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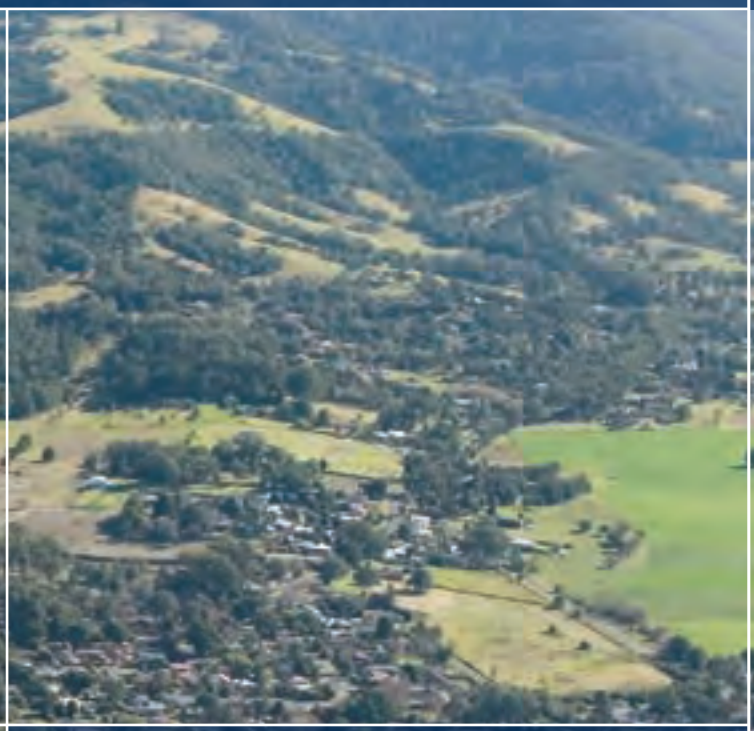

Foxground and Berry bypass

Princes Highway upgrade

Environmental assessment

Volume 2 – Appendix F

Technical paper: Terrestrial flora and fauna

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Princes Highway upgrade

Prepared for

Roads and Maritime Services

Prepared by

Biosis Research Pty Ltd
18-20 Mandible Street, Alexandria NSW 2015

In association with

AECOM Australia Pty Ltd
Level 11, 44 Market Street, Sydney NSW 2000

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Executive summary

Biosis Research Pty. Ltd. was commissioned by AECOM on behalf of the Roads and Maritime Services of NSW (RMS) to carry out a terrestrial ecological assessment of the Foxground and Berry bypass (the project).

RMS is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The aim of this terrestrial flora and fauna assessment is to address the Department of Planning and Infrastructure Director-General's requirements for the project, including the identification of issues of conservation significance associated with the project. The specific objectives were to:

- Gather existing information regarding terrestrial flora and fauna within and surrounding the study area, focussing on threatened species, populations and ecological communities.
- Examine the nature, extent and condition of fauna habitats and vegetation associations within the study area, through a combination of desktop and field studies.
- Determine areas supporting vegetation associations that are, or are likely to be, of conservation significance, or support resources that may be utilised by species or populations of conservation significance.
- Assess the potential occurrence of flora and fauna species or populations of conservation significance, in particular, threatened species and populations.
- Determine areas that may be of importance as habitat corridors.
- Assess the potential impacts of the project on threatened species and populations (including their habitats) and endangered ecological communities.
- Evaluate the impact of the project on threatened biota listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) by undertaking assessments of significance in line with requirements of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and Director-General's requirements for the project and following the Part 3A Guidelines for Threatened Species Assessment (DEC and DPI, 2005).
- Evaluate the impact on Matters of National Environmental Significance (MNES) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the project by implementing significant impact criteria for threatened biota and migratory species as outlined in the EPBC Act Policy Statement 1.1 Significant Impact Guidelines: Matters of National Significance (2009).

