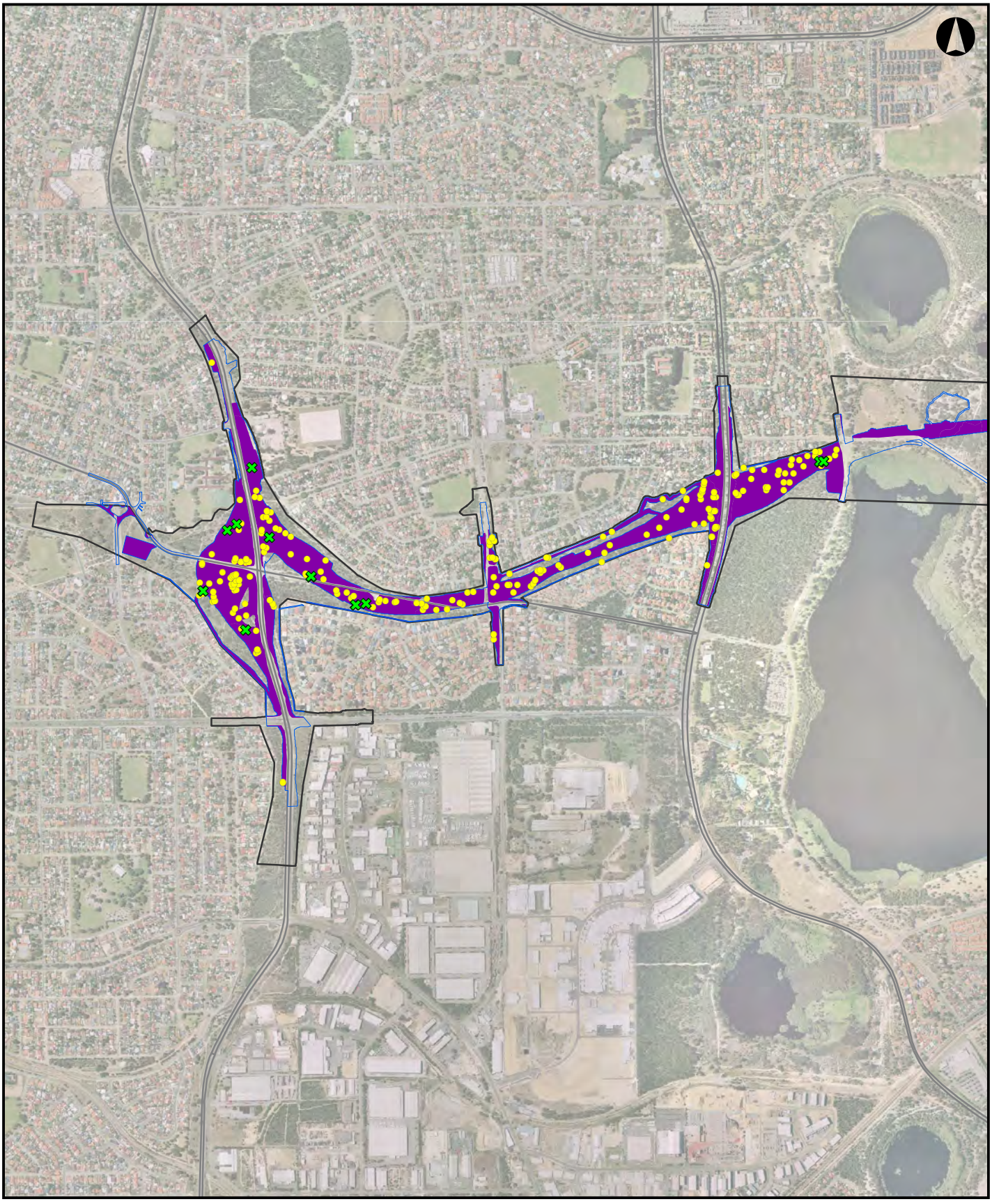

Impacts on Carnaby's Black Cockatoo Habitat

South Metro Connect

Figure 8.1-2a

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Carnaby's Black Cockatoo Habitat Impacted by Construction Footprint
- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos Impacted by Biological Footprint
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos Impacted by Biological Footprint (DBH > 500mm)
- Construction Footprint
- Project Area

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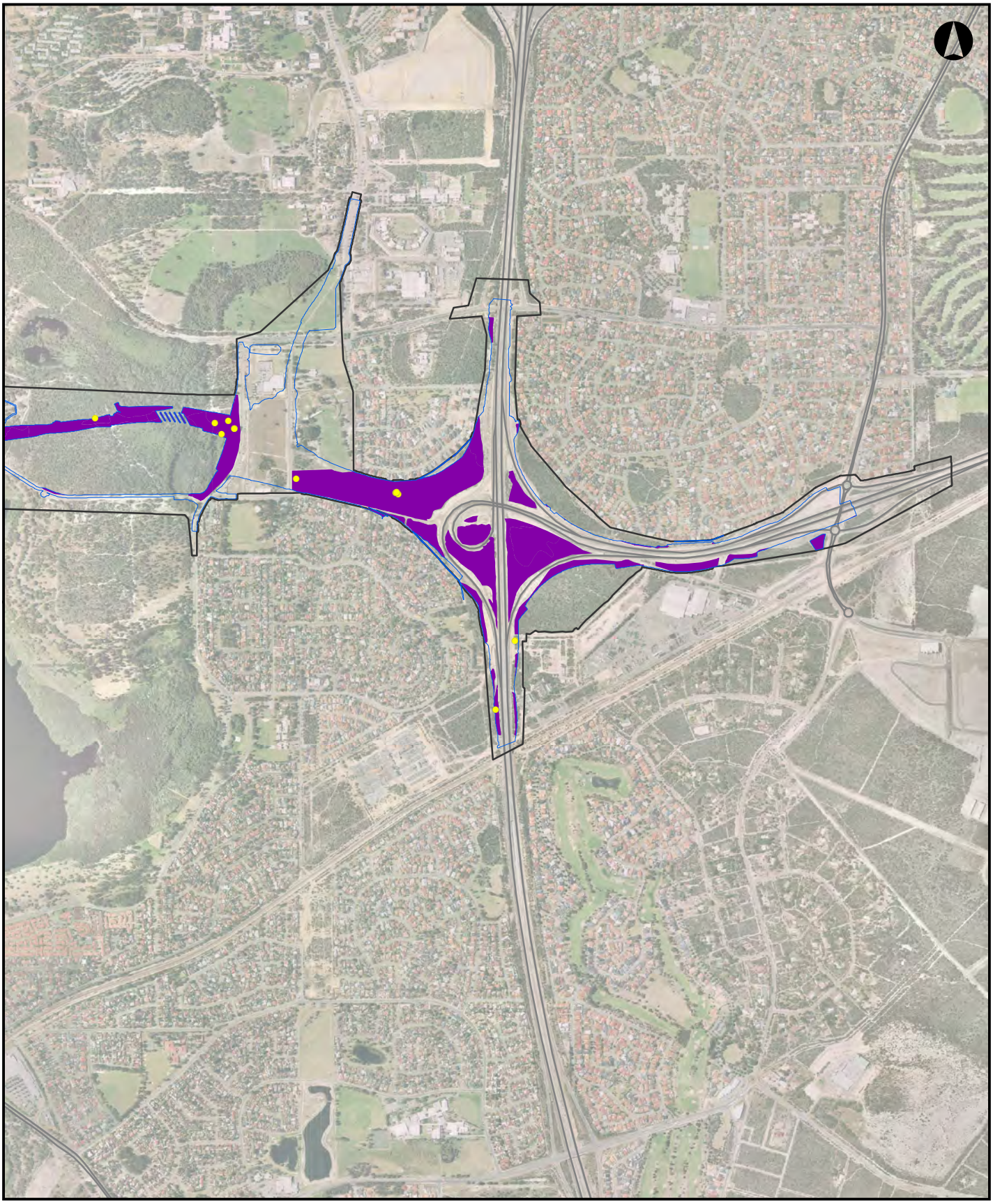

Impacts on Carnaby's Black Cockatoo Habitat

South Metro Connect

Figure 8.1-2b

0 100 200 300 400 500

Metres

1:21,500 (A4)

Datum: GDA94 Projection: MGA z50

- Carnaby's Black Cockatoo Habitat Impacted by Construction Footprint
- Potential Breeding Trees Containing Hollows Suitable for Black Cockatoos Impacted by Biological Footprint
- Potential Future Breeding Trees (without hollows) Suitable for Black Cockatoos Impacted by Biological Footprint (DBH > 500mm)
- Construction Footprint
- Project Area

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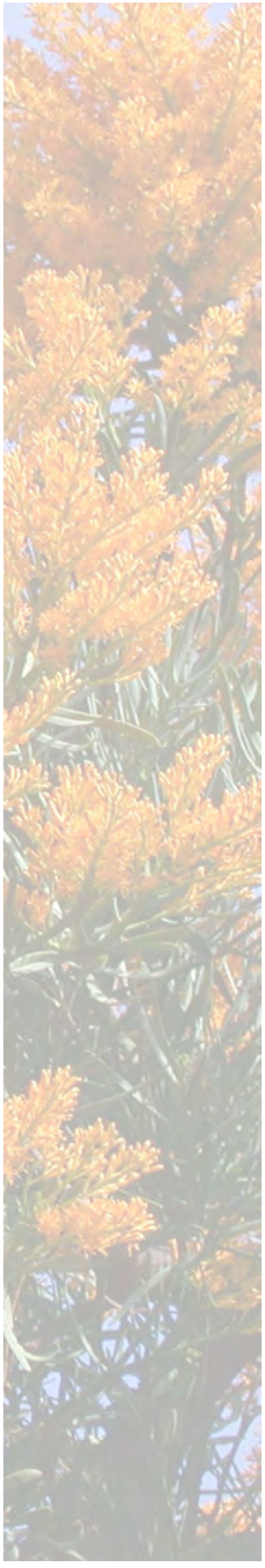


Table 8.1-2: Summary of Potential Impacts on Forest Red-Tailed and Carnaby's Black Cockatoos

DSEWPaC 'Significant Impact Threshold Values'[1]	Impacts of the Proposed Project	Local Context (Project Area)	Regional Context (15km Radius of Project Area)
Clearing of more than 1ha of foraging habitat	78.3ha of suitable Carnaby's Black Cockatoo and 73.2ha of Forest Red-tailed Black Cockatoo foraging habitat will be cleared	Represents 44% of total suitable foraging habitat (177ha) for Carnaby's Black Cockatoo and 45% (of 163ha) for Forest Red-tailed Black Cockatoo	Represents 0.85% of potential foraging habitat in the region for Carnaby's Black Cockatoo[3] (9,133ha, encompassing 6,796 ha with DEC managed estate and regional parks, and 8,401ha within Bush Forever sites. These two areas are non-exclusive)
Clearing of a known roosting site (including individual trees used for roosting)	No known roost locations	No known roost locations will be disturbed	Not applicable (n/a)
Clearing of breeding habitat in woodland stands of 0.5ha or more that contain three or more breeding trees of a suitable size (DBH >500mm)	No confirmed nesting or roosting sites within project area. However, 249 potential breeding trees will be removed, including 20 trees with existing hollows. Assuming that each tree occupies an area of 100m^2 for nesting, an area of 2.5ha of potential future nesting habitat will be lost	Represents 41% of total number of trees of a suitable size (out of 605 trees) within the project area, and 28% of trees with existing potential nesting hollows (out of 71 trees) No known nesting sites will be disturbed	Numbers of potential, suitable and known breeding trees are unknown within the region
Creation of a new gap of more than 4km between patches of black cockatoo habitat	No new gaps of this size will be created	n/a	n/a

DSEWPaC 'Significant Impact Threshold Values'[1]	Impacts of the Proposed Project	Local Context (Project Area)	Regional Context (15km Radius of Project Area)
Altering hydrology or fire regimes so that black cockatoo habitat of more than 1ha would become degraded or destroyed	Project is unlikely to affect the deep rooted trees forming major habitat	n/a	n/a

DEC – Department of Environment and Conservation

[1]Significant Impact Threshold Values as prescribed by DSEWPaC for black cockatoos

[2]Values represent total clearing areas, including both permanent clearing and vegetation removed for construction which will later be rehabilitated

[3]Regional foraging habitat data for the Forest Red-tailed Black Cockatoo is unavailable as vegetation mapping is insufficient at a regional scale. However, given the comparatively wider variety of vegetation communities that support foraging habitat for Forest Red-tailed Black Cockatoos, the existing regional extent of foraging habitat for this species would be greater than that for Carnaby's Black Cockatoo

8.1.2. Listed Insects

Synemon gratiosa (Graceful Sun-moth) – Endangered

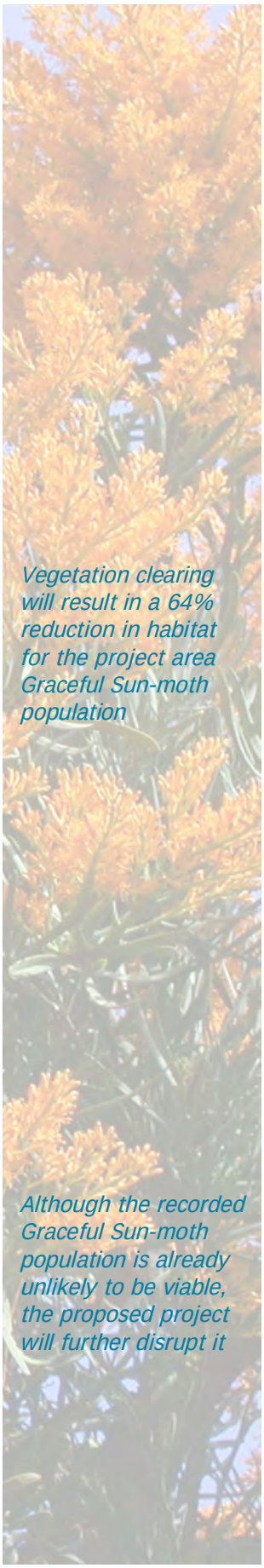
The Graceful Sun-moth is restricted within the Swan Coastal Plain between the suburb of Wanneroo to the town of Mandurah. Adult Graceful Sun-moths breed once in their lifetime during February to April each year and, as adults, have a short flight period of approximately one month. The species may have a two-year or longer larval/pupal cycle. The Graceful Sun-moth adult is active from late February to early April.

Graceful Sun-moth adult males establish small territories in open woodland areas and frequently use airspace above tracks or firebreaks during the breeding season. This behaviour causes the male moths to be easily detected if present.

The Graceful Sun-moth is dependent on two known host plant species during its larval stages, *Lomandra hermaphrodita* and *L. maritima*. *L. maritima* is commonly found in coastal dune systems and was not recorded in the project area. Loss of habitat is believed to be a key threat to the species. Much of the potential habitat for the Graceful Sun-moth occurs in areas subject to urban development pressures, particularly on the coastal and sub-coastal parts of the Perth metropolitan region. Within the project area, Graceful Sun-moth habitat has been mapped as:

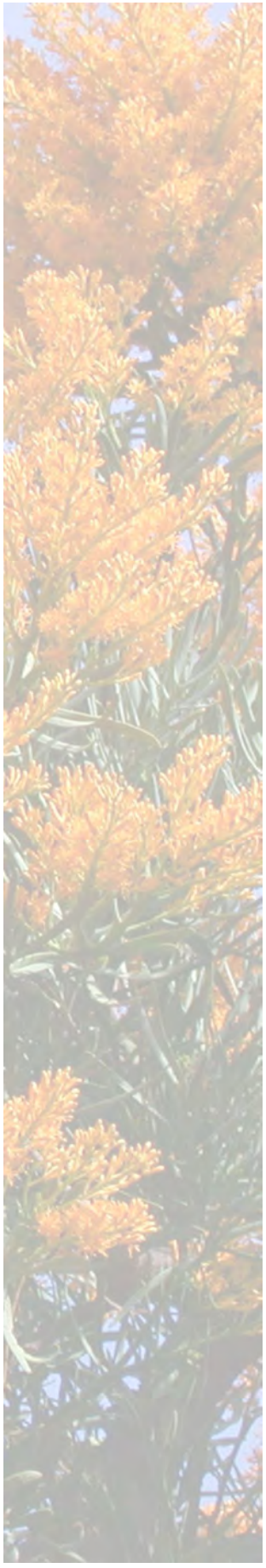
- Confirmed habitat – north-west and north-east quadrants of the Stock Road/Forest Road intersection where adults have been recorded;
- Suitable habitat – actual locations of *L. hermaphrodita* plants; and
- Potential habitat – vegetation communities in where *L. hermaphrodita* was recorded.

Six adults of a Graceful Sun-moth population were recorded in the north-west quadrant of the Stock Road/Forrest Road interchange (Appendix P). Additional records were made in the north-east quadrant of this interchange during a March 2011 survey (Appendix S). *L. hermaphrodita* occupies the understorey and serves as



Vegetation clearing will result in a 64% reduction in habitat for the project area Graceful Sun-moth population

Although the recorded Graceful Sun-moth population is already unlikely to be viable, the proposed project will further disrupt it



the host plant. The total extent of confirmed habitat in this area is 8.7ha, of which 5.6ha (64 percent) will be disturbed.

The probable short range (less than 100m) of adults further limits their ability to move beyond their existing habitat where suitable areas are separated by gaps greater than this range.

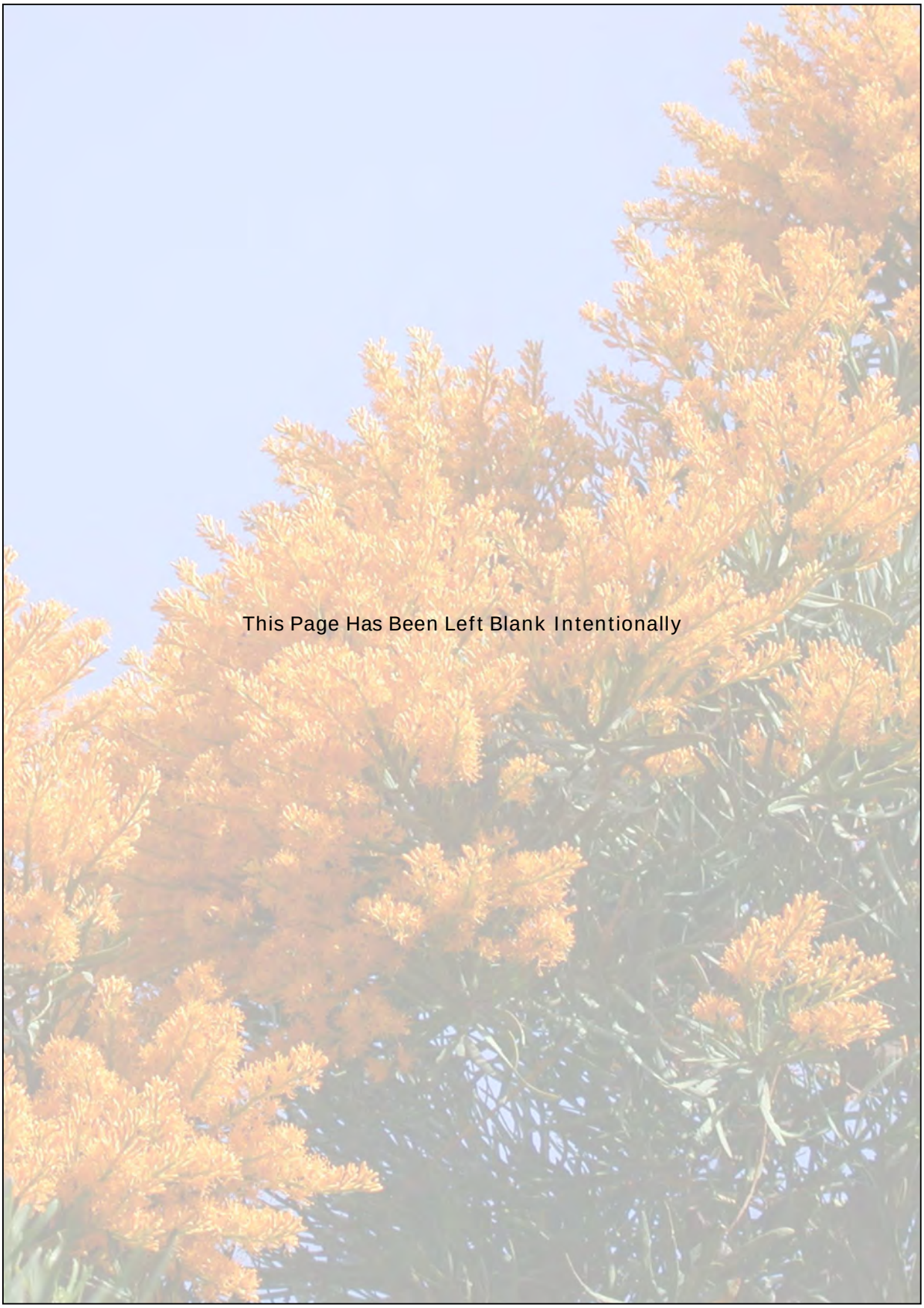
A detailed gridded assessment has been undertaken in approximately 12 percent of the project area, identifying approximately 3,275 individual plants of suitable habitat. Of this suitable habitat, approximately 1,112 individual plants (34 percent) will be directly disturbed by vegetation clearing.

A total of 127.5ha of the project area comprises vegetation communities that *contain L. hermaphrodita*. Vegetation clearing will result in the loss of 60.5ha (48 percent) of these vegetation communities, excluding the confirmed habitat (8.7ha). The extent of Graceful Sun-moth habitat to be removed is shown in Figure 8.1-3.

The early stages of butterflies (and day-flying moths) are highly vulnerable to fire, even those that live underground, which may lose their food supply soon after fire events, rendering reserve populations at risk of extinction due to lack of dispersal from unaffected areas. Should a hot fire pass through the project area close to the stage at which Graceful Sun-moth larvae emerge from the ground (February to April), the local species population viability will be threatened even more than it is presently estimated to be.

Potential alterations in hydrology will not impact habitat for the Graceful Sun-moth. Section 6.6.2.4 discusses the potential impacts of altered hydrology on susceptible vegetation (i.e. groundwater dependent vegetation), with areas of predicted impact indicated in Figure 6.6-2. No suitable habitat for the Graceful Sun-moth occurs within the potentially impacted area, so the species will not be impacted by potential changes in groundwater levels.

For detailed information on these impacts, refer to Section 6.7.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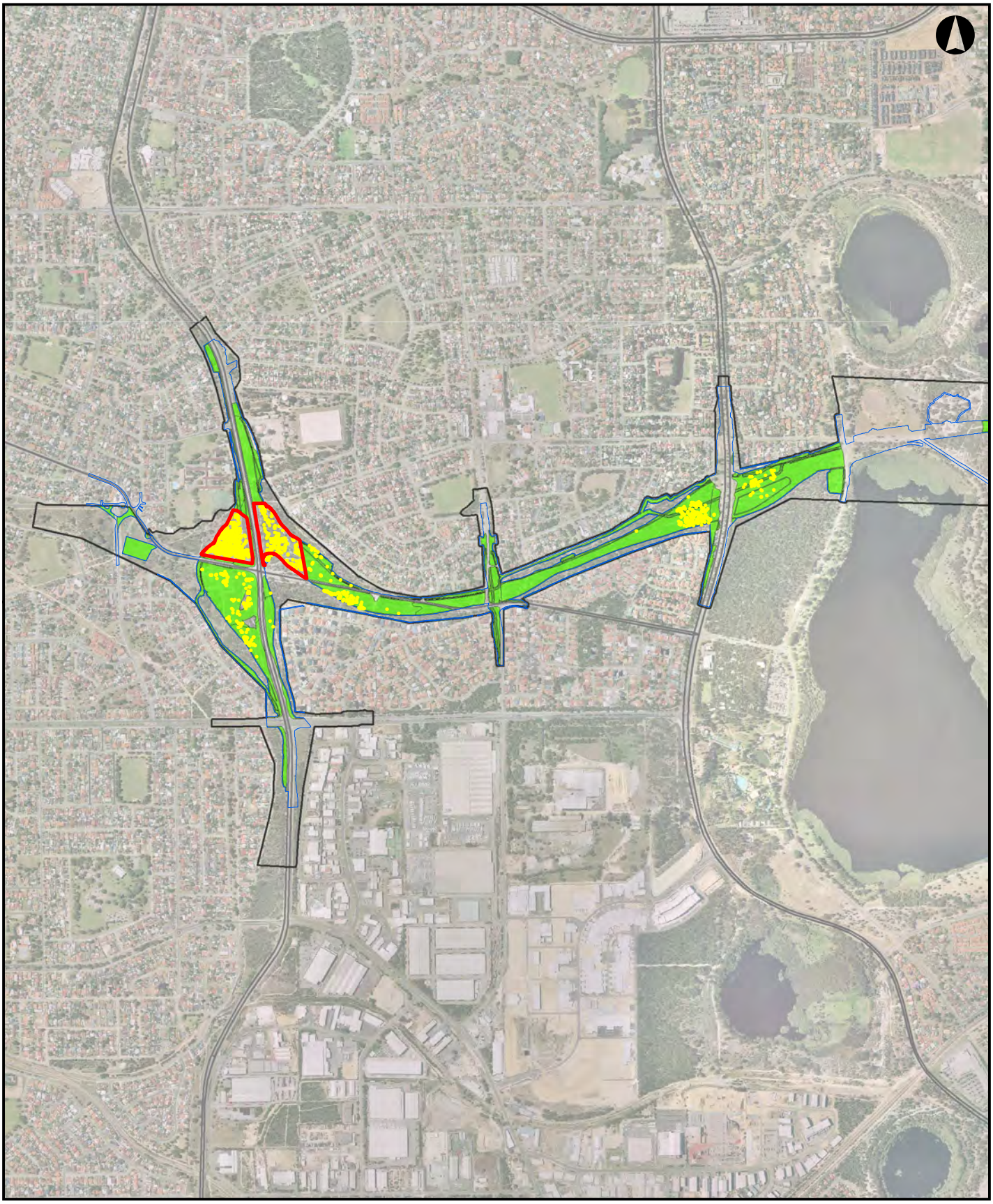

Impacts on Graceful Sun-moth Habitat

South Metro Connect

Figure 8.1-3a

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Metres

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Datum: GDA94 Projection: MGA z50

- Confirmed GSM Habitat Impacted by Construction Footprint
- Potential GSM Habitat Impacted by Construction Footprint
- Suitable GSM Habitat Impacted by Construction Footprint
- Construction Footprint
- Project Area

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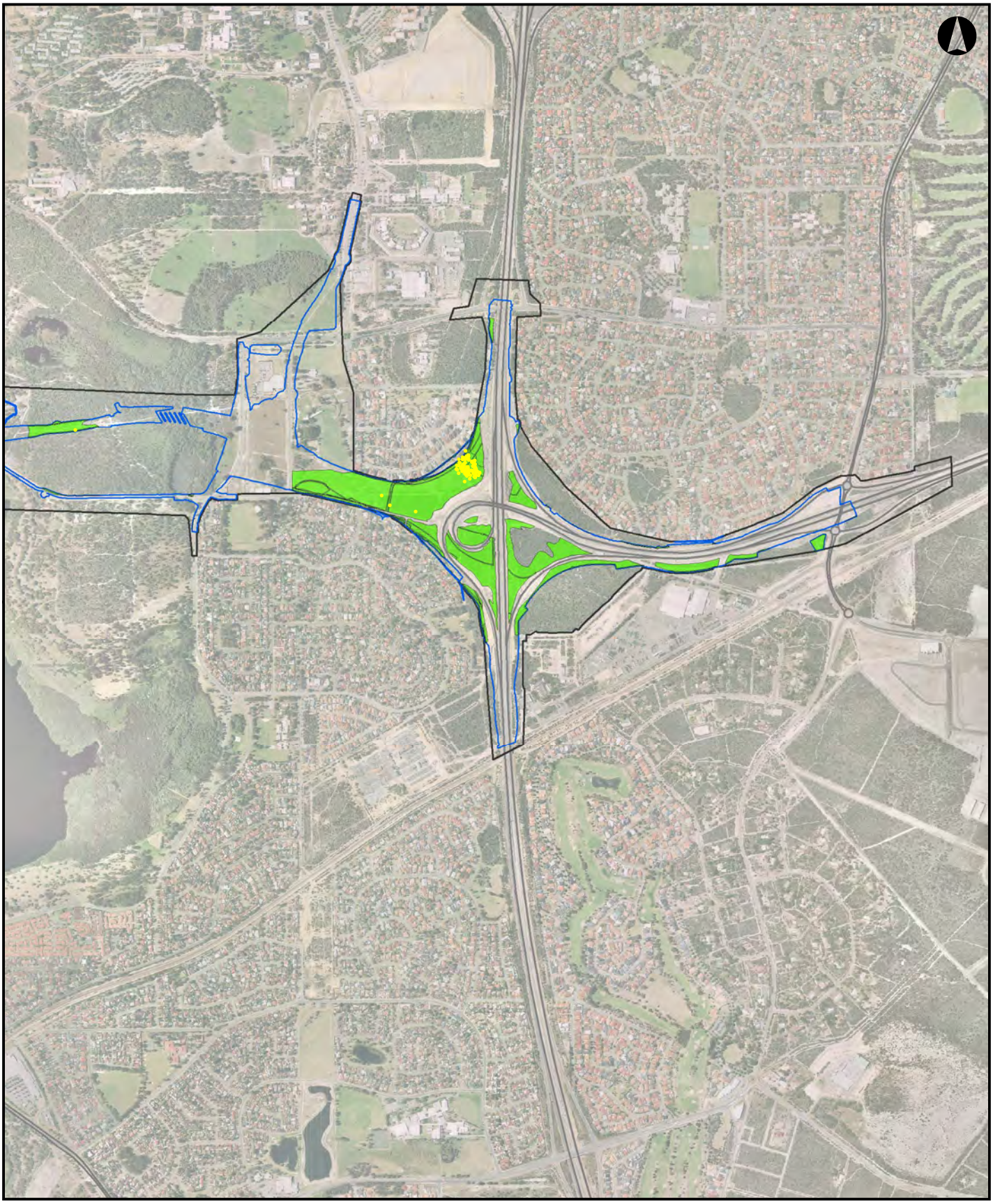

Impacts on Graceful Sun-moth Habitat

South Metro Connect

Figure 8.1-3b

0 100 200 300 400 500

Metres

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Datum: GDA94 Projection: MGA z50

- Confirmed GSM Habitat Impacted by Construction Footprint
- Potential GSM Habitat Impacted by Construction Footprint
- Suitable GSM Habitat Impacted by Construction Footprint
- Construction Footprint
- Project Area

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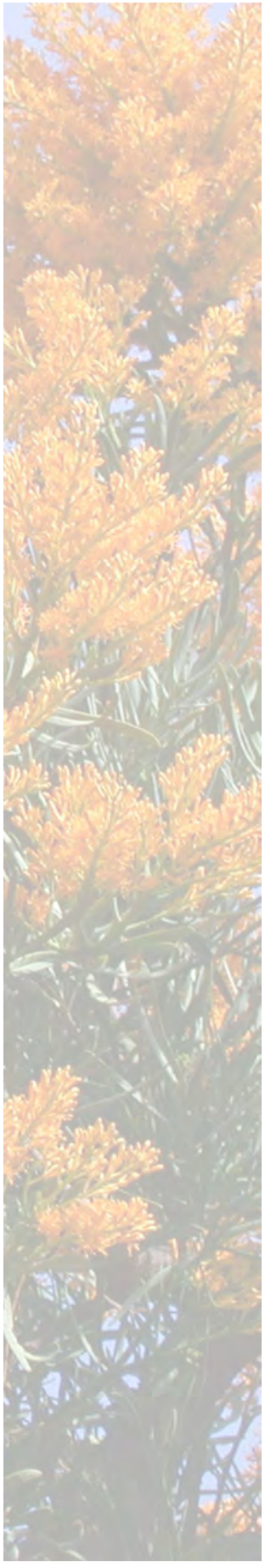


8.1.3. Listed Mammals

Dasyurus geoffroii (Chuditch, Western Quoll) – Vulnerable

The Chuditch primarily occurs in Jarrah forest in south-west Western Australia. Occasionally, the Chuditch has been recorded in the wheatbelt and goldfields regions, where fragments of suitable habitat remain.

Targeted vertebrate fauna surveys have not recorded evidence of this species. It is considered unlikely to occur in the project area and, as such, is not afforded further attention. It is not anticipated that this project will have an impact on the significance classification or regional viability of this species.

Phascogale calura (Red-tailed Phascogale) - Endangered

The Red-tailed Phascogale is restricted to isolated patches of remnant native vegetation throughout the wheat belt of south-west Western Australia. These are no longer contiguous and do not allow for recolonisation or movement between populations. Records identify the Red-tailed Phascogale to travel as far north as Beverly, south-east of Perth. The Red-tailed Phascogale's preferred habitats are *Allocasuarina* woodlands with hollow-containing eucalypts (e.g. *Eucalyptus wandoo*) and *Gastrolobium* species.

Targeted vertebrate fauna surveys have not recorded this species. It is considered unlikely to occur in the project area and, as such, is not afforded further attention.

Setonix brachyurus (Quokka) - Vulnerable

The present distribution of the Quokka includes two offshore Western Australian islands, Rottnest and Bald Island, and some sites on the south-west Western Australian mainland. The area that is proposed for development of the project is not known to contain Quokkas nor were they recorded during the targeted fauna surveys.

8.1.4. Listed Plants

Caladenia huegelii (Grand Spider-orchid) – Endangered

The Grand Spider-orchid occurs in scattered localities within 20km of the coast, from the Upper Swan and Gnangara areas north of Perth, through suburban Perth and southwards to Gracetown and the Scott River in the Margaret River area of Western Australia. The flowers appear from September to October. Several populations of this species exist within the region and suitable habitat, comprised of grey sands under *Banksia* woodland, occurs within the project area. Threats to this species include declining habitat due to clearing and fragmentation, habitat degradation, inappropriate fire regimes and weed invasion.

The project area was extensively searched in 2009 (Section 5.8; Appendix K) during the peak flowering period, when this species is at its most conspicuous. No *Caladenia huegelii* individuals or populations were recorded during spring 2009; however, six other common *Caladenia* species were recorded, indicating that suitable *Caladenia* habitat occurs within the project area. As such, a further survey was undertaken in spring 2010 in identified suitable habitat, but did not record *Caladenia huegelii* specimens.

Whilst appropriate environmental conditions could be manifest within the project area, targeted surveys have not recorded this species and, as such, it is considered unlikely to occur in the project area. By reducing native vegetation clearing and by implementing vegetation management strategies contained within a Construction Environmental Management Plan (CEMP) to assist in managing impacts, such as fire and weed invasion on other *Caladenia* species, *C. huegelii*, should it occur, will be indirectly managed. It is not anticipated that this project will have an impact on the significance classification or viability of this species.

Darwinia sp. Muchea (B.J. Keighery 2458) (Muchea Bell) – Critically Endangered

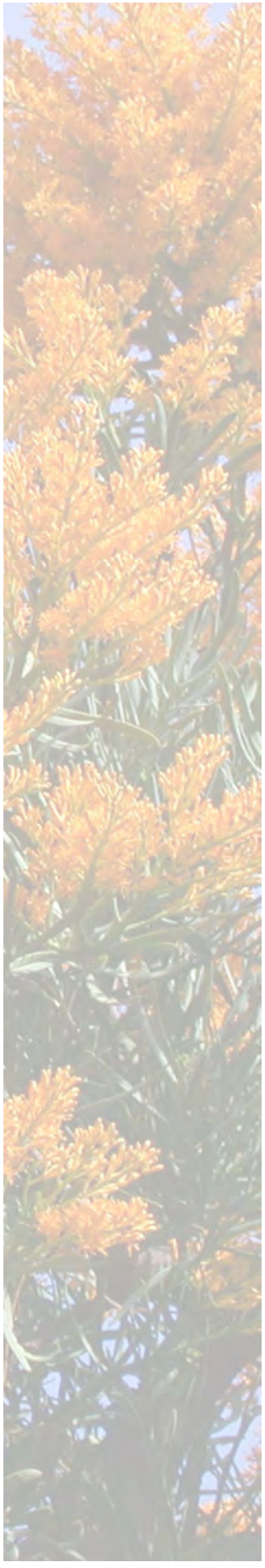
The species is only known from a restricted area of distribution in the Muchea area and flowers from October to November. It is likely that there has been a decline in the species' numbers in more recent times due to grazing by rabbits, weed invasion, changes in hydrology, inappropriate fire regimes, vegetation clearance and dieback caused by *Phytophthora cinnamomi*, which may continue in the future. However, there are no quantitative data available to substantiate the species decline.

Whilst appropriate environmental conditions could be manifest within the project area, targeted surveys have not recorded this species and, as such, it is considered unlikely to occur in the project area. By reducing native vegetation clearing and by implementing vegetation management strategies contained within a CEMP to assist in managing impacts, such as fire and weed invasion, Muchea Bell, should it occur, will be indirectly managed. It is not anticipated that this project will have an impact on the significance classification or regional viability of this species.

Lepidosperma rostratum (Beaked *Lepidosperma*) - Endangered

Beaked *Lepidosperma* is endemic to Western Australia and is known from four populations in the east of the Perth metropolitan region. It is likely to have disappeared from most of this urbanised area, but may occur in other remnant bushland habitats elsewhere on the Swan Coastal Plain.

Beaked *Lepidosperma* is associated with Marsh Banksia (*Banksia telmatiaea*) and Hairy Clawflower (*Calothamnus hirsutus*). These species are not known in the project area and *Banksia telmatiaea* is considered unlikely to occur in the project area. It was not recorded in the targeted spring flora and vegetation surveys.



The main potential threats in the region to Beaked *Lepidosperma* include weed invasion and grazing. Whilst appropriate environmental conditions could be manifest within the project area, targeted surveys have not recorded this species and, as such, it is considered unlikely to occur in the project area. By reducing native vegetation clearing and by implementing vegetation management strategies contained within a CEMP to assist in managing impacts, such as weed invasion, Beaked *Lepidosperma*, should it occur, will be indirectly managed. It is not anticipated that this project will have an impact on the significance classification or regional viability of this species.

8.1.5. Listed Migratory Species

Migratory species are those animals that migrate to Australia and its external territories, or pass through or over Australian waters during their annual migrations. Listed migratory species also include native species identified in an international agreement approved by the Minister for Sustainability, Environment, Water, Population and Communities. The Minister may approve an international agreement for this purpose if satisfied that it is an agreement relevant to the conservation of migratory species.

Three such international agreements, the China–Australia Migratory Bird Agreement (CAMBA), the Japan–Australia Migratory Bird Agreement (JAMBA) and the Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA) are international bilateral agreements between the Government of Australia and the governments of China, Japan and the Republic of Korea for the protection of migratory birds in danger of extinction.

The agreements list terrestrial, water and shorebird species that migrate between Australia and the respective countries. For the agreements, the majority of listed species are shorebirds. The agreements require the parties to:

- Protect migratory birds from take or trade except under limited circumstances;
- Protect and conserve habitats;
- Exchange information; and
- Build cooperative relationships.

Species denoted as listed migratory species are Matters of NES under the *EPBC Act*. An action will require approval if the action has, will have, or is likely to have, a significant impact on a listed migratory species. The action must be referred to the Minister and undergo an environmental assessment and approval process.

A search of the EPBC database (Appendix Y) shows that five migratory species have the potential to occur within the project area. Two bird species listed as migratory, but not identified by the database search, were recorded in the project area. A total of seven listed migratory bird species occur within the project area.

8.1.5.1. Migratory Terrestrial Birds

Haliaeetus leucogaster (White-bellied Sea-Eagle) - CAMBA

The White-bellied Sea-Eagle ranges from India and Sri Lanka, east to southern China and south through South-East Asia, the Philippines, Wallacea and New Guinea (including the Bismarck Archipelago) to Australia. The White-bellied Sea-Eagle is distributed along the coastline (including offshore islands) of mainland Australia and Tasmania. It also extends inland along some of the larger waterways, especially in eastern Australia. The inland limits of the species are most restricted in south-central and south-western Australia, where it is confined to a narrow band along the coast. Recent analysis indicates that the distribution of the sea eagle may shift in response to climatic conditions, with an apparent decreased occupancy of inland sites (and increased occupancy of coastal sites) during drought conditions.

The White-bellied Sea-Eagle is found in coastal habitats (especially those close to the seashore) and around terrestrial wetlands in tropical and temperate regions of mainland Australia and its offshore islands. The habitats occupied by the sea eagle are characterised by the presence of large areas of open water (larger rivers, swamps, lakes and the sea). Birds have been recorded in (or flying over) a variety of terrestrial habitats.

It has been recorded at or in the vicinity of freshwater swamps, lakes, reservoirs, billabongs, saltmarsh and sewage ponds. They also occur at sites near the sea or seashore, such as bays and inlets, beaches, reefs, lagoons, estuaries and mangroves. Terrestrial habitats include coastal dunes, tidal flats, grassland, heathland, woodland, forest (including rainforest) and even periurban areas.

The White-bellied Sea-Eagle feeds opportunistically on a variety of fish, birds, reptiles, mammals and crustaceans, and on carrion and offal, generally foraging over large expanses of open water.

Breeding territories are located close to water and mainly in tall open forest or woodland, although nests are sometimes located in other habitats such as dense forest (including rainforest), closed scrub or in remnant trees on cleared land. They are sensitive to disturbance when nesting, especially during the early stages of the breeding season, and may abandon nests and young if confronted by humans or exposed to human activity. The disturbance of nesting pairs by human activity can thus lower breeding success and has been associated with some local population declines.

During the project survey, the White-bellied Sea-Eagle was recorded at three wetlands in the Beeliar chain: Bibra Lake, Kogolup Lake and Thomsons Lake. In the past, it was recorded at three other wetlands. It is likely to be an occasional visitor to the project area and, while this species may potentially nest in the study area, nesting has not been observed, so the likelihood is low (Appendix O). Furthermore, as no riparian vegetation will be cleared, it is considered unlikely that there will be an impact on the breeding habits of this species.

Merops ornatus (Rainbow Bee-eater) - JAMBA

The Rainbow Bee-eater is widely distributed throughout Australia and eastern Indonesia, including Bali, the Lesser Sundas and Sulawesi, and east to Papua New Guinea into the Pacific islands, including south-western Micronesia. The majority of the global population breeds in Australia (including those known on Rottnest Island and islands in the south-west Torres Strait). The Rainbow Bee-eater is not considered globally threatened.

The Rainbow Bee-eater occurs mainly in open forests and woodlands, shrublands and in various cleared or semi-cleared habitats, including farmland and areas of human habitation (Higgins 1999). It usually occurs in open, cleared or lightly-timbered areas that are often, but not always, located in proximity to permanent water (Badman 1979; Boekel 1976; Fry 1984; Roberts 1979; Storr 1984a, 1984b, 1985a). It also occurs in inland and coastal sand dune systems, in mangroves in northern Australia, and has been recorded in various other habitat types including heathland, sedgeland, vine forest, vine thicket and on beaches (Higgins 1999).

During targeted vertebrate fauna surveys, the Rainbow Bee-eater was recorded in the project area, where it was observed foraging in most habitats including *Banksia*, *Eucalyptus-Xanthorrhoea, Eucalyptus-Banksia, Eucalyptus-Melaleuca* and *Kunzea* shrublands, parklands and on roadside batters. The Rainbow Bee-eater has been recorded in trees within open sandy areas/tracks within the project area. Vegetation clearing will result in a loss of approximately 90ha (47 percent) of potentially suitable foraging/nesting habitat within the project area (Figure 8.1-4). Clearing will occur at the location of one previously used nesting site. Nesting areas are often re-used and banding studies indicate that at least some migrant birds return to the same nesting area each year. Pairs usually excavate a new nesting burrow for each breeding season, so it is not anticipated that the disturbance of the previously used nesting site will have a significant impact upon population viability, as there are other suitable nesting sites within close proximity.