The terrestrial ecological field investigations of the project were conducted during February 2007, November 2008, May 2009, June 2011 and November 2011. Surveys were carried out using a combination of habitat-based assessment, trapping, anabat recording, spotlighting and targeted sampling techniques. The study area consists of the area of earthworks for the proposed road and Town Creek downstream of the proposed diversion point (subject site), and a buffer of about 50 metres on either side of the subject site to account for potential indirect impacts.

Endangered ecological communities (EEC)

One endangered ecological community (EEC) was recorded in the study area: Riverbank forest. This community meets the criteria for the EEC *River-flat eucalypt forest on coastal floodplains of the North Coast, Sydney Basin and South East Corner bioregions* listed under the TSC Act. An assessment of significance was carried out for this EEC and it was determined that despite the direct impacts to about 2.9 hectares and indirect impacts to about 7.1 hectares of this ecological community the project is unlikely to have a significant impact upon this EEC.

Subtropical dry rainforest was recorded more than 0.2 kilometres from the study area. This community is included within the EEC *Illawarra subtropical rainforest in the Sydney Basin bioregion* listed under the TSC Act. The preferred option avoids impacts on this community.

Flora

A total of 17 vascular flora species listed on the TSC Act and/or the EPBC Act, or their habitat, have been previously recorded within a 10 kilometre radius of the study area. An additional 14 species are recorded from the NSW Office of Environment and Heritage (OEH) Illawarra sub-region of the Southern Rivers catchment management authority with a further four species identified by OEH for consideration in the environmental assessment.

No threatened flora species were recorded in the study area, however, based on the proximity of previous records and the presence of identified habitat preferences, potential habitat may exist within the study area for four threatened flora species including: White-flowered Wax Plant (*Cynanchum elegans),* Illawarra Socketwood (*Daphnandra* sp. 'Illawarra'), Delicate Cress (*Irenepharsus trypherus)* and Hill Zieria (*Zieria granulata*).

Additionally OEH have identified five flora species to be assessed as subject species for the project including two of the species cited above and an additional three species. The additional three flora subject species are Illawarra Greenhood (*Pterostylis gibbosa*), Leafless Tongue Orchid (*Cryptostylis hunteriana*) and Bauer's Midge Orchid (*Genoplesium baueri*).

Assessments of significance carried out for these seven threatened flora species determined that the project is unlikely to have a significant impact upon any of these species. A referral to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities is therefore not required for any threatened flora species.

Fauna

Fauna habitat within the study area ranged from predominantly cleared areas, which have low to moderate habitat quality in terms of fauna habitat characteristics, to fragmented patches of native vegetation, that contained important habitat features such as tree hollows, rocky shelters, riparian vegetation, fallen logs and feeding resources.

A total of 114 fauna species listed on the TSC Act and/or the EPBC Act, or their habitat, have been previously recorded within a 10 kilometre radius of the study area or within the Illawarra sub-region of the Southern Rivers catchment management authority. Nine threatened and six migratory species were recorded during the field surveys. Based on the proximity of current and previous records and the presence of identified habitat preferences, known and/or potential habitat exists within the study area for 51 threatened and 29 migratory fauna species.

Impacts to the known/potential habitat of 27 threatened species were considered negligible and therefore, assessments of significance were not conducted for these species. Assessments of significance were carried out for the remaining 24 threatened fauna species; the Part 3A assessments of significance for TSC Act-listed species concluded the project would be unlikely to result in a significant impact. The significant impact criteria assessments for EPBC Act-listed species concluded the project would be unlikely to result in a significant impact provided the mitigation measures outlined in this report are implemented. A referral to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities is therefore not required for any threatened fauna species.

Impacts to the known/potential habitat of the 29 migratory species were considered negligible. Individuals of these species that may occur in the study area were not considered likely to be an ecologically significant proportion of the population. Further, potential habitat in the study area was not considered important for the migratory species. As such, no significance assessments under the EPBC Act were carried out for these species. A referral to the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities is therefore not required for any migratory species.