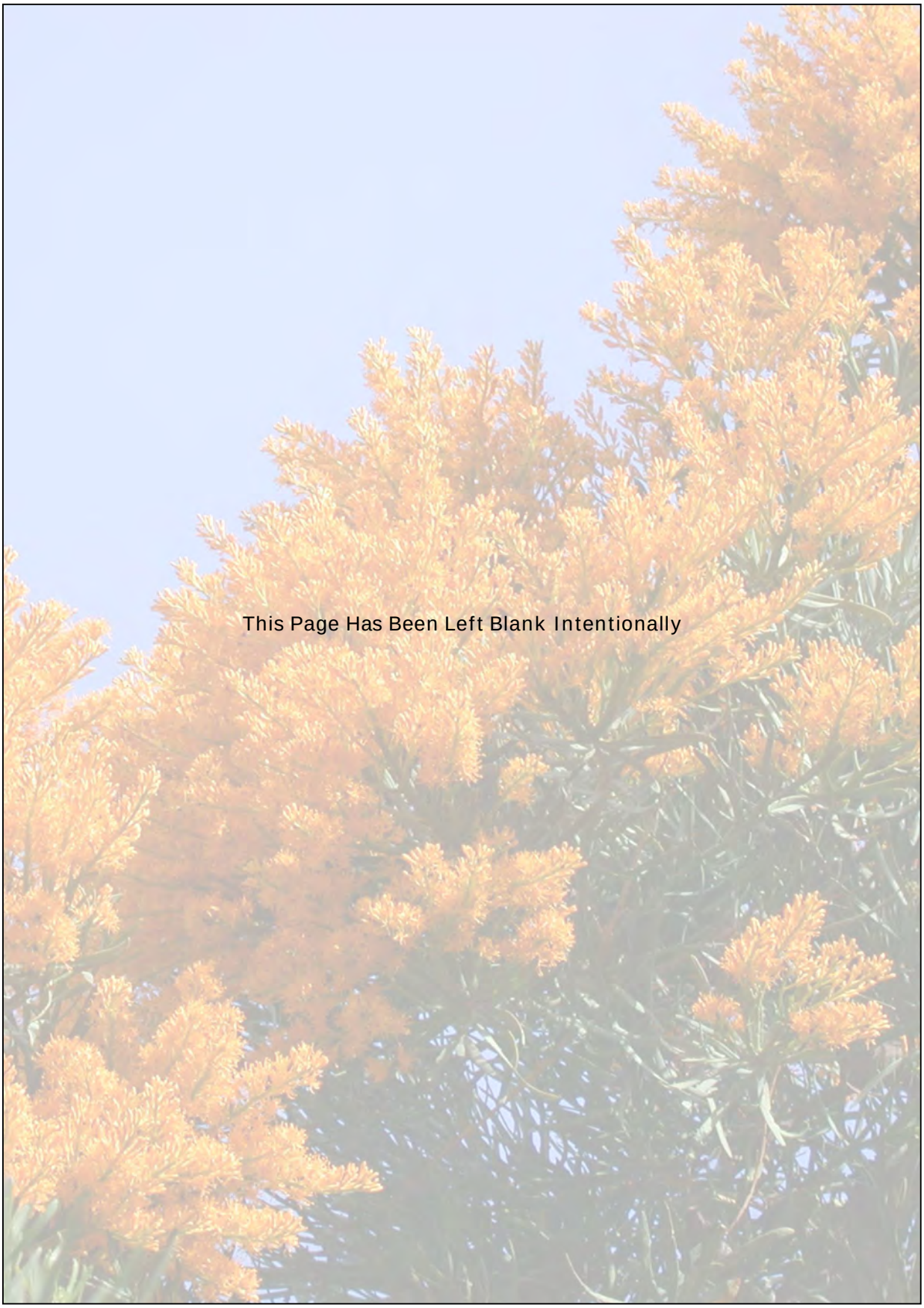
Habitat loss presents the largest potential impact on Rainbow Bee-eaters from the proposed project. While the scale of habitat loss is high in a local context, the species is considered common in most areas it inhabits and is a habitat generalist (in terms of both foraging and nesting requirements).

In view of these factors, the scale of potential impact on this species is negligible in a regional context. The consequences of habitat loss for the Rainbow Bee-eater in the project area could include:

- A reduction in suitable breeding habitat; and
- A reduction in open woodland foraging habitat.

Additionally, individuals of this species could potentially be impacted by:

- Road mortalities; and
- Fire.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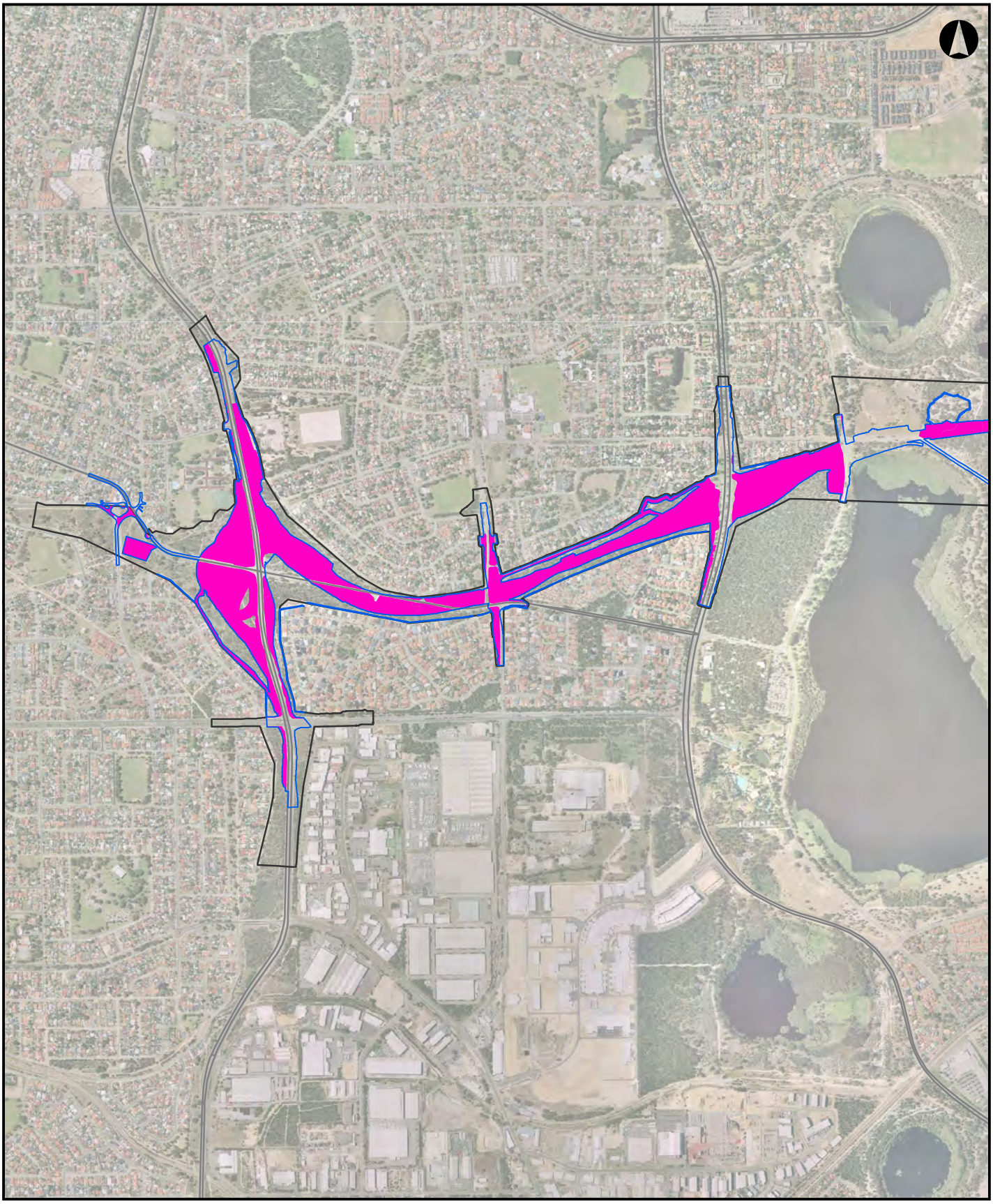

Impacts on Rainbow Bee-eater Habitat

South Metro Connect

Figure 8.1-4a

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Metres

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Datum: GDA94 Projection: MGA z50

Rainbow Bee-eater Habitat Impacted by Construction Footprint

Construction Footprint

Project Area

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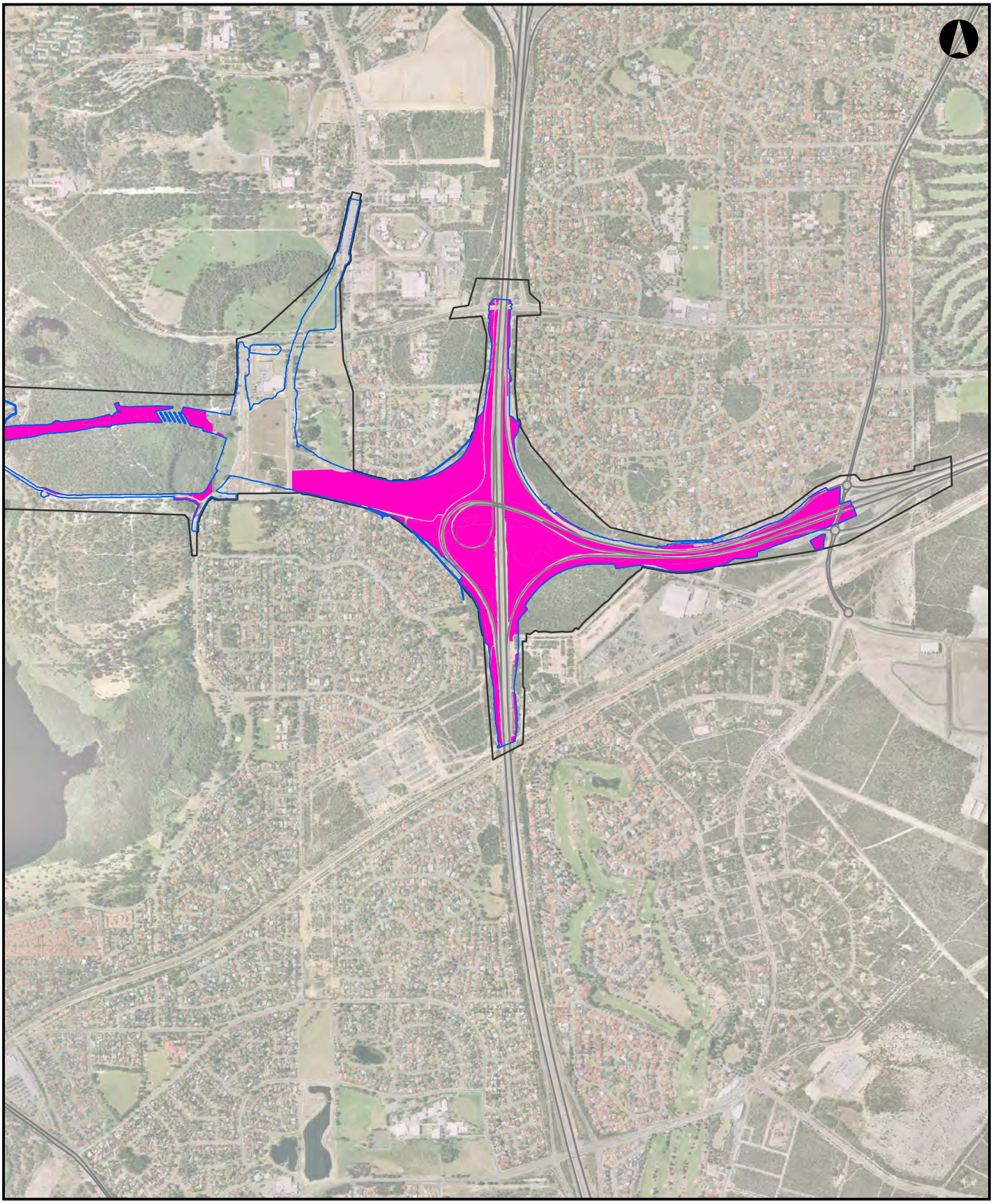

Impacts on Rainbow Bee-eater Habitat

South Metro Connect

Figure 8.1-4b

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Metres

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Datum: GDA94 Projection: MGA z50

Rainbow Bee-eater Habitat Impacted by Construction Footprint

Construction Footprint

Project Area

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Plegadis falcinellus (Glossy Ibis) - CAMBA

Ibis generally forage around wetland margins and in damp pastures and generally nest colonially in wooded wetlands, constructing nests in trees. The Glossy Ibis is generally an uncommon, non-breeding visitor to the Swan Coastal Plain (Appendix O), although breeding has been recorded (Johnstone and Storr 1998).

This species was not recorded in the south-west until 1898 and its population has been increasing since that time (Johnstone and Storr 1998). Although this species was not listed in the EPBC Search Report (Appendix Y), it had been recorded at several wetlands in the Beeliar chain, notably at Bibra Lake and North Lake, so was included in this environmental impact assessment. In the 2009/2010 surveys, the Glossy Ibis was recorded at three wetlands, with highest counts of 44 at Thomsons Lake, 28 at North Lake and 23 birds at Bibra Lake (Appendix O)

Although a migratory species, the Glossy Ibis is listed as of Least Concern on the International Union for Conservation of Nature (IUCN) Red List, as it has an extremely large range and, despite the population trend appearing to be decreasing, it has a large population worldwide (IUCN 2010).

Existing impacts on Glossy Ibis in the project area may include mortalities due to collisions with powerlines. This existing impact is proposed to be reduced by the installation of reflective discs, which have been demonstrated to provide disincentive for birds to approach electrical wiring.

Individuals of this species could potentially be impacted by:

- Road mortalities; and
- Fire.

The Glossy Ibis will not be directly affected by habitat loss, fragmentation nor edge effects, as there will be no loss of shoreline or lakebed habitats within the project area.

Pandion cristatus (Eastern Osprey)

The Eastern Osprey is a mainly coastal species that breeds on offshore islands. It occurs in Indonesia, Philippines, Palau Islands, New Guinea, Solomon Islands, New Caledonia and Australia.

Eastern Ospreys occur in littoral and coastal habitats and terrestrial wetlands of tropical and temperate Australia and offshore islands. They are mostly found in coastal areas, but occasionally travel inland along major rivers, particularly in northern Australia. They require extensive areas of open fresh, brackish or saline water for foraging. They frequent a variety of wetland habitats including inshore waters, reefs, bays, coastal cliffs, beaches, estuaries, mangrove swamps, broad rivers, reservoirs, large lakes and waterholes. It is therefore highly likely that individuals of this species will visit the wetland areas of the Beeliar chain at some stage in the future. For this reason, despite not being contained in the EPBC Search Report, nor observed in the project area, they are included in this environmental impact assessment.

The Eastern Osprey was not recorded during the 2009/2010 study, but was recorded at Bibra Lake in 2009 and North Lake in 2001 (Birds Australia Atlas Database 2010). This species generally inhabits coasts, estuaries and island waters, and it usually breeds on offshore islands (Johnstone and Storr 1998). The Eastern Osprey is likely to be an infrequent non-breeding visitor to habitats inside the project area.

8.1.5.2. Migratory Wetland Birds

Only one of the wetland birds recorded within the project area during the 2009/2010 survey is listed as a protected species (Appendix O). The other two listed species below were contained in the EPBC Search Report, but have not been recorded within the project area.

Ardea alba (Great Egret, White Egret) – JAMBA, CAMBA

This species has undergone taxonomic revision since the generation of the EPBC Search Report (Appendix O). The Australasian population is a separate species, *Ardea modesta*. Refer to discussions on *Ardea modesta* for potential occurrence, impacts and mitigation (Appendix O). *Ardea alba* is not discussed further in this report.

Ardea modesta (Eastern Great Egret) – JAMBA, CAMBA

The Eastern Great Egret is a widespread species of southern and eastern Asia and Australasia. Breeding populations are located in Pakistan, India, Sri Lanka, Bangladesh, Burma, Thailand, China, Korea, north-eastern Russia, Japan, Indo-China, Indonesia, Papua New Guinea, Solomon Islands, Australia and New Zealand.

The Eastern Great Egret can be found in inland rivers, lakes and shallow freshwater wetlands. This species is highly mobile and can be found throughout most of the western fringes of the State in coastal areas and towards the semi-arid interior (Johnstone and Storr 1998). In Australia, the largest breeding colonies and greatest concentrations of breeding colonies are located in near-coastal regions of the Northern Territory.

This species was recorded opportunistically during the 2009-2010 surveys in Bibra Lake and Thompsons Lake. Previous surveys of Bibra Lake, Champion Lakes (Bamford 2003) and databases searches have also recorded this species.

The Eastern Great Egret has a diverse diet that includes fish, insects, crustaceans, molluscs, frogs, lizards, snakes and small birds and mammals. In Australia, the Eastern Great Egret is threatened by loss and/or degradation of foraging and especially breeding habitat through alteration of water flows, drainage and/or clearing of wetlands for development, frequent burning of wetland vegetation used as nest sites, salination and invasion by exotic plants or fish.

This species does not breed in the project area; however, may forage in the wetland environment. As the proposed project will not impact riparian vegetation nor result in significant changes to wetland flows (refer to Sections 6.2 and 6.3), no impacts on the population of the Eastern Great Egret will occur. As this species is known to occur in the project area on occasion, bird and habitat management and mitigation measures will still apply.

Ardea ibis (Cattle Egret) – JAMBA, CAMBA

The Cattle Egret is a relatively recent colonist of Australia from Asia. The Cattle Egret typically occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands. High numbers have been observed in moist, low-lying poorly drained pastures with an abundance of high grass; it avoids low grass pastures. It has been recorded on earthen dam walls and ploughed fields. It is commonly associated with the habitats of farm animals, particularly cattle, but also other domesticated animals. The Cattle Egret is known to follow earth-moving machinery (looking for exposed foodstuff) and has been located at rubbish tips. It predominantly uses shallow, open and fresh wetlands including meadows and swamps with low emergent vegetation and abundant aquatic flora. They have sometimes been observed in swamps with tall emergent vegetation. The Cattle Egret often forages away from water on low lying grasslands, improved pastures and croplands. The Cattle Egret roosts in trees, or amongst ground vegetation in or near lakes and swamps.

The Cattle Egret is an occasional visitor to the Swan Coastal Plain, mainly occurring in autumn. This species is only known from occasional records in the study area, being recorded at North Lake and South Lake over five years ago, but has not been recorded during the 2009/2010 survey. No wetlands in the study area are likely to be significant for this species.

Although a migratory species, the Cattle Egret is listed as of Least Concern on the IUCN Red List, as it has an extremely large range and a large global population that appears to be increasing (IUCN 2010). Whilst the environmental conditions and some of the potential threats to this species could be manifest at the proposed project location, targeted vertebrate fauna surveys have not recorded evidence of this species during the 2009/2010 survey. The proposed project will not have an major impact on resident migratory populations of this species.

8.1.5.3. Migratory Marine Birds

Apus pacificus (Fork-tailed Swift) – CAMBA, JAMBA, ROKAMBA

In Western Australia, there are sparsely scattered records of the Fork-tailed Swift along the south coast, ranging from near the Eyre Bird Observatory and west to Denmark. They are widespread in coastal and sub-coastal areas between Augusta and Carnarvon, including some on nearshore and offshore islands. They are found in the north and north-west Gascoyne Region, north through much of the Pilbara Region, and the south and east Kimberley.

The Fork-tailed Swift is almost exclusively aerial, flying from less than 1m to at least 300m above ground and probably much higher. Studies have recorded the swift eating small bees, wasps, termites and moths.

In Australia, they mostly occur over inland plains, but sometimes above foothills or in coastal areas. They often occur over cliffs, beaches, islands and sometimes well out to sea. They also occur over settled areas, including towns, urban areas and cities. They mostly occur over dry or open habitats, including riparian woodland and tea tree swamps, low scrub, heathland or saltmarsh. They are also found at treeless grassland and sand plains covered with spinifex, open farmland and inland areas, and coastal sand dunes. They forage aerially, up to hundreds of metres above ground, but also less than 1m above open areas or over water. They often occur in areas of updraughts, especially around cliffs. They are said to search along edges of low-pressure systems, which assist flight. They sometimes feed aerially among tree-tops in open forest (Higgins 1999). They probably roost aerially, but are occasionally observed to land (Higgins 1999).

The Fork-tailed Swift usually arrives in Australia around October, some arrive early in September; however, this is rare. They depart for their breeding sites in Siberia in late April.

There are no significant threats to the Fork-tailed Swift in Australia, although potential threats include habitat destruction and predation by feral animals. Due to the wide range of the species throughout Australia, the potential impacts of the proposed project are predicted to be negligible.

Other Listed Migratory Marine Species

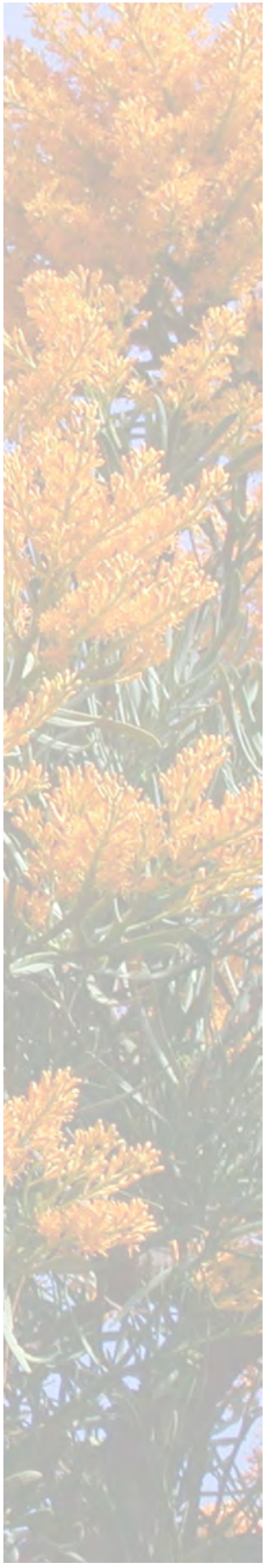
The Great Egret and Cattle Egret are also listed migratory marine species. Potential impacts on Great Egret and Cattle Egret and their management are detailed in Section 8.1.5.2.

8.1.6. Other Matters Protected by the EPBC Act

Limnodromus semipalmatus (Asian Dowitcher)

The Asian Dowitcher is a listed marine species. It is a large wader and member of the *Limnodrominae* family. An estimated 23,000 Asian Dowitchers occupy the East Asian-Australasian Flyway. The Asian Dowitcher breeds in Siberia, Mongolia and north-east China, moving south for the boreal winter to the non-breeding areas on the Asian coast (from the Persian Gulf to the Malay Peninsula). They depart the breeding grounds in late July–August; however, some birds remain until early September. The south-east coast of Sumatra and northern Java are probably the main staging and non-breeding areas for the species. Only a few arrive in Australia, with no known movements within Australia. They are occasionally recorded in the Northern Territory, rarely in Western Australia or along the south-west coast. They have been recorded along the east coast from mid-September; however, they are rare in eastern Australia.

There are a number of threats that affect migratory shorebirds in the Flyway. The greatest threat is indirect and direct habitat loss.



Limnodromus semipalmatus was not recorded in the project area during project surveys. *L. semipalmatus* is unlikely to use near-coastal wetlands (including those adjacent to the project area), except as occasional vagrants. Whilst the environmental conditions and the potential threats to this species could be manifest in the project area, targeted surveys did not record it and, as such, it is considered unlikely to occur in the project area.

By reducing native vegetation clearing and implementing vegetation management strategies contained within a CEMP to assist in managing impacts, such as habitat loss, *L. semipalmatus*, should it occur, will be indirectly managed. It is not anticipated that this project will have an impact on the significance classification or regional viability of this species.

8.2. Management and Mitigation Measures

This section discusses the management and mitigation proposed for reducing the scale of impacts on EPBC list species, as described above. The majority of management and mitigation addresses impacts on all species; however, where necessary, specific management measures are described.

8.2.1. Habitat Loss

Habitat loss will occur predominantly as a result of clearing activities for construction. The scale of this impact has been addressed through the consideration of alternative project design options. The design development phase has paid considerable attention to minimising habitat loss through the application of the following avoidance measures:

- Modified design features to reduce the width of the footprint and therefore the amount of habitat to be disturbed (e.g. steep batters (2.5:1 slope rather than 3:1), retaining walls in lieu of batters, reduction in width of median strip from 15m to 4m, adjustments to the final finished level of the carriageways to reduce the amount of cut and fill);
- Placement of the highway alignment in order to minimise disturbance to riparian vegetation and avoid disturbance of shoreline habitat at the northern end of Bibra Lake;
- Designing the proposed cut west of Roe Swamp such that the drainage pipes are positioned above the local groundwater level (approximately 16.5m Australian Height Datum (AHD)) to avoid dewatering and subsequent impact on *Banksia* woodland;
- Proposed bridges at Roe Swamp and between North and Bibra lakes to:
  - minimise the risk of hydrological impacts leading to habitat decline;
  - minimise vegetation clearing and habitat loss; and
  - enhance fauna connectivity;
- Proposed implementation of an 'incremental top-down' construction methodology over Roe Swamp that avoids the need for:
  - Continuous clearing under the structure that would otherwise be required for a non-elevated road carriageway; and
  - An access road and associated vegetation clearing;

- Delineating the extent of clearing by installing fencing at the boundaries of the construction zone and tagging specific trees for retention;
- Restoring degraded parts of Horse Paddock Swamp and Roe Swamp; and
- Rehabilitating cleared areas on completion of works, where possible.

In addition to these general management practices aimed at mitigating impacts on a variety of species, specific management is also proposed below.

8.2.1.1. Habitat Loss for Listed Threatened Birds

Neither Carnaby's Black Cockatoo nor Forest Red-tailed Black Cockatoo are known to nest within 27km of the project area. However, given the increasing pressures of urbanisation and black cockatoo habitat loss, it is recognised that nesting habits of these species may change in the future. There has already been a noticeable shift in recent decades of the breeding range of Carnaby's Black Cockatoo into the Jarrah/Marri forests of the Darling Scarp and the Tuart forests of the Swan Coastal Plain.

Impacts on habitat for Listed Threatened species was a design focus and resulted in an alignment that:

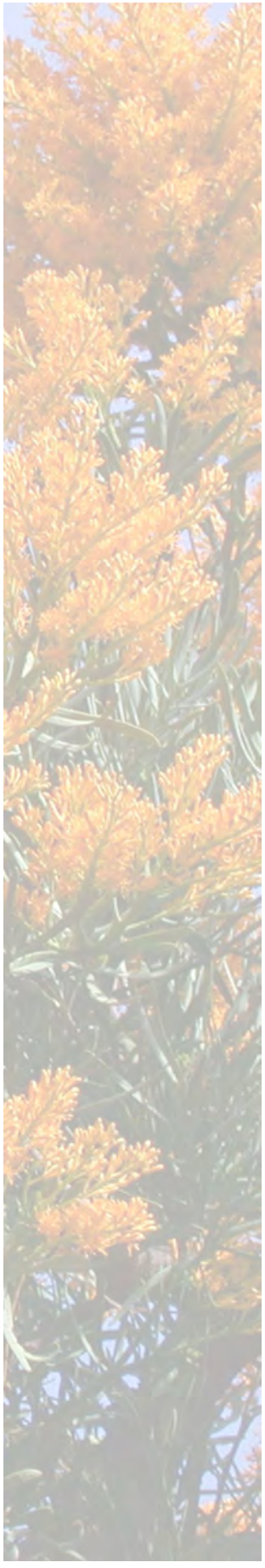
- Minimised removal of significant trees with existing potential nesting hollows; and
- Minimised the length of clearing required through black cockatoo foraging habitat.

Further management and mitigation measures (detailed in Sections 6.6.4 and 6.7.4) will be undertaken to minimise the impact of habitat loss including:

- Including species suitable for black cockatoo habitat in the revegetation of degraded parts of Horse Paddock Swamp and areas cleared during construction that are surplus to the operational requirements of the road; and
- As an approved offset, investigating the effectiveness of translocating mature *Banksia* trees to minimise losses of black cockatoo foraging habitat and implementing a translocation programme if determined to be a viable option.

8.2.1.2. Habitat Loss for Listed Threatened Insects

Habitat loss and fragmentation are the most significant impacts on listed insects by the proposed project. The design development phase has paid considerable attention to minimising habitat loss of *L. hermaphrodita*. This has been achieved through the modification of design elements to reduce the width of the footprint and, therefore, the amount of *L. hermaphrodita* habitat to be disturbed, as outlined above. Nevertheless, the configuration requirements of the interchange between Roe Highway and Stock Road (i.e. free flow movements in almost all directions) are such that the removal of confirmed Graceful Sun-moth habitat is unavoidable. Furthermore, avoiding suitable and potential habitat is problematic due to its extent throughout the project area.



Further management and mitigation measures (detailed in Sections 6.6.4 and 6.7.4) will be undertaken to minimise the impact of habitat loss, including:

- Delineation of known habitat to minimise damage to *L. hermaphrodita* outside the highway footprint during construction; and
- Contributing funding to a Graceful Sun-moth translocation and research programme (as an approved offset) that may involve:
    - Quantifying suitable *L. hermaphrodita* habitat within the project area with the aim of identifying habitat fragments of greater than 10ha and implementing conservation measures for these areas;
    - Translocating known habitat and/or adult Graceful Sun-moths from the known population as founder moths into new areas containing suitable habitat;
    - Monitoring Graceful Sun-moth populations in translocation area to measure translocation success; and
    - Monitoring Graceful Sun-moth populations within and outside the project area for at least two years to capture the biannual larval-adult life cycle.

8.2.1.3. Habitat Loss Listed Migratory Terrestrial Birds

With the exception of the Rainbow Bee-eater, which may potentially breed/nest within the project area, migratory terrestrial bird species (pursuant to the *EPBC Act*) will not be directly affected by habitat loss, as there will be no loss of shoreline or lakebed habitats within the project area.

Rainbow Bee-eater nesting habitat will be disturbed as a result of aligning of the proposed project along the cleared high tension power line access track. However, the proposed project is likely to result in alternative cleared sandy areas being created, particularly on embankments and access areas adjacent to the proposed project.

8.2.1.4. Habitat Loss for Listed Migratory Wetland Birds

Habitat loss and fragmentation are the most significant impacts on the listed migratory wetland birds arising from the proposed project. In addition to the design elements included to minimise habitat loss, further management and mitigation measures will be undertaken (detailed in Sections 6.6.4 and 6.7.4) to minimise the impact of habitat loss, including:

- Minimising damage to surrounding wetland habitats (shoreline) outside the project footprint during construction, by fencing or clearly delineating the construction site boundaries;
- Revegetating degraded parts of Horse Paddock Swamp and Roe Swamp;
- Obtaining water required for construction from off-site sources to avoid on-site groundwater drawdown; and
- Installing artificial nesting boxes to replace lost nesting hollows for wetland birds beyond the 50dB(A) noise contour.

8.2.2. Road Mortalities

Road mortalities may impact the listed bird species, should they occur within the project area. Risk of road mortalities will be minimised through:

- Installing visual barriers, such as 3m vertical poles or native trees grown to sufficient height, at 3–4m intervals along the edge of the alignment where it passes through existing habitat, commensurate with the requirements of construction, detailed design and community consultation, to encourage birds to fly over the height of the traffic on the road;
- Avoiding the creation of rehabilitated foraging or potential nesting habitat immediately adjacent to the road alignment;
- Installing fauna-proof fencing either side of the proposed construction footprint, to contain movement of construction machinery; and
- Maintaining permanent fencing throughout the alignment, where it passes through sensitive habitat.

8.2.3. Collision with Powerlines

Replacement power lines will have high visibility reflectors fitted onto them. It is likely that they will be strung higher than the current lines and this will further reduce the likelihood of birds flying into them or attempting to perch on them.

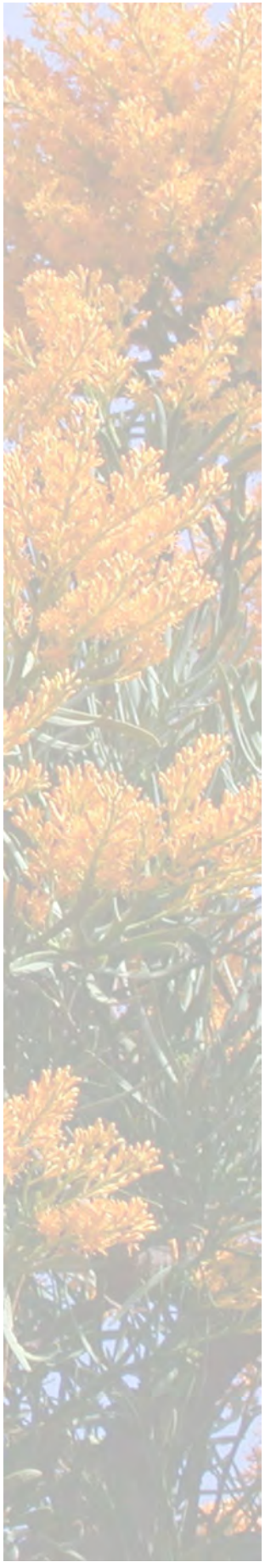
8.2.3.1. Noise

Operation of the proposed project will result in increased traffic noise and is a potential risk to migratory and wetland birds. Studies indicate that traffic noise may affect bird communication that is important for defence and mate selection (Jacobson 2005; Appendix T).

Appendix T presents an assessment of the effects of traffic noise on wetland birds. It is known that some form of habituation occurs in response to repeated noise. An issue of concern arises when acclimatisation does not occur and noise causes a decrease of survivability and reproduction, as a result of a retreat away from favourable habitats (SKM 2006). Although, this may be relevant for wetland birds, there is no species-specific information on the effects of noise. As indicated in Appendix T, the effect of traffic noise on birds becomes apparent above noise levels of 55dB. Figure 6.10-6 illustrates the areas where noise levels of 55dB are expected to extend from the proposed project into the wetland areas. The noise assessment of the effects of traffic noise on wetland birds also indicates that noise levels from 50dB(A) cause physiological stress and masking of vocalisations of wetland birds.

There is insufficient research to quantify the extent of this impact. Until fauna adapt to the noise, there are expected to be a temporary displacement of populations away from areas predicted to have 55dB noise levels and greater. The consequences of noise in the project area on migratory and wetland birds are difficult to quantify but may include:

- Temporary avoidance of areas with predicted noise levels of 55dB and greater; and
- Physiological stress and masking of vocalisations at noise levels from 50dB(A).



8.2.4. Altered Hydrological Conditions

The risk of perched seasonal aquifers being impacted by the proposed project has been assessed as negligible beyond a 50m zone on either side of the proposed alignment. Within this zone, there is the potential for a decline in the health of Groundwater Dependent Ecosystems (GDE); however, the deeper rooted black cockatoo habitat species are not expected to be significantly impacted. Changes in hydrological conditions will be minimised by maintaining existing groundwater flows through the project area, as well as ensuring surface water movements are not impeded. Further details are provided in Section 6.3.

Stormwater will be stored in drainage basins, which will lead to habitat loss. The southern-most drainage basin at the Stock Road interchange will make use of a natural depression in the landscape; and therefore will not require the removal of vegetation. Accordingly, for the short-term, existing black cockatoo habitat will be retained. There is the risk that over time, excess waterlogging will lead to a decline in the health or successional change of habitat. This impact has been incorporated in the construction clearing footprint.

Water required for construction will be obtained from off-site sources to avoid localised groundwater drawdown. Water abstraction and consumption will be undertaken in accordance with the necessary permits required, pursuant to the *Rights in Water and Irrigation Act 1914*.

8.2.5. Fire

Fire risk will be managed during construction through the development and implementation of a CEMP. The management plan will aim to ensure that no uncontrolled fires occur within the project area or Beeliar Regional Park, as a result of construction activities. Management of potential fire impacts on vegetation is outlined in Section 6.6.4.8.

Fire management during the operational life of the proposed project will include the maintenance of existing fire breaks. The need for additional fire breaks will be considered in consultation with Fire and Emergency Services Authority of Western Australia (FESA) and the Department of Environment and Conservation (DEC). However, it is noted that the proposed project itself (including sections with noise barriers) serves as an extensive fire break between the north and south sides of the alignment.

8.2.6. Artificial Night Lighting

Innovations with respect to lighting through the wetland section of the proposed project are under investigation. Options being considered for use, as they relate to listed terrestrial and wetland bird impact management, include installation of:

- Low level lighting aimed directly at the road surface;
- Directional lighting that avoids light spill into adjacent habitats;
- Sensor lights, particularly along the Principal Shared Path (PSP), that only operate when required; and
- Screens to limit fugitive light spill from the proposed project.

The implementation of innovative lighting solutions will be dependent on its conformance to road safety standards, which is the primary focus for road lighting. Consideration will be given to the above strategies for lighting design, where possible.

8.2.7. Listed Plants

Since no *EPBC Act* listed plants have been recorded in the project area during targeted surveys, they are considered unlikely to be impacted by the development and, as such, specific management measures for listed plants are not outlined. Avoidance measures have been implemented in order to reduce impacts from the proposed project on vegetation (even though unlikely to contain *EPBC Act* listed plants). Rather, potential impacts will be managed via vegetation clearing controls and the development of vegetation management strategies contained within a CEMP. This will include measures to avoid, minimise, reduce, rectify and manage impacts on flora and vegetation during the project phases (detailed design, construction and operation, detailed in Section 6.6.4).

8.2.8. Habitat Fragmentation and Edge Effects

The design development phase has paid significant attention to minimising habitat fragmentation through the inclusion of the following avoidance and mitigation measures:

- Proposed bridge at Roe Swamp to maintain habitat connectivity;
- Proposing to implement a construction methodology that avoids the need for continuous clearing under the structure or an access road and its associated vegetation clearing; and
- Proposed bridge between Bibra Lake and Horse Paddock Swamp.

The proposed construction method for the bridge at Roe Swamp avoids the need for active clearing between the two bridge abutments by avoiding ground level access requirements. Vegetation underneath the alignment will be retained and maintained to provide groundcover for fauna movement by restricting access to rubber wheeled light weight vehicles on currently cleared power line tracks. This vegetation largely comprises *Melaleuca* woodland habitat. A decline observed in vegetation condition due to shading in these areas will be supplemented by planting with low light and moisture tolerant species. Ground habitat features such as fallen logs, top soil and leaf litter will also be installed to supplement an observed decline in fauna habitat.

The proposed bridge between Horse Paddock Swamp and Bibra Lake will combine a fauna, bicycle and pedestrian underpass linking Bibra Lake with Horse Paddock Swamp. This will be in the form of an archway and will be designed with a large opening.

Edge effects will be managed through the development and implementation of:

- Soil Hygiene and Weed Control Plan; and
- Rehabilitation and Revegetation programme.

8.3. Residual Impacts on Matters of National Environmental Significance

The following sections outline the residual impacts on each matter of NES, once the above management and mitigations have been applied.

8.3.1. Residual Impacts on Listed Threatened Birds

The objective for management of impacts on black cockatoos is to ensure a net overall gain in extent of protected habitat. Having minimised the extent of habitat loss required for the project, as much as is reasonably practicable through design, Main Roads will achieve this objective by replacing lost habitat at a ratio to be agreed in consultation with the DSEWPaC and DEC through an approved offset strategy, in accordance with the framework and principles outlined in Section 10.

8.3.2. Residual Impacts on Listed Threatened Insects

The proposed project will result in the loss of at least 64 percent of habitat for the confirmed Graceful Sun-moth population at Stock Road and it is likely that this will result in the loss of the entire population. However, because this population exists in the smallest habitat fragment currently known to support a population of Graceful Sun-moths, it is considered likely that it is unviable in the long-term.

Main Roads therefore commits to allocating funding, by way of an indirect offset, to research programmes that will investigate the biology of the species, as well as the biology of its preferred habitat. Such research is likely to include the implementation of a translocation programme, both for adult Graceful Sun-moths and *Lomandra hermaphrodita*. Funding details are to be negotiated with the DEC and the Botanical Gardens and Parks Authority and are discussed in Section 10.

8.3.3. Residual Impacts on Listed Plants

No impacts are likely to occur on *EPBC Act* listed plant species, as they are not known to inhabit the project area. The implementation of the management measures described above will ensure measures for mitigating and managing impacts on vegetation and, therefore, potential habitats for *EPBC Act* listed plants are applied.

8.3.4. Residual Impacts on Listed Migratory Birds

The implementation of the management measures described above, as well as the development and implementation of a CEMP, are considered sufficient to ensure that the proposed project is unlikely to have a significant impact upon the population viability of the listed terrestrial migratory birds.

9. Environmental Commitments

Main Roads has made a number of commitments in relation to the environmental management outcomes of the proposed project. These proposed commitments are documented in the relevant factor sections within this PER and are summarised in Table 9.1-1 along with respective timing, responsibility and advice.

9.1. Summary of Environmental Commitments

Table 9.1-1 lists the key factors identified by EPA and outlines the commitments provided to ensure that impact on those factors are minimised. The table commits to outcomes, rather than specific measures intended to achieve that outcome. Certain measures are proposed that are currently considered likely to be required to achieve these stated outcomes; however, Main Roads intends to retain the ability for its nominated construction partner to introduce alternative methods or innovations to achieve the stated outcomes, where applicable. As such, the proposed solutions are only one currently apparent, viable way of attaining the stated outcomes. Other ways or means of solution may emerge with further design and project planning, so the nominated proposed solution should not be seen to limit the attainment of the stated outcomes.

Table 9.1-1: Summary of Environmental Management Commitments

Factor	Objective		Commitment	Possible Solution	Timing	Advice
Wetlands	To maintain existing ecological functions and environmental values.	1.1	Maintain wetland ecological connectivity either side of the proposed road where it crosses Roe Swamp	Ensure no more than 2.1ha of intact native vegetation ('Degraded to Good' or better condition rating) is removed from within the Roe Swamp CCW Monitor vegetation survival under the bridge at Roe Swamp Supplementary planting with low light tolerant species as required	During construction	DEC
		1.2	Minimise ground compaction areas in Roe Swamp that would otherwise have occurred as a result of traditional construction methods	Vehicular access restricted to rubber wheeled, light weight vehicles only on currently cleared transmission line access track between bridge abutments in Roe Swamp Access will only be permitted for works that cannot be undertaken safely from above or by foot (such as tree lopping, pile positioning, etc)	During construction	-
		1.3	Ground and surface water conveyance through Roe Swamp will be maintained	Provide a bridge at Roe Swamp Locate the bridge over the topographical low point of Roe Swamp Include culverts through formation to the extent of the predicted maximum flood extents (calculated from approximately 100 years of historical data)	Prior to commencement of construction	DoW
		1.4	Hydrological function associated with Murdoch drain will be retained	Reconstruct Murdoch Drain north of its current alignment as close to the proposed project as practicable, giving consideration to the inclusion of a vegetation buffer between the proposed project and the drain	During construction	DoW

Factor	Objective		Commitment	Possible Solution	Timing	Advice
		1.5	Maintain existing groundwater levels between Bibra Lake and Horse Paddock Swamp	Construct a bridge at Horse Paddock Swamp	During construction	DoW
		1.6	Contain and treat road runoff to remove potential contaminants to baseline levels	Creation of a bioretention basin east of Horse Paddock Swamp for road runoff capture	During construction	DEC
		1.7	Prevent project construction activities from causing the spread of dieback	Vegetation removal and topsoil stripping between Bibra Drive and Progress Drive will be limited to dry conditions and will not occur when water expresses above natural ground levels Implementation of a Site Hygiene Plan during construction	During construction	DEC
		1.8	Prevent the release of sediment into wetlands	Vegetation removal and topsoil stripping between Bibra Drive and Progress Drive will be limited to dry conditions and will not occur when water expresses above natural ground levels Surface water will be contained within the construction site	During construction	DEC
		1.9	Prevent the release of Acid Sulfate Soils into wetlands	Excavation between Bibra Drive and Progress Drive will be subject to requirements outlined in Commitment 2.2	During construction	DEC
		1.10	Minimise the risk of contaminants being released into the wetland system	All potentially contaminating activities such as refuelling and maintenance of construction plant and equipment will be undertaken within designated areas to be located outside of wetland areas	During construction	DEC

Factor	Objective		Commitment	Possible Solution	Timing	Advice
Acid Sulfate Soils	Prevent the occurrence of acidification within the project area due to construction activities	2.1	Confirm the occurrence or otherwise of Acid Sulfate Soils (ASS) where excavations are required	Undertake a Detailed Site Investigation (DSI) for the presence of ASS where excavation are required for construction	Prior to commencement of excavations	DEC
		2.2	Manage ASS in accordance with regulatory requirements to prevent liberation of ASS into the project area	Prepare and implement an ASS Management Plan Plan operational procedures in accordance with ASS constraints	Prior to, during and two years after completion of construction	DEC
Sources of Potential Contaminants	Avoid exposure of contaminated materials in the project area as a result of construction activities	3.1	Contamination status of project area will be confirmed and mapped, where present	DSI that focuses on the reported historical landfill adjacent to Bibra Drive	Prior to commencement of construction	DEC
		3.2	Contaminated material will be handled and disposed appropriately and sites will be validated in accordance with procedures and regulations	If determined necessary as a result of 3.1, prepare and implement subsequent investigations and plans in accordance with WA Contaminated Land series	Prior to commencement of construction within the affected area	DEC
Vegetation and Flora	To maintain abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge	4.1	A maximum of 79ha of remnant native vegetation will be removed	Design includes retaining walls and narrowed median strip to minimise cross-sections and formation widths All storage and laydown areas will be located within the project footprint or will be established within previously cleared land Construction activities will be contained within the project footprint.	Commencement of and during construction	DEC
		4.2	Areas cleared for construction will be rehabilitated Areas already cleared and not required for other purposes will be restored following completion of construction	Areas disturbed as a result of construction activities and no longer required for operational purposes will be rehabilitated Vegetation and topsoil removal and handling will be managed in accordance with a Vegetation and Topsoil Management Plan	Completion of construction with monitoring to occur for 5 years following completion	DEC