Wildlife corridors and connectivity

Of particular importance for this project is the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. Remnant bushland in the Seven Mile Beach and Coomonderry Swamp area is isolated by several kilometres of cleared land from the escarpment forests to the north of Berry. Scattered patches of bushland exist between these two areas, including Toolijooa Ridge, Harley Hill, Moeyan Hill, along Broughton Creek and along public roads (Shoalhaven City Council 2005), providing limited connectivity between the two largely intact areas for fauna. The project crosses some of these areas of bushland and is likely to impact on local and/or regional wildlife corridors due to habitat fragmentation.

Mitigation

Important ecological features have been avoided during the initial route selection stage, where possible. The following mitigation measures would be implemented to ameliorate impacts on terrestrial flora and fauna, including:

- Enhancement of riparian corridor vegetation including control of exotic aquatic species. All works in waterways would be undertaken works in accordance with Guide 10 Aquatic habitats and riparian zones of the RMS 'Biodiversity Guidelines' (2011).
- Four dedicated fauna underpasses with fauna fencing and fauna 'furniture'.
- Incidental fauna passage under all bridges.
- Rope bridges at eight separate locations along the route.
- Restoration, regeneration and rehabilitation of areas of native vegetation in the vicinity of the project. The preparation of a Vegetation Management Plan (VMP) to guide and provide a monitoring framework should be prepared in consultation with local Landcare groups and the Catchment Management Authority (CMA) committing to input local expertise and resources during implementation.
- Monitoring and control of weed populations that establish on disturbed areas, with particular attention to eradication of noxious weeds. The monitoring and control should be undertaken by persons experienced in weed management and in accordance with Guide 6 Weed management of the RMS 'Biodiversity Guidelines' (RTA 2011).
- Fencing and protection of EECs and potential habitat of threatened species that occur within the impact zone following the RMS 'Biodiversity Guidelines' (RTA 2011).
- Minimising disturbance to stream banks and streambeds wherever possible.

Clearing of vegetation would follow Guide 1 Pre-clearing process of the RMS 'Biodiversity Guidelines' (RTA 2011).

Biodiversity offsets

A Biodiversity Offset Strategy has been prepared to guide offsetting of residual impacts that cannot be mitigated, such as the unavoidable loss of Riverbank forest (River-flat eucalypt forest EEC). The following two offset actions are proposed in order to achieve a “maintain or improve” biodiversity outcome for the region as a result of the project:

Action 1 Revegetation and rehabilitation of riparian vegetation in strategic locations.

Action 2 Use an appropriate legal instrument to secure native vegetation to ensure that the land is managed for conservation.

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1 Introduction

1.1 Background

RMS is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The project comprises the following key features:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.

- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.
- Eight underpasses including roads, drainage structures and fauna underpasses:
  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Tindalls Lane, Gembrook Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent ancillary facility site for general road maintenance.

Construction activities as part of the project would include the following:

- Site preparation and establishment works.
- Temporary construction facilities, including construction compounds, stockpile sites, creek crossings, sediment control basins and haulage roads.
- Temporary works, including relocation/protection of services, tie-ins, traffic facilities and side tracks.
- Earthworks and bridge construction.
- Pavement construction.
- Drainage construction.
- Road furniture installation.
- Site restoration.

The project and the key features of the project are shown in **Figure 1.1**.

This terrestrial flora and fauna assessment should be read in conjunction with the *Aquatic Ecology and Water Quality Management Assessment*, which is provided at Appendix G of the environmental assessment (CEL 2012).

During detailed design, refinements could be made to the design features and construction methods (refer to Chapter 4 of the environmental assessment).

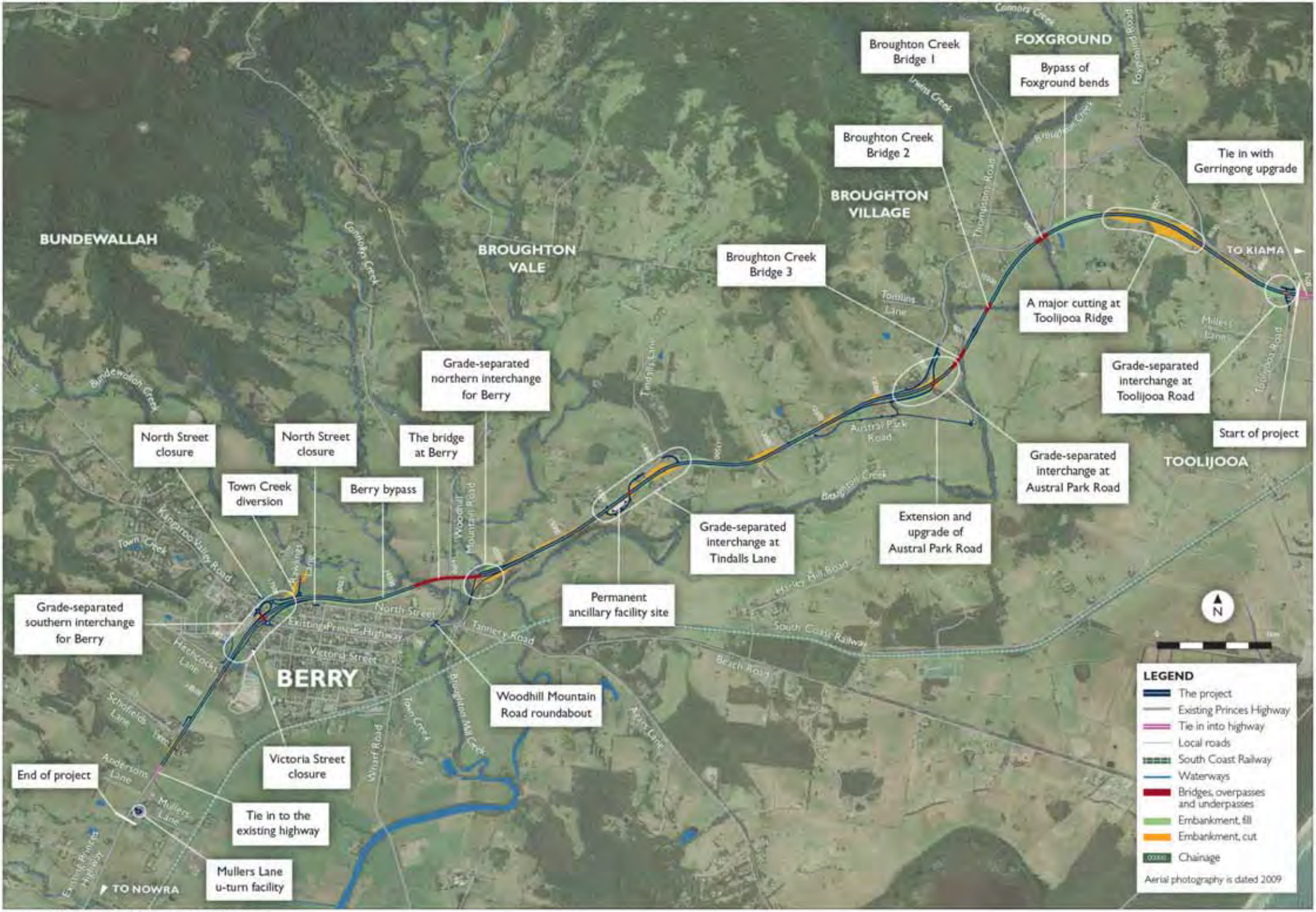


Figure 1-1: Foxground and Berry bypass project area

1.2 Objectives of the report

Biosis Research Pty. Ltd. (Biosis Research) was engaged to investigate potential terrestrial flora and fauna issues in relation to the project. The terrestrial flora and fauna assessment involved two major components:

a) Preliminary investigations to assist the process of selecting a preferred route option (Biosis Research 2007).

b) Detailed investigations of the preferred option for the project (this report).