Factor	Objective		Commitment	Possible Solution	Timing	Advice
				Rehabilitation success will be monitored		
		4.3	Improve the functionality of local ecological linkages between the northern and southern sides of Hope Road	Hope Road west of the proposed cul-du-sac will be removed and rehabilitated with local native flora (other than a 6m wide strip to accommodate a proposed Principal Shared Path (PSP))	Completion of construction	DEC
		4.4	Avoid the importation of fill contaminated with pollutants, *Phytophthora* and/or weeds	A Site Hygiene and Quarantine Plan will be prepared that details requirements for site access controls, site movements, and wash down procedures where necessary	Prior to commencement of clearing	DEC
Fauna	To maintain abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge	5.1	Protect fauna from contact with construction operations and highway traffic	Install permanent fauna proof fencing on either side of the construction footprint where it traverses remnant native vegetation A three month trapping programme will be undertaken to remove fauna from the construction area and relocate to alternative suitable habitat Suitable alternative habitats for relocation will be determined in consultation with DEC	Prior to commencement of construction	DEC
		5.2	Maintain connectivity for fauna to migrate between the northern and southern sides of the alignment	Install fauna underpasses that are separated by no more than 100m where the proposed project is of sufficient height between Progress Drive and Bibra Drive to accommodate underpasses of up to 600mm height and width	During construction	DEC
		5.3	Maintain connectivity for fauna to move in an east/west direction through the section between Progress Drive and Stock Road	Provision of a connection under North Lake Road, Coolbellup Drive, Sudlow Road and Stock Road. Underpasses will be of varying size to accommodate a variety of species	During construction	DEC

Factor	Objective		Commitment	Possible Solution	Timing	Advice
Ecological Linkages	To maintain abundance and diversity of flora species and allow for long-term genetic conveyance along continuous regional corridors that link many different vegetation complexes. To maintain abundance and diversity of fauna species and allow for fauna movement along continuous regional corridors that link different habitat types.	6.1	Maintain surface water connectivity between habitats	Construction of a bridge between Bibra Lake and Horse Paddock Swamp Construction of a bridge at Roe Swamp	During construction	DEC
		6.2	Maintain connectivity for local ecological linkages within the project area	Install fauna underpasses that are separated by no more than 100m where the proposed project is in fill of sufficient height between Progress Drive and Bibra Drive to accommodate underpasses of up to 600mm height and width Provision of a connection under North Lake Road, Coolbellup Drive, Sudlow Road and Stock Road	During construction	DEC
Aboriginal Heritage	To ensure that changes to the biophysical environment do not adversely affect Aboriginal heritage and comply with relevant heritage legislation.	7.1	Subject to agreement with traditional custodians relocate a selection of prominent, mature *Nuytsia floribunda* for use as entry statements and for the possible punctuation of interpretive trails that highlight Aboriginal heritage values of the project area	Translocate a selection of prominent, mature *N. floribunda* trees occurring within the project footprint	During clearing activities	DIA Botanical Gardens and Parks Authority

Factor	Objective		Commitment	Possible Solution	Timing	Advice
Noise	To protect the amenity of nearby residents and visitors to the recreation reserve from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards	8.1	Noise levels will not exceed the SPP5.4 limit at properties adjoining the proposed new road	Model the noise impacts of the detailed design to determine all reasonable and practicable measures required to minimise the extent of noise impacts on sensitive receptors	Completion of Construction	DEC
		8.2	Noise levels will be within SPP5.4 target levels at the ground floor of the vast majority of properties adjoining the proposed new road			
		8.3	Noise levels will be within SPP5.4 limit levels at the ground floor of the vast majority of properties that will be affected by upgrades to existing roads, as defined by SPP 5.4 clause 5.2.2			
		8.4	There will be a reduction in noise levels due to the proposed upgrades to existing roads at the remaining properties currently exceeding the noise limit.			
		8.5	Minimise the effects of construction noise Reduce the visual impact of construction activities Improve public safety by improving separation between private residences and construction activities	Where possible, commensurate with construction programming, permanent noise barriers will be erected along property boundaries prior to commencement of construction in areas adjacent to affected properties	Prior to commencement of earthworks adjacent to receptors and allowing for removal of vegetation where required	DEC

Factor	Objective		Commitment	Possible Solution	Timing	Advice
Recreation	To ensure existing and planned recreational uses are not compromised	9.1	Maintain connectivity for pedestrians and Regional Park users between either side of the proposed alignment	Install pedestrian underpasses: at the track immediately west of Roe Swamp, alongside Progress Drive; and under the bridge at Horse Paddock Swamp Install a boardwalk around the northern end of Bibra Lake, between the lake and the proposed road	During construction	City of Cockburn
Visual amenity	To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape	10.1	Minimise impacts on key view across Bibra Lake, from North Lake, for users of local schools and for residents living in close proximity to the proposal	Design, implement and maintain the Landscape and Urban Design in line with the intent of the Landscape and Urban Design Framework	As part of detailed design and implementation	-
		10.2	Minimise impacts on visual amenity and landscape values of Beeliar Regional Park	Design, implement and maintain the Landscape and Urban Design in line with the intent of the Landscape and Urban Design Framework	As part of detailed design and implementation	DEC
		10.3	Express local identity (focusing on cultural and natural heritage) and visually enhance the road environment	Allocate a fixed percentage of project funding to the implementation of a Public Art and urban design programme	As part of detailed design and implementation	-
Greenhouse gases	Minimise emissions of greenhouse gases during construction	11.1	Provide a benchmark carbon emissions value against which to drive improvements in efficiencies for the proposed and future projects	Calculate Business as Usual (BAU) direct and indirect emissions for construction activities in accordance with methods provided in Appendix W based on detailed design	Prior to commencement of Construction	Verified by independent auditor
		11.2	Report on actual carbon emissions	Included in completion report	Completion of construction	EPA

Factor	Objective		Commitment	Possible Solution	Timing	Advice
General	Ensure project commitment objectives are achieved	12.1	Ensure adherence to site environmental management procedures	Development and implementation of a project specific Environmental Management System Appointment of a suitably qualified Site Environmental Officer Preparation of a detailed Construction Environmental Management Plan (CEMP) Delivery of project inductions and toolbox meetings Implementation of strict control and audit programme	During construction	DEC
		12.2	OEPA will be able to track performance against Commitments	Prepare an annual Compliance Report	Annually until 5 years following completion	OEPA
		12.3	OEPA will be able to determine adequacy of Conditions and Commitments for application on future projects	Prepare a Performance Review	5 years following project completion	OEPA

9.2. Outcome Based Commitments

The following section details a number of specific commitments where a defined outcome can be defined. It is presented in a format commensurate with EPA Environmental Assessment Guideline No.4 Towards Outcome Based Conditions. This enables a clear outline of the desired outcome to be presented, from which conditions can be imposed on the proposed project.

9.2.1. Annual Compliance Reporting

9.2.1.1. Commitment

Upon commencement of construction, Main Roads will prepare and submit an Annual Compliance Report (ACR) for the duration of construction activities and five years following practical completion.

9.2.1.2. Outcome

Annual Compliance Reports will:

- detail Main Roads' performance against each of its project commitments;
- highlight non-compliance;
- describe corrective and preventative actions; and
- indicate proposed changes to compliance assessment requirements

9.2.1.3. Monitoring Programme

Main Roads will monitor its compliance with project commitments through construction and up to five years following practical completion. Specific monitoring requirements are outlined for each individual commitment detailed below.

9.2.1.4. Reporting Requirements

A Compliance Assessment Plan will be submitted to the EPA prior to the commencement of annual reporting requirements of the commitments detailed below and will indicate the:

- Timing of reporting requirements;
- Duration of annual compliance reporting;
- Approach for reporting against individual commitments; and
- Method and frequency for reporting non-compliance and corrective actions taken

9.2.2. Hope Road Bioretention Basin

EPA's objective for water quality is:

> *To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.*

9.2.2.1. Commitment

To ensure that water quality is not adversely impacted by the proposed project by establishing an efficient infiltration and bioretention basin which mimics the natural wetlands within the project area.

A large infiltration basin (Hope Road Bioretention Basin) with dedicated vegetated bioretention elements will be constructed and maintained in an area adjacent to Horse Paddock Swamp as illustrated in Figure 3.5-3. This basin is one component of a series of surface water treatments for the proposed project and as it is in close proximity to several wetlands it will be designed as much as possible to mimic these wetlands.

9.2.2.2. Outcome

Vegetated bioretention basins primarily operate by directing stormwater through surface vegetation and allowing runoff to filter and percolate through a prescribed filter media layer. During filtration, pollutants are retained through fine filtration, adsorption and some biological uptake. The most vital functioning element in a bioretention basin is the vegetation, which provides a substrate for biological activity, facilitating gaseous exchange to the soil, and aids microbial communities in biodegradation and assimilation of contaminants collected at the treatment site.

Detailed design of the proposed bio-retention basin will aim to incorporate vegetation suited to the local climate and post construction hydrology, and will be selected on the basis of a specific inundation frequency analysis. The design will ensure that:

- stormwater will preferentially engage the bioretention area until the 350mm extended detention depth is reached (typically the 3 month Annual Recurrence Interval (ARI) event);
- larger infrequent events will be retained within the wider infiltration basin area (between 3 month and 5 year ARI);
- rainfall events greater than 5 year ARI will overtop a spill way and flow into Horse Paddock Swamp;
- filter medium has a saturated hydraulic conductivity of 180mm/hr, compared with the existing soil hydraulic conductivity of 625mm/hr; and
- the combination of reduced hydraulic conductivity with the nutrient stripping capacity of the vegetation will ensure:
    - total suspended solids are reduced by 85%;
    - total phosphorus levels are reduced by 65%; and
    - total nitrogen levels are reduced by 45%.

9.2.2.3. Monitoring Programme

Groundwater monitoring bores will be installed (if not already available) at locations up- and down- gradient of the bioretention basin. A Sampling and Analysis Programme (SAP) will be developed and submitted to EPA in the Annual Compliance Review Report that immediately precedes the commencement of operation, which will specify:

- Analytes to be measured;
- Frequency of measurements;
- Trigger levels for corrective actions; and
- Nominated corrective actions in the event that trigger points are exceeded.

Main Roads will monitor the groundwater quality for up to three years following completion of construction.

9.2.2.4. Reporting Requirements

Main Roads will include the results of monitoring in accordance with the SAP required by 9.2.2.3 in its Annual Compliance Report commencing with the ACR immediately following completion of construction.

Main Roads will submit a closeout report as part of its final ACR to be to be submitted 3 years following completion of construction and seek confirmation from the Office of the EPA (OEPA) that the commitment has been met.

9.2.2.5. Contingency

In the event that monitoring indicates that the basin is not operating effectively, Main Roads will undertake a performance review of the bioretention basin in consultation with the Department of Water and Department of Environment and Conservation (DEC) to determine appropriate corrective actions. The outcome of the review will be reported to the OEPA with Detailing recommendations for corrective actions.

Main Roads will implement the proposed corrective actions upon approval from OEPA.

9.2.3. Acid Sulfate Soils

Although the EPA does not have a specific objective for Acid Sulfate Soils (ASS), in relation to pollution management, the EPA states the following objective:

> *To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.*

9.2.3.1. Commitment

Main Roads will ensure that construction activities do not result in the release of sulphuric acid and other contaminants to the environment as a result of oxidation of ASS.

9.2.3.2. Outcome

The risk of the release of sulphuric acid and contaminants due to oxidation of ASS as a result of construction activities will be minimised through a programme that:

- Includes a DSI into the presence of ASS for all areas identified in Appendix E as medium to high risk that are within the construction footprint and will be subject to excavation;
- Requires the preparation of an Acid Sulfate Soil Management Plan (ASSMP) that specifies appropriate treatments for the management of any PASS, to the requirements of the Department of Environment and Conservation's Acid Sulfate Soils Guideline Series; and
- Implements the ASSMP In accordance with this commitment.

9.2.3.3. Monitoring Programme

Detailed monitoring procedures will be outlined in the ASSMP if required as a result of 9.2.3.2. The ASSMP will stipulate monitoring locations, frequency and trigger values that will be determined depending on the extent of ASS identified by the DSI and the length of time that excavations will be open. Monitoring locations will include (but not be limited to) bores, bunded ASS treatment areas, surface water and excavations.

Baseline monitoring will be undertaken prior to the commencement of construction to establish a baseline for the project. The duration of monitoring will be as defined in the ASSMP.

9.2.3.4. Reporting Requirements

Main Roads will submit monitoring data to the DEC in accordance with a reporting schedule agreed for the ASSMP. In addition, Main Roads will incorporate monitoring results in its Annual Compliance Report, as outlined in 9.2.1.1. The final Annual Compliance Report that addresses this commitment will be the report scheduled for submission following completion of monitoring required pursuant to the ASSMP.

9.2.3.5. Contingency

In the event that results of monitoring undertaken during and after disturbance and treatment of ASS, required pursuant to 9.2.3.2, exceed trigger levels defined in the ASSMP:

1) Main Roads will report such findings to the Office of the Environmental Protection Authority within 7 days of the exceedances being identified; and
2) Main Roads will implement actions to bring measured variables back within trigger levels using methods consistent with the DEC Acid Sulfate Soils Guideline Series and to the satisfaction of the OEPA, on advice of the DEC.

9.2.4. Sources of Potential Contaminants

Although the EPA does not have a specific objective for sources of potential contaminants, in relation to pollution management, the EPA states the following objective:

> *To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.*

The key objective of the following commitment is to ensure that disturbance of historical or in situ contaminants does not lead to an unacceptable risk to human health and/or environmental harm.

9.2.4.1. Commitment

Prior to the commencement of construction, Main Roads will confirm and map the contamination status within the project area.

9.2.4.2. Outcome

Unplanned disturbance of historical ground contamination within the project area will be avoided through the execution of a Detailed Site Investigation (DSI) that focuses on the reported historical landfill adjacent to Bibra Drive. The DSI will be undertaken prior to commencement of ground disturbing activities within the vicinity of the identified site. This will include:

a) A detailed desktop investigation into the reported site as preliminary input to the site investigation;
b) If required as a result of a), reporting of the site to the DEC and a site sampling and laboratory analysis programme in areas determined to coincide with the construction footprint, which will be confirmed during detailed design; and
c) The preparation of a management plan in accordance with the DEC *Contaminated Sites Management Series* guidelines in the event that disturbance of contaminated soils is assessed to be likely, as a result of b).

9.2.4.3. Soil Monitoring Programme

Should the DSI indicate the presence of historical soil contamination that will be disturbed by construction activities, Main Roads will implement a monitoring program in accordance with the management plan prepared pursuant to item 9.2.4.2c). The monitoring programme will commit to the analysis of material excavated for construction purposes from within the target area and will include details of handling and disposal of materials removed from the site. Monitoring will continue for the duration of excavation activities within the target area.

9.2.4.4. Reporting Requirements

Prior to the commencement of construction, Main Roads will submit the results of the DSI required by 9.2.4.2b) to the OEPA and to the DEC.

If required, Main Roads will submit the management plan required by 9.2.4.2c) for approval by the DEC.

The ACR, required pursuant to 9.2.1.1, will include details regarding the monitoring of excavations within confirmed contaminated areas required pursuant to 9.2.4.2c). Reporting on monitoring required pursuant to 9.2.4.2c) will cease once the final results of monitoring has been reported on. Upon submission of this report, Main Roads will seek confirmation that the commitment has been completed.

9.2.4.5. Contingency

The management plan required pursuant to item 9.2.4.2c) will include procedures for responding to the disturbance of unidentified contaminants within the target area. It will also include contingencies for management of material unexpectedly encountered and/or not adequately removed during the initial site remediation.

9.2.5. Flora and Vegetation – Weeds and Vegetation Condition

The EPA objective in relation to flora and vegetation is:

> *To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.*

The key objective of the following commitment is to protect the bushland within the road reserve from increased weed invasion and further degradation from introduced species (weeds).

9.2.5.1. Commitment

Main Roads will ensure that no new species of weeds (including Declared Plants and environmental weeds) are introduced into the final amended road reserve as a result of the proposed project, for 3 years following completion of construction.

Prior to the commencement of construction, Main Roads will submit to the EPA a report detailing the results of a baseline assessment of the areas of bushland within the road reserve and adjacent to the construction footprint, that describes the:

- existing suite of weed species present;
- varying density and abundance (based on percentage foliage cover) of total weeds at a range of sites;
- existing bushland condition (in accordance with the Keighery (1994) scale) at a range of sites and extrapolated in between;
- spatial distribution of populations of Declared Plants and environmental weeds; and
- spatial extent of the varying bushland condition.

9.2.5.2. Outcome

The proposed commitment will ensure that construction activities do not result in the introduction and/or proliferation of weeds to the extent that it causes a decline in vegetation condition within the final amended road reserve.

Main Roads, through the implementation of a weed management programme, will ensure that in comparison to the existing baseline, there is no increase within the final amended road reserve in:

1) the number of species of Declared Plants;
2) the extent of existing Declared Plant populations; or
3) percentage foliage cover of total weeds as an indicator of density and abundance

9.2.5.3. Monitoring Programme

Prior to commencement of construction, Main Roads will install a series of monitoring quadrats in areas not proposed for clearing or direct disturbance as a result of construction activities. The quadrats will be used as the basis for a weed composition and vegetation condition survey, which will form the baseline against which change will be monitored. The initial survey will establish:

- weed species composition;
- the presence of Declared Plants and environmental weeds;
- weed density and abundance; and
- vegetation condition in accordance with the Keighery (1994) scale.

Once a baseline is established, an ongoing monitoring programme will be carried out throughout construction and up to five years following completion of construction. The monitoring programme will include two assessment methods run concurrently – permanent monitoring quadrats and rapid assessment sites (including photo points).

A minimum of twelve permanent monitoring quadrats measuring 10 metres by 10 metres will be established at locations considered representative of the project area's vegetation communities. The majority will be situated within native vegetation between Bibra Drive and Progress Drive. All monitoring quadrats will be pegged. At each quadrat, the following data will be recorded during each monitoring event:

- Weed species present;
- Projected foliage cover of each weed species present;
- Number of plants of any Declared Plants or environmental weeds present; and
- The bushland condition (in accordance with the Keighery (1994) scale) of the vegetation within the quadrat.

A series of rapid assessment areas will be established and will be recorded using GPS to enable relocation of the points for annual monitoring. A minimum of eight rapid assessment areas will be established and will enable extrapolation of weed and bushland condition values across the site, between quadrat and transect locations. The rapid assessment will include visual assessment of:

- The visible bushland condition (in accordance with the Keighery (1994) scale);
- Observations of any Declared Plants or environmental weeds present; and
- A photograph taken at a designated point that can be compared to subsequent and/or previous photographs, to assess visible changes in bushland condition and weed cover.

In addition to monitoring sites, Main Roads will implement measures aimed at minimising the risk of introducing and spreading weeds and plant pathogens to the site. Such measures will include regular vehicle and machinery hygiene inspections and topsoil and mulch management. All inspections and monitoring will be formally recorded in accordance with compliance monitoring requirements.

9.2.5.4. Reporting Requirements

Main Roads will prepare and submit to the EPA a baseline report with the first ACR to be submitted following completion of the baseline survey.

Following commencement of construction, Main Roads will submit to the EPA an ACR that details the outcomes of the weed monitoring programme, includes all monitoring and inspection checklists completed since the previous report and details any corrective actions required or performed since the previous report.

Main Roads will submit to the EPA a final Close Out report that outlines the outcomes of the monitoring programme, including details of any corrective or remedial actions during the five year compliance period and notifies the EPA that the monitoring programme is complete.

9.2.5.5. Contingency

In the event that monitoring identifies a change in weed composition at any of the monitoring sites, a broader assessment of the extent of change will be undertaken. The broader assessment will include a report on appropriate methods for addressing the specific issue, including recommendations for:

- Annual weed control; or
- Targeted control of declared plants and/or environmental weeds

Main Roads will develop a control programme appropriate for the species targeted for control and with due consideration for ecological function within wetland areas. The control programme will be developed in consultation with DEC and implemented on approval from the EPA.

9.2.6. Flora and Vegetation – Rehabilitation and Restoration

The EPA objective in relation to flora and vegetation is:

> *To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.*

9.2.6.1. Commitment

Main Roads will implement a progressive rehabilitation programme for areas within the final Roe Highway road reserve that are cleared for construction purposes or currently degraded and are not required for operational purposes such as access and maintenance.

Main Roads will utilise local provenance species aimed primarily at increasing available black-cockatoo foraging, potential future nesting and roosting habitat. The rehabilitation and restoration programme will also focus on enhancing local biodiversity and improving visual aesthetics within the road reserve.

9.2.6.2. Outcome

Rehabilitation and restoration will achieve nominated completion criteria (including criteria relevant to Cockatoo foraging, potential nesting and potential roosting habitat) within 5 years following completion of construction, in treated areas within the final road reserve portion of the proposal area.

Main Roads will agree completion criteria with DEC prior to completion of construction activities. It is proposed that completion criteria will be based on the following measurements:

1) Average native stems per hectare;
2) Native foliage cover;
3) Species diversity;
4) A ratio of weeds to natives, based on projected foliage cover of; and
5) Extent of erosion on roadside batters.

9.2.6.3. Monitoring Programme

Main Roads will implement a monitoring programme that commences the first spring following commencement of progressive rehabilitation and restoration works and continues until five years following completion of construction.

Monitoring sites will established within areas of both rehabilitated and restored areas and will relate to three assessment types; monitoring transects, Land Function Analysis (LFA) transects and rapid assessment areas (including photo points).

The monitoring transects will measure 50 - 100 metres in length (depending on the size of the area rehabilitated or restored) to a width of 2 metres. Quadrats of 2 m^2 will be assessed at 10 metre intervals along the length of the transect. A minimum of one 50 metre long transect will be established for each hectare treated.

Each quadrat will record the following data for annual monitoring events:

- Native species present;
- Weed species present;
- Number of stems of each native species present; and
- Projected foliage cover of each native species present.

The LFA transects will measure 50 metres in length and to a width of 1 metre, a minimum of six permanent transects will be established. Control transects will also be established in a minimum of four locations within the road reserve, where vegetation will not be cleared, in order to establish benchmark data. The data collected will be in accordance with Tongway and Hindley (2004) and will include the calculation of the following indices, for both the baseline assessment and ongoing annual monitoring events within rehabilitated and restored areas:

- Site Stability;
- Infiltration; and
- Nutrient cycling.

Over time, indices should be seen to be approaching those of benchmark locations (established and scored within areas of uncleared vegetation) indicating a sustainable functional ecosystem. Deviation from benchmark locations will indicate that remedial actions are required to prevent a decline in ecosystem function.

A series of rapid assessment areas will be established and will be recorded using GPS to enable relocation of the points for annual monitoring. A minimum of one rapid assessment area for each hectare treated (and not supporting a monitoring transect) will be established and will enable broad assessment of the visual appearance of rehabilitated and restored areas. The rapid assessment will include visual assessment of:

- the visible health of maturing vegetation (classified as 'healthy', 'slightly stressed', 'stressed' or 'very stressed');
- observations of bare areas or erosion scours;
- other observations including vandalism or grazing of vegetation; and
- a photograph taken at a designated point that can be compared to subsequent and/or previous photographs, to assess visible progress in maturing vegetation growth and visual aesthetics.

Following completion of construction of the project and annually during spring for 5 years, Main Roads will continue monitoring of transects and rapid assessment areas to monitor the progress and success in achieving completion criteria within rehabilitated and restored areas within the proposal area.

9.2.6.4. Reporting Requirements

Monitoring results will be compiled in a report and provided to the EPA as part of the ACR. The ACR will highlight the results of the monitoring programme, discuss performance and specify any corrective actions recommended.

9.2.6.5. Contingency

In the event that annual monitoring outcomes reveal less than satisfactory progress towards reaching completion criteria, Main Roads will develop corrective actions in consultation with DEC and seek approval from the EPA for their implementation. Main Roads will implement corrective actions, upon approval by the EPA.

9.2.7. Fauna

The EPA's objective for fauna is:

> *To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.*

9.2.7.1. Commitment

Main Roads will ensure that adverse impacts of project construction activities on conservation significant fauna species are minimised as much as practicable.

Prior to the commencement of construction, Main Roads will implement a programme that focuses on the protection of Threatened and conservation significant native vertebrate fauna. The programme will ensure that native fauna is protected from project construction activities through:

- The installation of fauna proof fencing along the boundary of the construction footprint, where it coincides with remnant native vegetation;
- The implementation of at least a three month fauna trapping programme that targets threatened and conservation significant terrestrial vertebrate species, following installation of the fauna proof fencing;
- The relocation of trapped species to areas of appropriate habitat outside the construction footprint, as determined through consultation with DEC;
- The identification of potential nesting sites for conservation significant species;
- Staging construction works to ensure that construction activities adjacent to potential nesting sites occur outside of peak nesting periods; and
- Ensuring that, at the commencement of construction, no nesting is occurring within the construction footprint by threatened or conservation significant species.

9.2.7.2. Outcome

Threatened and conservation significant native vertebrate fauna will be protected from direct strike by construction machinery as much as is reasonably practicable. In addition, retention of fauna proof fencing where the alignment coincides within native remnant vegetation will minimise the occurrence of fauna mortality during operation.

9.2.7.3. Monitoring Programme

Main Roads will develop and implement a monitoring programme that records:

- Details of all species trapped and relocated as a result of the trapping programme;
- Injuries and mortalities as a result of construction activities; and
- Results of daily construction site inspections.

9.2.7.4. Reporting Requirements

Main Roads will include the results of the trapping and relocation programme in its first Compliance Report submitted following the completion of the trapping programme. A summary of the results of ongoing monitoring will be included in all subsequent compliance reports for the duration of construction activities. Numbers and types of fauna deaths will be highlighted, along with a description of the probable cause and corrective actions imposed.

9.2.7.5. Contingency

In the event of any mortality of terrestrial vertebrate fauna as a result of construction activities, a review of procedures will be undertaken. As a result of the review, corrective actions will be implemented. The investigation report will be included in the following Compliance Report, with details of the corrective actions implemented and any changes to procedures detailed.

9.2.8. Noise

The EPA's objective with regards to noise is:

> *To protect the amenity of nearby residents from noise impacts resulting from activities associated with the proposal by ensuring the noise levels meet statutory requirements and acceptable standards.*

9.2.8.1. Operational Phase Noise Management Commitment

Main Roads commits to achieving the noise target at the ground floor of the majority of receivers adjacent to the proposed new road, in line with State Planning Policy 5.4 *Road and Rail Transport Noise and Freight Considerations in Land Use Planning* (SPP 5.4) requirements. Where achieving the noise target is not practicable, Main Roads commits to limiting both the extent and magnitude of road traffic noise impacts on sensitive receivers.

9.2.8.2. Outcome

As a result of the above commitments, Main Roads will ensure that:

a) Noise levels will not exceed the SPP5.4 *limit* at the properties adjoining the proposed new road as defined by SPP5.4, as defined by SPP 5.4 clause 5.2.2;
b) Noise levels will be within SPP5.4 *target* levels at the ground floor of the vast majority of properties adjoining the proposed new road; and
c) Noise levels will be within SPP5.4 *limit* levels at the ground floor of the vast majority of properties that will be affected by upgrades to existing roads, as defined by SPP 5.4 clause 5.2.2. There will be a reduction in noise levels due to the proposed upgrades to existing roads at the remaining properties currently exceeding the noise limit.

9.2.8.3. Post Construction Compliance Noise Monitoring

Main Roads will carry out compliance noise monitoring following the opening of the project. Monitoring results will be used to determine the accuracy of predicted noise emissions and to evaluate if the noise mitigation provided is adequate to achieve the stated outcome in the design year.

9.2.8.4. Reporting Requirements

Main Roads will include the results of the compliance noise monitoring undertaken following opening of the proposed project in the next Annual Compliance Report to be issued, as required by Commitment 9.2.1.1. The report will also include an assessment of whether the noise levels predicted are likely to be achieved in the design year.

9.2.8.5. Contingency

In the event that monitoring described in 9.2.8.3 indicates that there are locations within the study area where the stated outcome outlined in 9.2.8.2 has not been met, Main Roads may apply suitable contingency or remedial measures such as:

- Upgrading noise barriers adjacent to the affected area, where feasible; or
- Carrying out architectural treatments at individual dwellings exceeding the stated objectives in consultation with the affected property owners.

9.2.8.6. Construction Phase Noise Management Commitment

Main Roads commits to managing the temporary noise and vibration impacts associated with project construction, in accordance with Regulation 13 of the *Western Australian Environmental Protection (Noise) Regulations 1997* (WAEPNR) and giving consideration to *AS 2436 – 2010: Guide to noise and vibration control on construction, demolition and maintenance site*.

9.2.8.7. Outcome

Construction noise and vibration impacts at properties adjacent to the proposed project will minimised as far as practicable. This outcome will be achieved by:

- Using the quietest reasonably available equipment on the project in accordance with AS 2436;
- Implementing construction techniques that minimise noise emission wherever practicable; and
- Fitting construction equipment with the less intrusive, broadband alarms instead of reversing beepers.

Main Roads will also ensure residual construction noise and vibration impacts are managed by implementing the following measures:

- Keeping the community informed of the likely residual impacts as well as mitigation and management measures undertaken to minimise their effects.
- Providing a 24 hour noise complaint response hotline
- Implementing a complaints response system where complaints are reported to the plant operator/construction manager in real time.

9.2.8.8. Construction Noise and Vibration Monitoring

Main Roads will carry out noise and/or vibration monitoring at the commencement of each type of construction activity. Monitoring results will be used to confirm the accuracy of predicted noise/vibration emissions and to refine the mitigation and management strategy as required.

Main Roads will also carry out attended noise/vibration monitoring in response to noise complaints.

9.2.8.9. Reporting Requirements

Main Roads will include the results of all noise and/or vibration monitoring in its ACR required in accordance with Commitment 9.2.1.1.

9.2.8.10. Contingency

In the event that construction activities still result in an elevated number of complaints, Main Roads will investigate suitable remedial measures in consultation with affected residents, such as:

- Modifying construction methods/equipment used; or
- Modifying scheduled work patterns to provide respite periods to affected residents.

9.2.9. Visual Amenity

The EPA objective for visual amenity is:

> *To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable.*

9.2.9.1. Commitment

Main Roads will manage visual effects and minimise visual impacts of the proposed project:

- Specifically on key views across Bibra Lake and from North Lake;
- Directly upon sensitive receptors such as local schools and affected residents living nearby; and
- Generally within the context of the visual and landscape values of Beeliar Regional Park.

The visual effects and impacts will be minimised during the preconstruction, construction and operational phases of the project. In addition, Main Roads will ensure that the Roe Highway Extension Landscape and Urban Design Framework (Appendix X) is utilised to design visual mitigations both for efficacy and aesthetics.

9.2.9.2. Outcome

The visual effect of the proposed project on sensitive receptors will be minimised as much as practicable through the implementation of visual amenity mitigation measures. As a result of these measures, construction and operational activities will be either fully or partially screened from the view of sensitive receptors by:

- The installation of visual screens around construction laydown areas and compounds;
- The installation of visual screens to separate sensitive visual receptors from operational activities;
- Minimising clearing as much as practicable to maintain vegetated screens between the proposed project and sensitive receptors, wherever practicable;
- Rehabilitating newly constructed roadsides as soon as practicable to ultimately establish screening vegetation between the proposed project and sensitive receptors;
- Where possible, commensurate with the requirements of construction scheduling, install permanent noise walls along property boundaries prior to commencement of construction adjacent to affected properties; and
- Incorporating urban design treatments to infrastructure such as noise walls, bridge abutments and retaining walls combined with an art strategy that avoids visual clutter.

9.2.9.3. Monitoring Programme

Prior to construction, an assessment of the construction staging plan will be undertaken to determine the level of compliance with the desired visual outcomes in 9.2.9.2. Recommendations for improvements will be provided where compliance is not achieved.

During the construction phase of the project, visual inspections of the construction site will be conducted on a monthly basis to ensure that works are carried out in accordance with the construction-phase visual mitigations. Additionally, complaints regarding the visual amenity of the construction site will be monitored.

Post-construction, Main Roads will conduct an initial survey of the visual mitigation measures upon completion of construction to assess the extent of achievement of the above outcomes. The survey will be conducted by a landscape planner with adequate visual impact assessment experience and in accordance with principles contained within *Visual Landscape Planning in Western Australia a Manual for Evaluation, Assessment, Siting and Design (2007)*. A second and final visual mitigation survey will be conducted before the third anniversary of completion of construction.

9.2.9.4. Reporting Requirements

The results of the monthly inspection reports will be provided and discussed in the Annual Compliance report provided in accordance with 9.2.9.1. The report will also include public complaints relating to visual impacts and document corrective actions, where applicable.

Post-construction, Main Roads will include a visual monitoring report prepared as a requirement of 9.2.9.3 with the annual Compliance Report provided to the Office of the Environmental Protection Authority. The report submitted in the third year following completion of construction will include a closeout report to verify the satisfaction of the desired visual outcomes in 9.2.9.2.

9.2.9.5. Contingency

A review of procedures will be undertaken in the event that monthly inspections determine that visual mitigation objectives are not being met. The outcomes of the review will be used to develop corrective actions where appropriate and revised procedures will be implemented.

9.2.10. Visual Amenity – Landscaping

The EPA objective for visual amenity is:

> *To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable.*

9.2.10.1. Commitment

Main Roads will ensure that elements of landscaping such as revegetation, screening, noise barriers and other project related treatments fit within the overall landscape and sense of place, integrating with the movement corridor that incorporates the highway, principal shared path, Beeliar Park track network and local access. In addition, Main Roads will ensure that the Roe Highway Extension Landscape and Urban Design Framework (Appendix X) is utilised during detailed design.

9.2.10.2. Outcome

The proposed commitment will result in a unified landscape, comprising revegetation, visual treatments, noise barriers, bridge treatments, roadside drainage, artwork and other measures that integrate road infrastructure within each of the relevant Landscape Character Units (LCUs) in accordance with the Roe Highway Extension Landscape and Urban Design Framework (Appendix X).

9.2.10.3. Monitoring Programme

Main Roads will oversee a formal design review process prior to finalising the construction documentation package for landscaping. Main Roads will conduct an initial landscape assessment of the project at practical completion and then every year following completion of construction for a period a period of three years. The landscape assessment will include assessment of the landscape against the outcomes listed in 9.2.10.2 including specific landscape outcomes for each LCU.

9.2.10.4. Reporting Requirements

Main Roads will include the landscape assessment report prepared as a requirement of 9.2.10.3 with the annual Performance Compliance Report to the OEPA. The third landscape assessment report following completion of construction will include a closeout report to verify that desired landscape outcomes in have been achieved.

9.2.10.5. Contingency

If a review identifies a deviation from the anticipated Landscape Objectives, measures will be outlined to rectify the situation. These may include additional planting or remedial landscape treatments.

9.2.11. Visual Amenity – Urban Design

The EPA objective for visual amenity is:

> *To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable.*

9.2.11.1. Commitment

Commensurate with the requirements for safety, environmental management and road function, the proposed urban design treatments of infrastructure elements such as bridge abutments, principal shared paths, balustrades, foot bridges and underpasses etc. will have an overall design (length, appearance, materials and finishes) that is both accessible and attractive; in keeping with the sense of place and complying with best practice Crime Prevention Through Environmental Design (CPTED) principles.

9.2.11.2. Outcome

An attractive and accessible urban domain will be created at pedestrian user interfaces and publically visible infrastructure such as: underpasses, principal shared paths, footbridges, retaining walls and embankments. The Roe Highway Extension Landscape and Urban Design Framework (Appendix X) will be used as a framework to deliver the following outcomes:

- Mitigate the visual effects of bulk infrastructure by the use of specific urban design elements;
- Include in the urban design of the road infrastructure forms that have a character that is: simple; of low visual mass; evenly proportioned; unified; uninterrupted; of rational order and rhythm (not necessarily symmetrical); slender and light weight; where these are commensurate with environmental and design objectives;
- Achieve best practice design and engineering for bridge aesthetics (RTA 2003).
- Design generally for integration into the surrounding public domain those elements such as: lighting, balustrades, street furniture and other details related to pedestrian and cycle access;
- Include adequate signage, tactile warning markers and fencing barriers; and
- Assist in creating safe pedestrian crossing points.

9.2.11.3. Monitoring Programme

Urban design proposals and detail design plans will be reviewed (including accredited CPTED practitioner review) prior to finalising the construction documentation package to ensure consistency of intervisibility objectives.

9.2.11.4. Reporting Requirements

A report will be prepared outlining the assessment criteria and results of the design review and submitted to the EPA with the first annual compliance report prepared following the completion of the review outlined in 9.2.11.3.

9.2.11.5. Contingency

If necessary, detailed design plans and specifications will be modified to incorporate potential revisions for implementation during construction.

9.2.12. Visual Amenity – Public Art

The EPA objective for visual amenity is:

> *To ensure that aesthetic values are considered and measures are adopted to reduce visual impacts on the landscape as low as reasonably practicable.*

9.2.12.1. Commitment

The project will include a public art strategy that contributes to, integrates with and enhances the overall movement corridor incorporating the highway, principal shared path, Beeliar Regional Park track network and local access. The project will make a contribution to the public art strategy through the contribution of a fixed percentage of project funding.

9.2.12.2. Outcome

The proposed commitment will result in the expression of local identity and cultural heritage through public art and urban design treatments that visually enhance the road and surrounding environment for users of the road and local visitors to the area.

The principles, strategies and ideas described within the Roe Highway Extension Landscape and Urban Design Framework (Appendix X) and associated Draft Public Art Strategy (Appendix X) will guide the further development of public art and associated urban design treatments during the detailed design phase of the project and will be implemented during construction.

9.2.12.3. Monitoring Programme

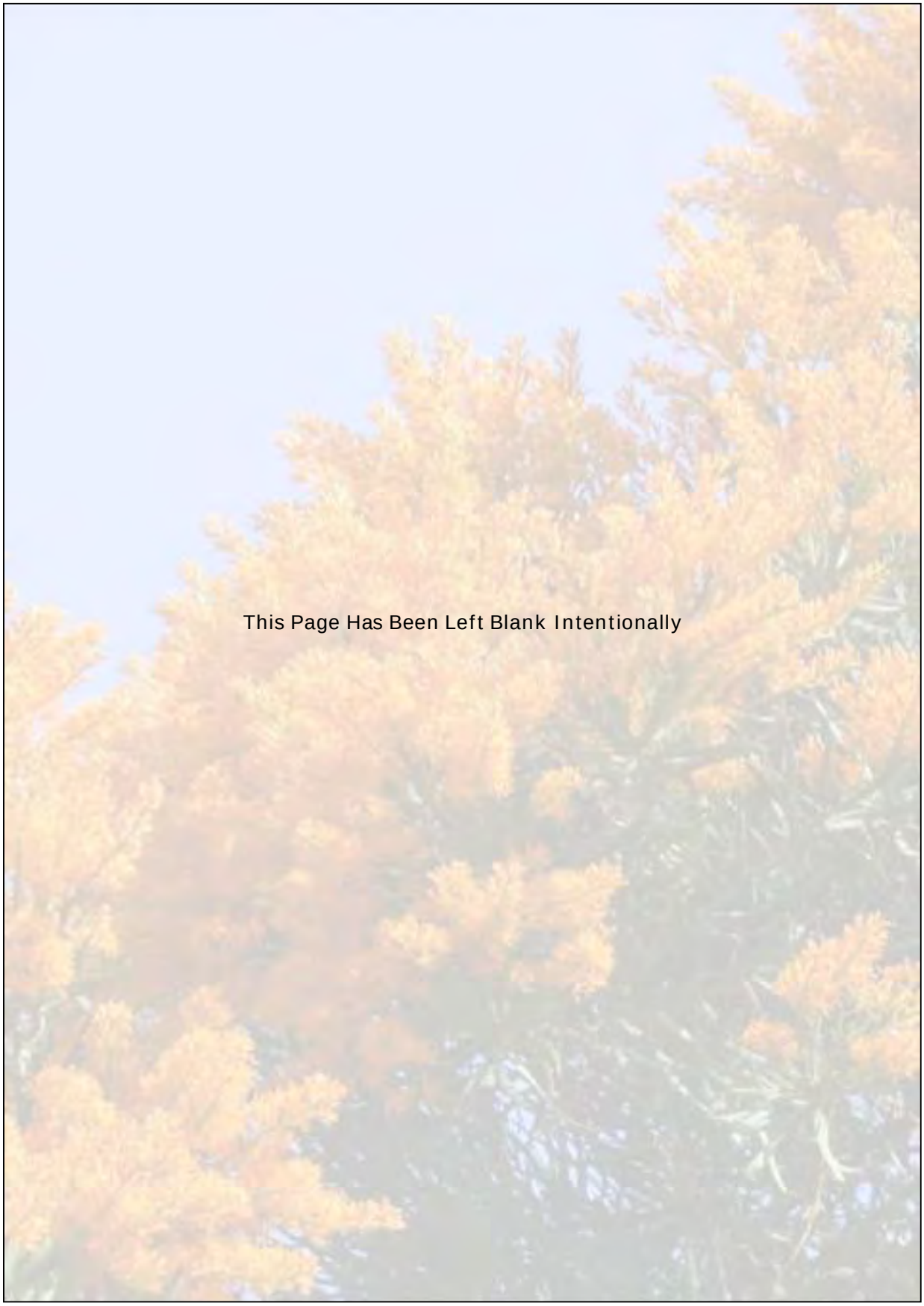
Detailed public art concepts will be reviewed prior to implementation to ensure compliance with the principles and objectives outlined in the Roe Highway Extension Landscape and Urban Design Framework (Appendix X) and associated Draft Public Art Strategy (Urban Thresholds 2010).

9.2.12.4. Reporting Requirements

A report outlining the outcome of the review identified in 9.2.12.3 will be prepared. The report will detail the findings and recommendations of the review. The review will be submitted to the EPA with the first ACR prepared by Main Roads.

9.2.12.5. Contingency

In the event that there are locations within the project where public art treatments require modification, these modifications will be made in accordance with the principles and objectives outlined in the Roe Highway Extension Landscape and Urban Design Framework (Appendix X) and associated Draft Public Art Strategy (Urban Thresholds 2010).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10. Offsets

The impact assessments presented in Sections 6 and 8 describe a number of residual impacts that are unable to be avoided, minimised, rectified or reduced and therefore require offsetting. This section details the strategies proposed to offset the residual impacts outlined in Sections 6 and 8. The offset package addresses residual impacts on environmental values relevant to the State, as assessed by the Environmental Protection Authority (EPA) and Matters of National Environmental Significance, as determined by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC).

The nature and use of environmental offsets are defined by both the State and Commonwealth under different policy statements:

- State – Guidance Statement No 19 – Environmental Offsets - Biodiversity (EPA 2008a), to be read in conjunction with, Position Statement No. 9 – Environmental Offsets (EPA 2006a); and
- Commonwealth – Draft EPBC Act Policy Statement 4.1 – Use of Environmental Offsets (DEWHA 2007).

Both the State and Commonwealth Governments operate policies that permit offsets to be developed after all avoidance and mitigation efforts have been exhausted and considered for project approvals for matters of environmental significance where adverse impacts cannot be avoided.

10.1. Offset Definitions

Position Statement No. 9 (EPA 2006a) provides the following definitions of offsets as associated with the key goal of 'net environmental benefit':

> *'Environmental offsets aim to ensure that significant and unavoidable adverse environmental impacts are counterbalanced by a positive environmental gain, with an aspirational goal of achieving a 'net environmental benefit' ..... Achieving a 'net environmental benefit' goal means that each offset proposal should address direct and contributing offsets to meet the offset principles in this Position Statement.'*

Draft Policy Statement 4.1 (DEWHA 2007) defines environmental offsets as:

> *'....actions taken outside a development site that compensate for the impacts of that development - including direct, indirect or consequential impacts. Environmental offsets provide an opportunity to achieve long-term conservation outcomes whilst providing flexibility for proponents seeking to undertake development which will have environmental impacts.'*

Both State and Commonwealth policy make the following points:

- Environmental offsets are not intended to make proposals with unacceptable impacts acceptable; and
- Offsets are not a substitute for normal environmental management responsibilities.

Commonality also exists between the State and Commonwealth policies around the definitions of Direct and Indirect Offsets. The following definitions are provided by Policy Statement 4.1.

10.1.1. Direct offsets

Direct offsets are aimed at on-ground maintenance and improvement of habitat or landscape values. They may include:

- Long-term protection of existing habitat – including through the acquisition and inclusion of land in the conservation estate, and covenanting arrangements on private land;
- Restoration or rehabilitation of existing degraded habitat; or
- Re-establishing habitat.

10.1.2. Indirect offsets

Indirect offsets are the range of other actions that improve knowledge, understanding and management leading to improved conservation outcomes. They may include:

- Implementation of recovery plan actions – including surveys;
- Contributions to relevant research or education programmes;
- Removal of threatening processes;
- Contributions to appropriate trust funds or banking schemes that can deliver direct offsets through a consolidation of funds and investment in priority areas; or
- On-going management activities such as monitoring, maintenance, preparation and implementation of management plans etc.

10.1.3. Application of Offsets

The criteria surrounding the use of offsets determine whether offsets may be needed and if needed, the scale of the offset required. Both the State and Commonwealth policies provide advice on the application of offsets and principles for their use.

Western Australia, through Guidance Statement No. 19 establishes the following criteria for proponents to determine if they have significant adverse residual impacts and therefore if it is appropriate to consider offsets:

- Significant adverse impacts on 'critical' or 'high value' assets;
- Exhaustion of avoidance and mitigation options; or
- Significance of adverse residual environmental impacts - the 'significance' of a proposal or scheme is also likely to influence the extent and type of environmental offsets that may be required. The more significant the adverse residual impact, the more likely a substantial offsets package will be necessary.