The overall objective of this report is to address the Department of Planning and Infrastructure's Director-General's requirements (DGRs) for the project. The DGRs relevant to the flora and fauna assessment are provided in **Table 1.1**. This report focuses on the terrestrial ecology requirements. The aquatic ecology requirements are addressed in Foxground and Berry bypass Aquatic Ecology and Water Quality Management Assessment, (CEL 2012).

Table 1.1: DGRs relevant to terrestrial ecology

Director-General's requirements
Flora and Fauna – including but not limited to:
An assessment of all project components on flora and fauna and their habitat (both terrestrial and aquatic, as relevant) consistent with the Draft Guidelines for Threatened Species Assessment (DEC 2005). The EA must provide details of the survey methodology employed including survey effort and representativeness for species targeted.
Specific consideration of impacts to threatened species, populations, ecological communities and/or critical habitat listed under both State and Commonwealth legislation that have been recorded on the site and surrounding land.
Details on the existing site conditions (both terrestrial and aquatic) and quantity and likelihood of disturbance (including quantifying the worst case extent of impact on the basis of vegetation type and total native vegetation disturbed).
As relevant, consideration of weed infestation and edge effects; habitat fragmentation, impacts to wildlife and riparian corridors; impacts to groundwater-dependent communities, riparian and aquatic habitat (including impacts on SEPP 14 wetlands and fish passage).
Provide details of how flora and fauna impacts would be managed during construction and operation for all project components, including adaptive management and maintenance protocols and monitoring programs.
Demonstrate actions to be undertaken to avoid, mitigate or offset impacts associated with the project (all components) consistent with the principles of "improve or maintain". Sufficient details must be provided to demonstrate the availability of viable and achievable options to offset the impacts of the project, where offset measures are proposed to address residual impacts.

The report also presents the results of surveys and the assessment of potential impacts upon terrestrial flora and fauna values within the project study area. The potential impacts have been assessed in accordance with relevant State and Commonwealth threatened species legislation.

The specific objectives of this terrestrial flora and fauna assessment were to:

- Gather existing information regarding terrestrial flora and fauna within and surrounding the study area, focussing on threatened species, populations and ecological communities.
- Examine the nature, extent and condition of fauna habitats and vegetation associations within the study area, through a combination of desktop and field studies.
- Determine areas supporting vegetation associations that are, or are likely to be, of conservation significance, or support resources that may be utilised by species or populations of conservation significance.
- Assess the potential occurrence of flora and fauna species or populations of conservation significance, in particular, threatened species and populations.
- Determine areas that may be of importance as habitat corridors.
- Assess the potential impacts of the project on threatened species and populations (including their habitats) and endangered ecological communities (EEC).
- Evaluate the impact of the project on threatened biota listed under the NSW Threatened Species Conservation Act 1995 (TSC Act) by undertaking assessments of significance in line with requirements of the NSW EP&A Act 1979 and DGRs for the project and following the Part 3A Guidelines for Threatened Species Assessment (Department of Environment and Conservation (DEC) and DP&I, 2005).
- Evaluate the impact on Matters of National Environmental Significance (MNES) under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) for the project by implementing significant impact criteria for threatened biota and migratory species as outlined in the EPBC Act Policy Statement 1.1 Significant Impact Guidelines: Matters of National Significance (2009).

1.3 Legislative framework

1.3.1 *NSW Environmental Planning and Assessment Act 1979 (EP&A Act)*

The EP&A Act and Environmental Planning and Assessment Regulations 2000 (EP&A Regulations) provide the statutory context for environmental assessment of the project and ultimately planning approval. The current project is to be assessed under Part 3A and other relevant provisions of the EP&A Act.