Guidance Statement No. 19 (EPA 2008a) also provides advice on the principles for the development of an offset package: '*Where the application of offsets is considered appropriate, it is the proponent's responsibility to identify and develop a suitable offsets package and demonstrate that offsets meet the EPA's principles:*

- *Principle A: Environmental offsets should only be considered after all reasonable attempts to mitigate adverse impacts have been exhausted;*
- *Principle B: An environmental offsets package should consider direct offsets and contributing offsets, as appropriate;*
- *Principle C: Environmental offsets should ideally be 'like for like or better';*
- *Principle D: Positive environmental offset ratios should apply where risk of failure is apparent;*
- *Principle E: Environmental offsets must entail a robust and consistent assessment process;*
- *Principle F: Environmental offsets must meet all statutory requirements;*
- *Principle G: Environmental offsets must be clearly defined, publicly registered, transparent, auditable and enforceable;*
- *Principle H: Environmental offsets must ensure a long lasting benefit.'*

The Commonwealth, through Policy Statement No. 4.1 (DEWHA 2007), provides the following guidance on the applicability of offsets:

> *'Environmental offsets are not applicable to all approvals under the EPBC Act. Each approval must be assessed on a case-by-case basis and must take into account the scale and intensity of impact from the development on the site and the potential for conservation outcomes through offsets. They should not be applied where the impacts of a development are considered to be minor in nature or could reasonably be mitigated. In some circumstances suitable offsets may not be available to adequately compensate for the impacts of a development and a decision on the overall acceptability of the project will need to be made.'*

Policy Statement No. 4.1 (DEWHA 2007) has identified eight principles for the use of environmental offsets under the *EPBC Act*. These eight principles will be used to assess proposed environmental offsets to ensure consistency, transparency and equity under the *EPBC Act*:

1) Environmental offsets should be targeted to the matter protected by the *EPBC Act* that is being impacted.
2) A flexible approach should be taken to the design and use of environmental offsets to achieve long-term and certain conservation outcomes which are cost effective for proponents.
3) Environmental offsets should deliver a real conservation outcome.
4) Environmental offsets should be developed as a package of actions - which may include both direct and indirect offsets.
5) Environmental offsets should, as a minimum, be commensurate with the magnitude of the impacts of the development and ideally deliver outcomes that are 'like for like'.
6) Environmental offsets should be located within the same general area as the development activity.
7) Environmental offsets should be delivered in a timely manner and be long lasting.
8) Environmental offsets should be enforceable, monitored and audited.

10.1.4. Global Offset Definitions

Biodiversity offsets are measurable conservation outcomes resulting from actions designed to compensate for significant residual, adverse impacts arising from project development after appropriate prevention and mitigation measures have been taken (BBOP 2010). The primary objective is no net loss of biodiversity with a goal of achieving a net environmental benefit. Offsets are not a substitute for normal environmental management responsibilities.

Avoiding and mitigating impacts on the environment at the project site remains the first priority during project development with offsetting used as a tool when all avenues of mitigation have been considered and exhausted. Major development proposal or schemes that have significant environmental impacts, particularly on 'critical' and 'high' value assets, will usually trigger an offset requirement.

10.1.5. Rationale

The offsets strategy for the proposed project is based on both field assessments and advice from the State and Commonwealth governments. The regulatory agencies for both governments assess offsets on the basis of the principles outlined in Section 10.1.3. The rationale for the offsets strategy is to achieve a net environmental benefit once the project has been implemented. When identifying suitable offsets, it is recognised that ecosystems are comprised of a range of habitat types and values that are interconnected. Accordingly, an offset package may contain values that address several offset requirements and therefore do not need to be cumulative. For example, a site that fulfils the requirements for offsetting native vegetation clearing can also be used to offset impacts on black cockatoos, assuming the vegetation composition and habitat requirements are met.

The following specific principles have been adopted when considering assessing the feasibility of proposed offsets:

- The offset represents a lasting environmental benefit;
- Preference is given to offsets that are relevant to the values being impacted by the proposed project, including the conservation of:
  - Existing black cockatoo potential nesting habitat;
  - Existing black cockatoo foraging habitat;
  - Conservation Category Wetlands (CCW);
  - The Graceful Sun-moth;
  - Locally and regionally significant native vegetation;
  - Bush Forever sites and Regional Park estate;
  - Migratory bird habitat; and
  - Wetlands, their hydrology and dependent vegetation.

The Western Australian Government determines the magnitude of ratios for offsetting on a case by case basis, with particular consideration given to the values being impacted, the significance of the impact and the likelihood or otherwise of the proposed offset achieving a net environmental benefit outcome. Such ratios apply not only to land area, but also to environmental values, species, vegetation, habitat ecosystem, landscape and hydrology (EPA 2006).

Conversely, the Commonwealth is more rigid in its use of offset ratios, and has recently applied ratios for impacts on Carnaby's Black-Cockatoo and Forest Red-tailed Black-Cockatoo habitat as follows:

- Protecting existing foraging habitat: 6:1; and
- Protecting existing potential nesting habitat: 10:1.

Accordingly, where impacts on potential nesting habitat are similar in scale and significance to those on foraging habitat, a ratio of 10:1 for potential nesting habitat will result in a larger land requirement. Assuming the potential nesting habitat also provides appropriate foraging habitat then the site also achieves the offset requirements for foraging habitat. Similarly, if the site contains other environmental assets that have been impacted by the proposal (such as CCW), then it may also qualify as an offset against those impacts.

10.2. Offset Requirements

South Metro Connect (SMC) has incorporated extensive design modifications to avoid, minimise and mitigate the extent of impacts on environmental factors (See Section 3.5). In addition, environmental management commitments will further limit the extent of impacts during construction and operation of the proposed project, resulting in a limited number of residual, unavoidable impacts (Section 6). Table 10.2-1 presents the offset requirements for the residual impacts associated with the proposed project.

Table 10.2-1: Summary of Residual Impacts and Offset Requirements

Factor	Extent of Residual Impact	Relevant agency	Proposed Offset
Native Vegetation	Removal, of 38ha of intact native vegetation	EPA	Impact offset through implementation of Offset Proposal 1
Bush Forever Site	Removal of 6.5ha of Bush Forever Site	EPA	Impact offset through implementation of Offset Proposal 1, resulting in a change in tenure from private freehold to conservation estate
CCW	Filling of 9.7ha of CCW and buffer	EPA	Restoration of 8.4ha of Horse Paddock Swamp and rehabilitation of an additional 5ha of degraded wetland fringes of North Lake through implementation of Offset Proposal 2
Beeliar Regional Park	Resumption of 5.4ha of Beeliar Regional Park	EPA	Transfer of 14.5ha of MRS road reserve to Beeliar Regional Park through implementation of Offset Proposal 3
Carnaby's and Forest Red-tailed Black Cockatoos	Removal of 78ha of foraging habitat	DSEWPaC /EPA	Purchase and transfer of 470ha of high quality black cockatoo habitat to conservation estate as described in Offset Proposal 1
Carnaby's and Forest Red-tailed Black Cockatoos	Removal of 2.5ha of potential nesting habitat	DSEWPaC /EPA	Purchase and transfer 25ha of high quality black cockatoo habitat (as a subset of foraging habitat) to conservation estate as described in Offset Proposal 1
Graceful Sun-moth	Reduction in the extent of habitat within which a Graceful Sun-moth population has been recorded to a size that is unlikely to remain viable for the GSM population	DSEWPaC /EPA	Contribution of funding towards management of confirmed populations of Graceful Sun-moths and research into options for translocating GSM and its habitat out of development areas described in Offset Proposal 4
Wetland migratory bird habitat	Indirect impacts on habitat resulting from noise and light emissions	DSEWPaC /EPA	Funding of a 3 year weed control programme to maintain open mud flats at nearby Ramsar listed Thomsons Lake as described in Offset Proposal 5 Funding of research aimed at investigating the effects of constructing and operating a highway within an urban wetland setting Some impacts will also be offset by the restoration of Horse Paddock Swamp and other wetland fringes throughout the Beeliar Regional Park as described in Offset Proposal 2, as well as through the transfer of freehold CCW to the conservation estate as described in Offset Proposal 1

10.2.1. Offset Proposal 1 – Purchase of Remnant Native Vegetation

10.2.1.1. Commitment

Main Roads will assist with the acquisition of land for conservation purposes, giving preference to land located in the southern metropolitan region, on the Swan Coastal Plain.

10.2.1.2. Purpose of Offset

A total of 79ha of native vegetation will be removed for construction of the proposed project. Of this, 41ha has been classified as being in Degraded condition or worse. The balance, totalling 38ha, is considered to be 'intact native vegetation'. Main Roads recognises the value of this vegetation, particularly vegetation communities that are:

- Within Beeliar Regional Park (5.4ha);
- Mapped as Bush Forever (6.5ha);
- Within Conservation Category Wetland boundaries and buffers (9.7ha); and
- Important habitats for significant fauna.

The purpose of Offset Proposal 1 is to offset the loss of the above values from within the project area and gives specific consideration for the acquisition of land that includes CCW.

10.2.1.3. Size of Offset

Main Roads proposes to apply a ratio of 6:1 to offset the loss of black cockatoo foraging habitat (468ha) and 10:1 to offset the loss of potential black cockatoo nesting habitat (2.5ha). As outlined in Section 6.7, up to 78ha of black cockatoo foraging habitat will be removed for construction of the proposed project. At a ratio of 6:1, this will require the acquisition of 468ha of bushland that contains black cockatoo foraging habitat. Within this area, 249 trees will be cleared that either contain hollows suitable for nesting (20) or have a diameter at breast height (DBH) of 500mm or more (229). In order to assign a spatial value to this loss, Main Roads proposes to use an area of 100m^2 for each of these trees, arriving at a total area of 2.5ha of potential nesting habitat being removed. At a ratio of 10:1, this will require the acquisition of 25ha of potential nesting habitat. Since this habitat coexists entirely with black cockatoo foraging habitat, it is considered appropriate that the two offset requirements are addressed through the acquisition of 468ha of black cockatoo foraging habitat.

It is likely that a site determined to be a suitable offset for impacted black cockatoo habitat will also address offset requirements for the majority of non-wetland vegetation that will be impacted by the proposed project. In addition, the preferred offset site has been selected on the basis that it contains CCW, which will offset the loss of Roe Swamp CCW to some extent. Additional offset are proposed for impacts on CCW and Beeliar Regional Park

In accordance with the nominated ratios, Main Roads will provide funding for the purchase of up to 468ha of remnant native vegetation on the Swan Coastal Plain that can provide similar values to those that will be lost as a result of the proposed project. Preference will be given to a large land parcel in the southern Perth metropolitan region to the satisfaction of the Department of Environment and Conservation (DEC), EPA and DSEWPaC as a suitable offset for the proposed project's residual impacts. Funding for purchase of land may be 'pooled' with other funding provided by proponents of unrelated projects. Once purchased, it is intended that the proposed offset will be protected as a conservation reserve.

10.2.1.4. Description of Offset

Areas of land that could provide possible offset values have been identified by the Department of Environment and Conservation. The proposed offset includes a substantial extent of intact, contiguous native vegetation with the majority in Very Good to Excellent Condition and addresses a number of residual impacts of the proposed project. The proposed offset area:

- Contains habitat suitable for Carnaby's and Forest Red-tailed Black Cockatoo foraging and potential nesting habitat. Although black cockatoos are not currently nesting within the project area, the proposed offset is located considerably closer to recorded nesting locations, and is therefore likely to provide greater nesting habitat value;
- Includes four of the five Floristic Community Types (FCTs) impacted by the proposed project, so meets 'like for like' requirements;
- Includes CCW areas. This supplements, but does not replace the need for the wetland restoration offset proposal closer to the project area, within the Beeliar Regional Park and should be viewed in conjunction with Offset Proposal 2);
- Will be transferred from its current private freehold status to conservation estate, providing a net increase in conservation reserve within the southern metropolitan region; and
- Will offset the loss of Bush Forever by increasing the extent of Bush Forever under secure (conservation) tenure.

In addition to directly offsetting impacts associated with the proposed project, the proposed offset provides additional conservation values including:

- Is known to include DRF that had been reported as potentially occurring within the project area, but not found during multiple targeted surveys; and
- Provides for the protection of substantially more CCW than will be impacted by the proposed project.

10.2.2. Offset Proposal 2 – Restoration of Horse Paddock Swamp and Other Degraded Wetland Areas

10.2.2.1. Commitment

Main Roads will implement a wetland restoration and rehabilitation programme within the Beeliar Regional Park. Direct offsets will incorporate both site led restoration activities and species led weed control that, when combined, achieve improvements over an area of approximately 13.4ha. In addition, indirect offsets are proposed through the provision of $100,000 to DEC's Environmental Community Grants Scheme, which, when combined with direct offsets, achieve a ratio in the order of 2:1.

The direct offset will be delivered in accordance with a Wetland Restoration Plan (WRP) to be developed by Main Roads in consultation with DEC. Main Roads will assume responsibility for implementing the WRP over a period of up to 5 years. The WRP will have the following objectives:

- A staged wetland rehabilitation programme of Horse Paddock Swamp over an area of 8.4ha, including the wetland buffer and upland areas, as indicated in Figure 10.2-1; and
- Weed control and rehabilitation of approximately 5ha of degraded wetland fringes of North Lake, as indicated in Figure 10.2-1.

The WRP will address, as a minimum, the following Scope of Works:

- Identification of suitable rehabilitation locations;
- Identification of target areas for weed control;
- Clear and measurable objectives;
- Detailed methodology, including:
  - Species lists;
  - Timing of works; and
  - Monitoring methodology;
- Completion criteria, linked to the following parameters:
  - Percent foliage cover;
  - Stem density;
  - Health of vegetation within restored and rehabilitated areas; and
  - Percent weed cover;
- Monitoring programme;
- Contingency and corrective actions; and
- Reporting requirements.

The WRP will be finalised prior to the commencement of any ground disturbing activities within the Roe Swamp CCW to enable the inclusion of an investigation into the viability of translocating wetland vegetation to Horse Paddock Swamp. If it can be proved viable, the rehabilitation programme will also include translocation to Horse Paddock Swamp of wetland vegetation sourced from within the construction envelope at Roe Swamp.

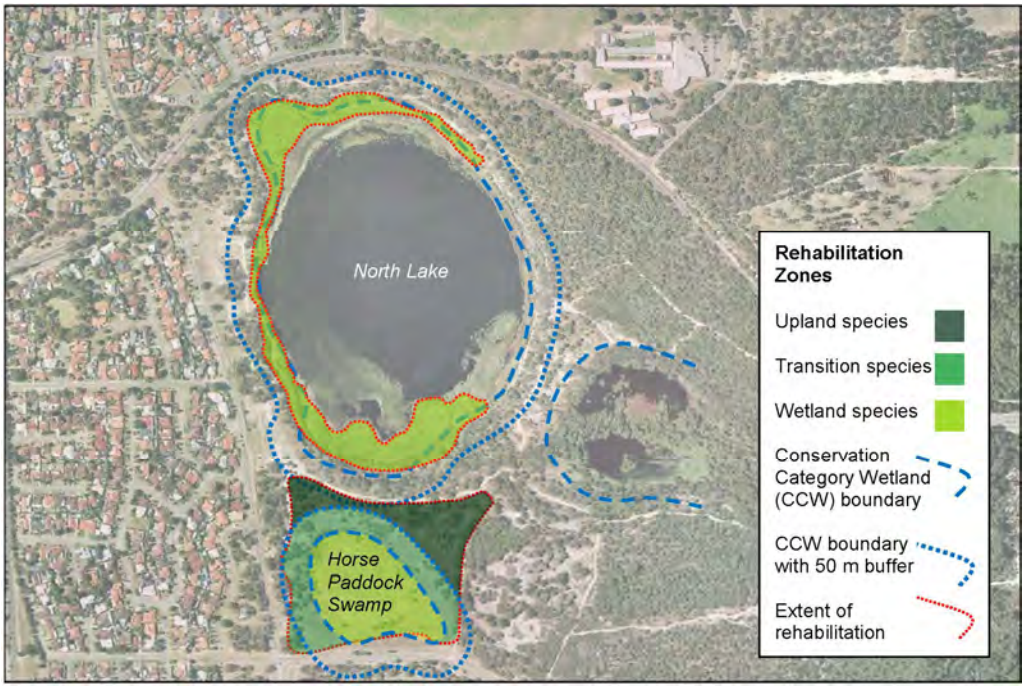

Figure 10.2-1: Proposed North Lake and Horse Paddock Swamp Rehabilitation Areas

10.2.2.2. Purpose of Offset

The purpose of this offset proposal is to offset the loss of CCW values as a result of clearing within Roe Swamp and its buffer, as well as offsetting the loss of native vegetation throughout the project area. Main Roads recognises the significance of the values lost through clearing within Roe Swamp CCW and its buffer, and proposes to offset this loss through the application of a 2:1 ratio, which will be achieved through a combination of direct and indirect offsets, by rehabilitating wetlands and wetland fringes within and adjacent to the project area and supporting volunteers undertaking direct on ground works to conserve wetlands. Accordingly, a combination of wetlands and wetland fringe rehabilitation and wetland weed control will be undertaken over an area of approximately 13.4ha with the balance required for a 2:1 offset ratio achieved through the contribution of $100,000 funding to DEC's Environmental Community Grants Scheme.

Weed control within North Lake and the restoration of Horse Paddock Swamp and North Lake wetland fringes is intended to establish historical wetland values through a programme of rehabilitation that:

- Enhances wetland vegetation characteristics (by improving the density and diversity of vegetation);
- Prepares the site and manages topsoil and microhabitat, salvaging and recycling suitable soil and habitat logs from areas of Roe Swamp designated for clearing;
- Prevents fauna and human access to the rehabilitation area by fencing (fencing may be removed upon successful establishment of planted vegetation);
- Removes and controls weeds;

- Collects and propagates suitable seed and vegetative material of appropriate provenance in a timely manner to allow seedlings to be planted at a planting density to be agreed with DEC;
- Re-establishes native wetland vegetation by planting seedlings and augmenting with direct seeding (if appropriate);
- Times the planting of seedlings to make the most beneficial use of natural rainfall and seasonal groundwater conditions by corresponding planting times with position in the landscape. For example, planting upland species following substantial winter rains; and planting wetland species at the end of summer (to ensure roots are below the water table for the longest possible duration over winter and spring);
- Considers limited artificial watering over the first summer to help ensure survival through the initial establishment period;
- Where practicable, translocates into Horse Paddock Swamp plants from within the construction corridor of Roe Swamp that have suitable sedimentary, rhizosphere and groundwater dependency characteristics to be viable and self-sustaining in the long term (likely viable species include: *Cyathochaeta teretifolia* W.Fitzg (P3), *Baumea preissii* and *B. articulata*);
- Seeks to preserve genetic diversity of wetland vegetation species within the project area by targeting for re-vegetation those provenance species that have been recorded within nearby wetlands, transition zones and upland areas (Appendix K); and
- Re-establishes at Horse Paddock Swamp and other locations, species that are relatively uncommon now on the Swan Coastal Plain, e.g. *Banksia littoralis* and *Melaleuca lateritia*.

10.2.2.3. Proposed Monitoring Programme

A detailed monitoring programme will be agreed with DEC during the preparation of the WRP. As a minimum, the detailed monitoring programme will include:

- An initial survey of the proposed rehabilitation area to establish the baseline;
- Annual spring monitoring surveys every spring for five years following the completion of construction;
- At least one permanently marked 10m x 10m monitoring quadrat will be set up per hectare of rehabilitation for each habitat type (ie, upland, transition and wetland);
- At least one permanently marked 10m x 10m reference quadrat (without impacts or disturbance planned) for each habitat type; and
- Monitoring transects of sufficient length to cross transition zones between habitat types, which will be designed to provide data regarding:
  - Site stability;
  - Infiltration; and
  - Nutrient cycling.

Information recorded for each quadrat or transect will include, but will not be limited to:

- Number of seedlings present;
- Species of seedlings in quadrat;
- Seedling health;
- An estimate of the percentage canopy coverage of the native vegetation present within the quadrat;
- Weed species present;
- An estimate of the percentage coverage of the quadrat by weed species;
- Other observations such as erosion, fire or vandalism;
- Recording onset of flowering to determine functionality as foraging habitat; and
- Recommendations for remedial action.

10.2.2.4. Reporting Requirements

Main Roads will include a monitoring report undertaken as a requirement of 10.2.2.3 with the annual Compliance Report to the Office of the Environmental Protection Authority (OEPA). Each monitoring report will include an assessment of progress toward successful achievement of the nominated completion criteria.

Following the fifth annual vegetation survey, Main Roads will provide a rehabilitation closeout report to verify the satisfaction of completion criteria. The completion report will assess the efficacy of what has been done and determine whether the key objective is met. Upon submission of the closeout report, Main Roads will seek confirmation from the OEPA that management of the rehabilitated area revert to DEC.

10.2.2.5. Contingency

Following each monitoring event, where progress toward the completion criteria is not evident, Main Roads, in consultation with DEC, will implement corrective measures such as (but not limited to):

- Supplementary planting of failed areas;
- Watering planted seedlings; and
- Pest and weed control.

Following the fifth annual monitoring survey, Main Roads will determine whether there are locations within the rehabilitation area where the criteria nominated in the WRP have not been met. If noted, Main Roads, in consultation with DEC, will develop suitable contingency or remedial measures such as (but not limited to):

- Supplementary planting of failed areas;
- Watering planted seedlings; and
- Pest and weed control.

Main Roads will implement remedial measures until the criteria outlined in the WRP have been met, or the OEPA agrees the work is complete (whichever is sooner).

10.2.2.6. Responsibility

Main Roads proposes to be responsible for the rehabilitation of Horse Paddock Swamp and other degraded wetland fringes and for the control of weeds within Roe Swamp and North Lake for a programme spanning five (5) years, or until OEPA agrees the objectives of the WRP have been achieved, after which time and following approval of the closeout report, the area will revert back to the responsibility of DEC under the management of the Beeliar Regional Park.

10.2.3. Offset Proposal 3 – Transfer MRS Road Reserve to Beeliar Regional Park

10.2.3.1. Commitment

Main Roads will transfer ownership of approximately 14.5ha of MRS Road Reserve that is not required for construction of the proposed project to Beeliar Regional Park to achieve a net gain in the size of Beeliar Regional Park of approximately 9ha.

10.2.3.2. Description of Offset

The Roe Highway MRS road reserve bisects Beeliar Regional Park. During concept design development, selection of the preferred option resulted in an alignment that extends outside the existing MRS boundary, requiring the resumption of approximately 5.4ha of Beeliar Regional Park. The original MRS reserve includes a substantial area for a proposed interchange located over the top of Roe Swamp. The proposed design avoids using this interchange area by relocating the original Bibra Drive interchange to the east and creating an interchange with Murdoch Drive as an alternative access point to the proposed project. In addition, as a result of the realignment, combined with other design features aimed at minimising the physical footprint of the proposed project, a more narrow reserve is needed than has been set aside as the MRS road reserve.

Once construction of the proposed project is complete and land dealing plans have been finalised, Main Roads will arrange for the transfer of unused MRS road reserve no longer required for the proposed project to the appropriate authority for inclusion in the Beeliar Regional Park. These proposed boundary amendments are indicated in Figure 10.2-2. The proposed boundary changes will result in the main basin of Roe Swamp and best condition vegetation within the project area being protected under secure tenure.

Prior to completion of construction, Main Roads will prepare, in consultation with DEC, an Arum Lily (*Zantedeschia aethiopica*) Control Programme (ALCP) with the objective of removing Arum Lily from the MRS road reserve. Main Roads will implement the ALCP prior to transfer of the MRS road reserve to DEC.

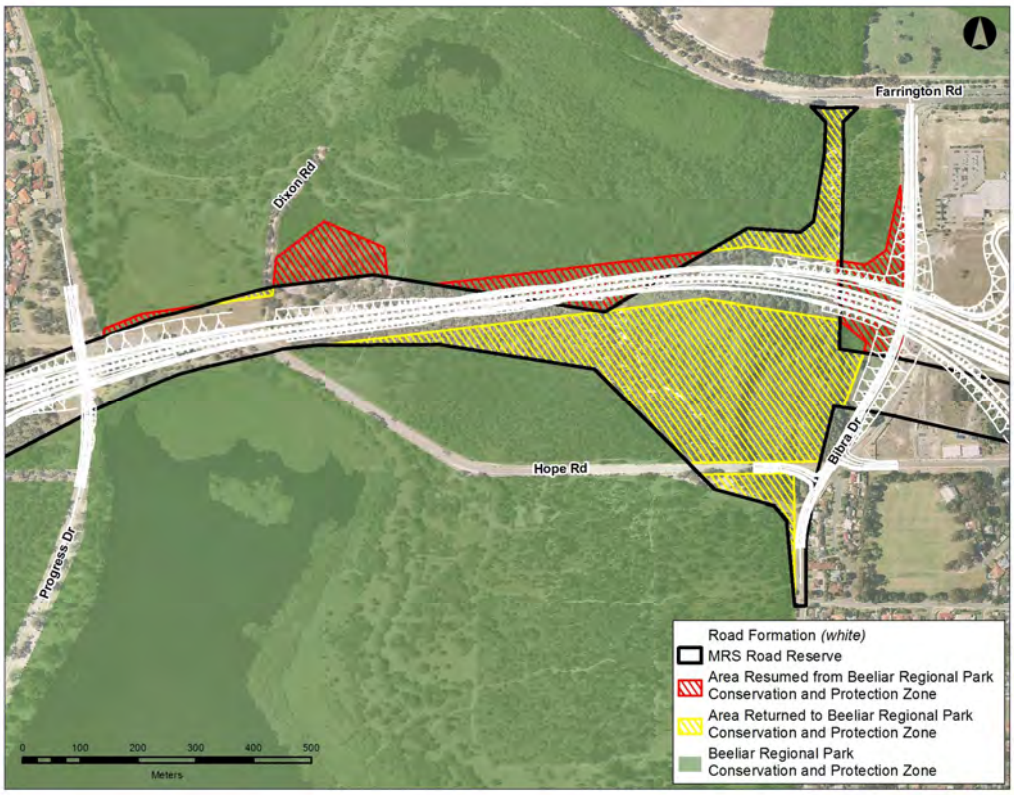

Figure 10.2-2: Proposed Beeliar Regional Park Boundary Amendments

10.2.3.3. Size of Offset

The extent of road reserve to be transferred to Beeliar Regional park is approximately 14.5ha. The proposed land transfer will result in a net increase in the size of Beeliar Regional Park of approximately 9ha. The exact extent will be finalised once construction activities are complete and land dealing plans have been finalised. Boundary changes will take into account access and maintenance requirements and final alignment adjustments as a result of detailed design requirements.

10.2.3.4. Predicted Outcome of Offset Proposal 3

The MRS Bibra Drive interchange is located over some of the highest value wetland vegetation of the project area. Transference of this to the area to the Beeliar Regional Park will ensure the protection of key wetland values for perpetuity.

10.2.4. Offset Proposal 4 – Provision of Funding to Graceful Sun-moth Research

10.2.4.1. Commitment

Main Roads commits to allocating funding towards improved management of known populations of nearby Graceful Sun-moths (GSM) and research into methods aimed at improving habitat and boosting existing populations.

10.2.4.2. Purpose of Offset

The proposed project will have unavoidable impacts on a confirmed population of Graceful Sun-moths, resulting in the removal of approximately 5.6ha (64 percent) of *Lomandra hermaphrodita* habitat where individual adults have been collected. While there is a possibility that this population may already be unviable in the long term, it is almost certain that the remaining confirmed habitat will no longer be viable for the maintenance of a healthy population of GSM as a result of the proposed project. The proposed project will also result in the removal of an additional 60.5ha of vegetation communities known to support *Lomandra hermaphrodita*. Despite significant efforts, few populations of GSM have been identified in the southern metropolitan area. The nearest confirmed collections are from Fred Samson Park (1.5km) or Wandi Nature Reserve (15km).

10.2.4.3. Description of Offset

Main Roads proposes to provide up to $250,000 for a combination of direct and indirect offsets to offset the predicted loss of this population.

Proposed direct offsets against GSM loss will occur during the construction planning and delivery phase and include:

- Undertaking additional surveys at potential habitats within the region;
- Actions to better manage or improve GSM habitat in nearby populations (such as Fred Samson Park and Wandi Nature Reserve), including:
    - Weed control;
    - Installation of fencing;
    - Supplementing poor quality or declining habitat with habitat due for removal as a result of construction; and
    - Supplementing declining populations through the translocation of adults captured from within the construction footprint.

Proposed indirect offsets against GSM loss include will occur during construction and continue for up to three years and include:

- Research investigating the success of supplementing existing habitat with translocated *Lomandra hermaphrodita*; and
- Research investigating the success of supplementing existing populations with translocated adults.

Main Roads will prepare a Graceful Sun-moth Management Plan (GSMMP) in consultation with DEC and other relevant stakeholders including Botanical Gardens and Parks Authority (BPGA) and DSEWPaC. The GSMMP be finalised prior to the commencement of any ground disturbing activities within the confirmed GSM habitat and will include the following Scope of Works:

- Statement of research objectives;
- Identification of known GSM populations near to the project area as suitable receiving sites for translocation of *Lomandra sp* and/or GSM adults;
- Appropriate timing for the translocation of GSM adults, including timing of construction activities to allow adults to be sourced from within the construction area; and
- Detailed research methodology, including translocation methods, monitoring and reporting requirements.

10.2.4.4. Predicted Outcome of Offset Proposal 4

The proposed offset will assist with the survival of existing populations outside the project area by:

- Ensuring improved management of known populations;
- Identifying additional populations within other habitats outside the project area;
- Providing a more clear indication of the number of viable populations within the region;
- Contributing to the body of scientific knowledge regarding mechanisms aimed at supplementing known populations and/or populating currently unpopulated habitat; and
- Contributing to the body of scientific knowledge regarding mechanisms aimed at improving the quality of existing habitat through translocation of habitat.

10.2.5. Offset Proposal 5 – Provision of Funding for Management of Wetland Migratory Bird Habitat

10.2.5.1. Commitment

Main Roads commits to allocate funding towards a weed control programme aimed at maintaining open mud flats at Thomsons Lake Ramsar Site and research aimed at obtaining empirical evidence of the effects of a highway through a wetland environment.

10.2.5.2. Purpose of Offset

Although the project will have minimal direct impact on recognised wetland migratory bird habitat, Main Roads recognises that the effect of light spill and noise emissions within the wetland area may result in behavioural changes for these species in close proximity to the road. Extensive literature reviews have been unable to determine any confirmed effects one way or another, making it difficult to quantify the scale of these impacts with any real accuracy. In addition, despite management measures to minimise the risk of bird strike by moving vehicles, the risk of bird strike remains.

Elevated noise levels within wetland migratory bird habitats have the potential to result in:

- Reductions in bird abundance, breeding and species richness;
- Masking of vocalisations;
- Temporary or permanent avoidance of the noise affected area; and
- Physiological stress.

Artificial night lighting may result in:

- Distraction of migrating birds;
- Changes in bird community composition;
- Changes in bird foraging and singing time; and
- Timing of reproductive cycles.

10.2.5.3. Description of Offset

Main Roads proposes to provide up to $300,000 for a combination of direct and indirect offsets aimed at offsetting impacts on these species. As a direct offset against impacts on migratory wetland birds, Main Roads proposes to implement a *Typha* control programme at the Ramsar listed Thomsons Lake over a three year period. The *Typha* control programme will be developed in consultation with DEC.

As an indirect offset, Main Roads proposes to undertake research into the effects of constructing a highway through a wetland area on wetland migratory birds. Prior to commencement of construction, Main Roads will develop, in consultation with DEC and relevant academic institutions, a research plan that includes the following scope of work:

- Clear outline of objectives;
- Undertaking to collect sufficient baseline (pre-construction) data, both current and historical;
- Methods to record ambient noise and light levels, pre and post construction;
- Duration of study; and
- Monitoring and reporting requirements.

10.2.5.4. Predicted Outcome of Offset Proposal 5

The proposed offset will improve the value of existing wetland migratory bird habitat within the Ramsar listed Thomsons Lake. Since this area is currently afforded the highest level of international protection under the Ramsar Convention, this offset is consider to represent a net environmental gain for wetland migratory birds.

Additionally, the proposed offset will provide a greater level of understanding of the effects of new transport infrastructure on wetland migratory birds within urban wetlands.

10.3. Offset Summary

The proposed project will result in the unavoidable loss, filling or resumption of approximately:

- 38ha of intact native vegetation;
- 78ha of black cockatoo foraging habitat;
- 2.5ha of potential black cockatoo nesting habitat;
- 9.7ha of CCW (including buffers);
- 6.5ha of Bush Forever;
- 5.4ha of Beeliar Regional Park;
- 5.6ha (64 percent) of habitat where a Graceful Sun-moth population has been recorded, likely to result in a complete loss of the population; and
- Disruption of wetland migratory birds within and adjacent to the project area.

In return, Main Roads will ensure that the community of Western Australia will benefit from the following:

- Offset Proposal 1: Purchase and transfer of tenure from freehold to the conservation estate of approximately 470ha of intact native vegetation, which includes CCW, is classified as Bush Forever and is suitable black cockatoo habitat;
- Offset Proposal 2: Restoration of approximately 8.4ha of the degraded Horse Paddock Swamp, weed control and restoration of approximately 5ha of North Lake wetland fringes and contribution of $100,000 to DEC's Environmental Community Grants Scheme to support volunteers undertaking direct on ground works to conserve wetlands;
- Offset Proposal 3: Net increase in the size of the Beeliar Regional Park by approximately 9ha;
- Offset Proposal 4: Improved management and protection of existing Graceful Sun-moth populations within the region, improved understanding of techniques for translocating habitat from development areas to degraded GSM habitat and improved understanding of techniques for translocating populations from development zones to existing populations or potential habitats; and
- Offset proposal 5: An improvement in the extent and quality of existing wetland migratory bird habitat at the Ramsar listed Thomsons Lake and an improved understanding of the effects of new transport infrastructure on wetland migratory birds.

11. Conclusion

Main Roads proposes to extend the Roe Highway west from its current terminus at Kwinana Freeway in Jandakot to Stock Road in Coolbellup. The proposal includes associated road, highway, freeway and intersection modifications. It will consist of a dual carriageway with two lanes in each direction, separated by a concrete barrier in place of a median strip. The preferred design was selected from several options during an extensive options analysis and consultative process that scrutinised project objectives; as well as specific environmental, social and economic criteria.

The proposed project will provide an increased capacity for freight and general traffic movements by providing a more direct route to various destinations and reducing time spent on the road. This will improve the efficiency of the Perth southern metropolitan road network. The proposed project will provide benefits to the broader community and industry by:

- Continuing Roe Highway as an orbital route that links directly from Midland to Fremantle Harbour and the proposed future Outer Harbour via Stock Road;
- Providing a new east-west link between Kwinana Freeway and Stock Road;
- Reducing congestion and improving safety on existing east-west links;
- Supporting economic development; and
- Providing a southern access into the Murdoch Activity Centre via an extension of Murdoch Drive to reduce pressure on the northern (South Street) access.

11.1. Significant Environmental Factors

Key environmental factors were initially identified in EPA Bulletin 1088 (EPA 2003). On the basis of this, South Metro Connect developed an Environmental Scoping Document, outlining a range of investigations to obtain a clear understanding of the environmental conditions and ecosystem functions within and adjacent to the project area. Throughout the project development stage, South Metro Connect has implemented a comprehensive community and stakeholder engagement program to develop a clear understanding of community values, concerns and requirements. In response to this engagement process; as well as a result of the findings of field investigations, SMC commissioned additional studies to obtain more data on which to base the impact assessment.

SMC has used the results of these studies to:

- Develop the least impacting design possible while achieving the primary project objective of connecting the existing Roe Highway with Stock Road;
- Consider and, as much as practicable, quantify the likely impacts of the proposed project on the environmental values of the project area; and
- Determine and commit to appropriate management strategies, including innovative construction techniques to minimise impacts during construction.

The preceding impact assessment (Section 6) specifically addresses each of the concerns raised by EPA in Bulletin 1088 (EPA 2003). Of these, it has been determined that significant impacts of the proposed project will be on flora and vegetation, Conservation Category Wetlands, conservation significant fauna and residential amenity. These impacts are summarised below.

11.1.1. Flora and Vegetation

The proposed project will result in the clearing of up to 79ha of native vegetation. Of this, 37.5ha is intact native vegetation ('Degraded to Good' condition or better). Included in this amount is 2ha of intact native vegetation within the Roe Swamp CCW boundary and 7ha of intact native vegetation classified as GDEs.

The project will not impact on any Threatened or Priority Ecological Communities and no DRF has been recorded within the project area during project surveys, however there are six State Priority flora species that will be impacted.

The vegetation communities BahS and CcAf will be completely removed from the project area. However, the FCT that make up the vegetation communities present in the project area are documented to be 'Well Reserved' (Gibson et al. 1994). In addition, given the degraded nature of CcAf and its location immediately adjacent to the existing Kwinana Freeway/Farrington Road intersection, the removal of this particular vegetation community is not considered to be significant.

Vegetation clearing will also result in the loss of 7ha of Bush Forever, including 4ha of intact native vegetation. Following clearing, the vegetation complex to be cleared from this site (Bassendean Complex – Central and South) will still remain at above 10 percent of its pre-European extent, which is the Bush Forever target for vegetation types in the Swan Coastal Plain.

In the unlikely event that there is a change to hydrological conveyance following mitigation, there may be a minor successional shift from the current GDE association of species to a different community type for 12 of the 70 mapped GDE sub-communities within a 50m zone of effect. This process mirrors existing ecological response to the highly variable climate patterns through time and is not expected to represent a significant change to ecosystem function.

Residual vegetation impacts will be offset through:

- The purchase of 468ha of good quality remnant native bushland that contains similar vegetation complexes to those being impacted by the proposed project, thus ensuring security of tenure for a much greater patch of vegetation than that being impacted (Offset Proposal 1);
- Restoration of Horse Paddock Swamp and degraded fringes of North Lake, combined with funding towards community based rehabilitation programmes (Offset Proposal 2); and
- Transfer of approximately 14.5ha of MRS road reserve to Beeliar Regional Park (achieving a net gain in 9ha) to ensure long term security of tenure for some of the highest quality vegetation within Roe Swamp (Offset Proposal 3).

11.1.2. Wetlands

The proposed project will have direct impacts on the Roe Swamp and Horse Paddock Swamp CCW boundaries and their buffers; as well as the Bibra Lake EPP boundary and buffer. Impacts on Bibra Lake and Horse Paddock Swamp are not considered significant due to the existing condition of the wetlands and the small area of direct impact. A total of 9.7ha of Roe Swamp CCW and buffer will be 'filled' as a result of the proposed project.

The values exhibited by Roe Swamp are commensurate with those of a CCW. The area of direct intersection with the project and mapped wetland area is 5.6ha (temporary and permanent clearing). The 50m buffer around Roe Swamp includes an area of 4.1ha intersecting with the proposal; however, with the exception of the western boundary, this is largely either unvegetated land, degraded habitat or already developed.

There will be partial additional fragmentation of the wetland within the boundary of the Roe Swamp CCW, because of placement of infrastructure within its boundary. However, the dominant surface water conveyance paths generally south to north will be maintained by using a high level bridging aperture and other openings for hydrological flow paths sympathetic to permit natural rain-fed flows.

Road runoff and potential contaminants will be contained within the road drainage system and will be directed through water treatment trains and infiltration basins before being filtered into the groundwater table.

The proposed project is considered unlikely to result in indirect or distal effects on groundwater availability to GDE vegetation as a result of subsurface deformation by road formation weight or 'piercing' of aquatards and consequent 'draining' of perched aquifers.

In the region of Bibra Lake – Horse Paddock Swamp:

- There will be no fragmentation of the wetland within:
  - Horse Paddock Swamp CCW boundary, as the road aligns to the south
  - North Lake lies to the north of Horse Paddock Swamp
  - Bibra Lake EPP boundary, as the road aligns to the north
- The proposed design makes use of high topographic relief between the Horse Paddock Swamp CCW and Bibra Lake EPP to avoid interruptions to water conveyance; and
- The proposed design will adopt the use of apertures, set at appropriate elevations, to aid return of shallow sub-surface and surface sheet flow movement, when natural flows occur, albeit infrequently.

Residual wetland impacts will be offset through:

- Implementation of restoration works at Horse Paddock Swamp, weed control and rehabilitation on degraded wetland fringes of North Lake and contribution of funding towards community based rehabilitation programmes to improve wetland habitats within and adjacent to the project area (Offset Proposal 2);
- Transfer of MRS road reserve to Beeliar Regional Park, the majority of which is within the Roe Swamp CCW, to ensure long term security of tenure (Offset Proposal 3); andProvision of funding towards weed control on Thomsons Lake Ramsar site to maintain habitat availability to affected wetland migratory bird species (Offset Proposal 5); and
- Provision of funding towards research into the effects of road infrastructure on wetland migratory bird populations via an ongoing monitoring programme.

11.1.3. Conservation Significant Fauna

The proposed project will result in the removal of habitat important to conservation significant fauna. This will include the loss of approximately 78ha and 73ha of suitable Carnaby's Black Cockatoo and Forest Red-tailed Black Cockatoo foraging habitat, respectively. In addition, based on the assumption that a significant tree occupies 100m2, and recognising that these species may start using these trees for nesting as pressures on existing nesting habitat increases over time, a total of 2.5ha (249 trees) of potential black cockatoo nesting habitat will be removed.

Impacts on the Graceful Sun-moth by the proposed project are expected to be significant at a local scale, with the removal of a substantial portion of confirmed GSM habitat to an extent that is considered unlikely to support a viable population.

Vegetation clearing will result in a loss of approximately 72ha (45 percent) of available Southern Brown Bandicoot habitat within the project area, equivalent to 0.7 percent of habitat within existing Bush Forever Sites. Vegetation clearing will also result in a loss of approximately 91ha (50 percent) of available potential habitat for the Perth Lined Lerista.

In addition, there are likely to be indirect impacts on other 'at risk' species as recognised in Bush Forever, with bird species, particularly wetland migratory birds, the most at risk of disturbance through noise, vehicle strike and light spill, as well as displacement from existing habitat.

Residual impacts on conservation significant fauna will be offset by:

- Purchase of approximately 480ha of remnant native vegetation that contains habitat suitable for Carnaby's and Forest Red-tailed Black Cockatoo foraging and potential nesting (Offset Proposal 1);
- Implementation of works towards the restoration of Horse Paddock Swamp and weed control and rehabilitation of degraded wetland fringes of North Lake to improve the availability of wetland habitat within the Beeliar Regional Park (Offset Proposal 2);
- Provision of funding towards management and protection of existing Graceful Sun-moth populations within the region, improved understanding of techniques for translocating habitat from development areas to degraded GSM habitat and improved understanding of techniques for translocating populations from development zones to existing populations or potential habitats (Offset Proposal 4); and
- Provision of funding towards an improvement in the extent and quality of existing wetland migratory bird habitat at the Ramsar listed Thomsons Lake and an improved understanding of the effects of new transport infrastructure on wetland migratory birds (Offset Proposal 5).

11.1.4. Residential Amenity (Noise)

Temporary construction noise and vibration impacts are likely to occur along the length of the proposed project, however, it is expected that these effects are manageable within the requirements of Western Australian Environmental Protection (Noise) Regulations 1997.

Noise modelling indicates that the proposed noise wall design achieves compliance with the noise target at all but 170 noise sensitive receivers in the project area, of which 29 are adjacent to the new section of road. Of these, seven exceed the target by 2dB(A) and 22 by 1dB(A).

The remaining 141 receivers that exceed the target but not the limit are adjacent to existing roads, where the net result of the proposed project is a decrease in the number of receivers exceeding the noise target from 205 to 141. That is, for the majority of residences currently impacted by noise from the existing road network, there will be an overall improvement in noise levels.

Furthermore, the overall number of receivers exceeding the noise target in 2031 decreases from 205 to 170 due to the project, and the number exceeding the noise limit decreases from 21 to five. All five receivers exceeding the noise limit are located adjacent to existing roads and are generally out of the scope of the proposed upgrade.

At the request of DEC's Noise Management Branch, the model outcomes are currently subject to peer review to ensure appropriate methodology has been applied. The outcome of this process will be provided to DEC prior to completion of the public review process.

11.2. Environmental Outcome

Main Roads has completed a range of detailed specialist environmental assessments for the proposed project. The outcomes of these investigations have been used to develop a design that avoids, mitigates and minimises environmental impacts as much as practicable. In addition, Main Roads proposes a range of environmental management and mitigation strategies to be applied during and after construction that will further reduce the severity and likelihood of environmental impacts occurring. A summary of Main Roads' commitments is provided in Section 9.1. Where commitments will result in measurable outcomes, these have been expanded and are presented in Section 9.2 in more detail.

Residual impacts remaining following the implementation of proposed management and mitigation strategies will be offset, as outlined in Section 10.

Main Roads considers that the application of the impact mitigation sequence as demonstrated in the preceding chapters, combined with the proposed offsets for unavoidable impacts on critical and high value assets will result in a net environmental gain.

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