One objective of the EP&A Act is to encourage the protection of the environment, including the protection and conservation of native fauna and flora, including threatened species, populations and ecological communities and their habitats. A second objective is to encourage the principles of ecologically sustainable development, including the precautionary principle as defined under the Protection of the Environment Administration Act 1991. The precautionary principle is defined as:

> *Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation* (IGAE 1992).

1.3.2 NSW *Threatened Species Conservation Act 1995* (TSC Act)

The TSC Act protects all threatened flora and fauna native to NSW (with the exception of fish and marine plants). It provides for the identification, conservation and recovery of threatened species and their populations and communities. It also aims to reduce the threats faced by those species.

1.3.3 Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The EPBC Act is a Commonwealth mechanism that requires proposed actions to be assessed in terms of their potential impact upon MNES. MNES currently listed under the Act are:

- World heritage properties.
- Natural heritage places.
- Wetlands of international importance.
- Threatened species and ecological communities.
- Migratory species.
- Commonwealth marine areas.
- Nuclear actions (including uranium mining).

Where a potential impact on a MNES is likely to occur as a result of a proposed action, the significance of that impact must be assessed. Guideline criteria for determining whether an impact is significant are provided under the Act. Where a proposed action would, or is likely to, have a significant impact on a MNES, a referral to the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities must be prepared. The purpose of the referral is to determine whether a proposed action requires approval and/or controls under the EPBC Act.

1.3.4 SEPP 14 wetlands

State Environmental Planning Policy 14 Coastal Wetlands (SEPP 14) aims to protect and preserve coastal wetlands. The areas covered by SEPP 14 are shown on a series of maps held by the Department of Planning and Infrastructure (DP&I). Over 1300 coastal wetlands have been mapped under SEPP 14, representing seven per cent of all coastal wetlands in NSW. Under SEPP 14, a person must not clear land, construct a levee, drain land or fill land which is covered by SEPP 14 except with the consent of the local council and the concurrence (agreement) of the NSW Minister for Planning.

1.3.5 SEPP 44 Koala habitat protection

State Environmental Planning Policy 44 Koala Habitat Protection (SEPP 44) aims to encourage the proper conservation and management of areas of natural vegetation that provide habitat for Koalas, ensuring a permanent free living population over their present range and attempting to reverse the current trend of Koala population decline.

SEPP 44 applies to land within the Local Government Areas (LGAs) listed under SEPP 44, Schedule 1 (including the Kiama and Shoalhaven LGAs. Under this policy the distinction is made between ‘potential’ and ‘core’ Koala habitat. Although the RMS is exempt in this case, the implications of SEPP 44 have been considered (Section 3.8.5).

1.4 Study area

1.4.1 Definitions

New South Wales threatened species legislation applies particular definitions to the site of a proposed development and the area likely to be impacted by a proposed development. In addition, the present NSW and Commonwealth Government approach to biodiversity conservation recognises a system of “bioregions” and “subregions”. In order to provide clarity of reporting and consistency with current legislation and policy, the following definitions apply throughout this document:

Project - proposed upgrade (widening in sections and realigning in sections) of the Princes Highway between about the junction of Toolijooa Road and the Princes Highway and about the junction of Schofields Lane and the Princes Highway on the NSW south coast (Foxground and Berry bypass).

Direct impacts – those that directly affect habitat and individuals. Direct impacts can include, but are not limited to, removal of vegetation and habitat, trampling of habitat or individuals, and fragmentation of habitat.

Indirect impacts – occur when project-related activities affect species, populations or ecological communities in a manner other than direct loss. Indirect impacts can include, but are not limited to, loss of individuals through starvation, exposure, predation, competition for reduced resources, erosion, weed invasion, or increased human activity within or adjacent to sensitive habitat areas.

Residual impacts – these are impacts that remain following actions to avoid and mitigate direct and indirect impacts.

Subject site – the area to be directly affected by the project (ie the development “footprint”).

Study area – the subject site and any additional areas which are likely to be affected by the project, either directly or indirectly. In the case of the project, the study area includes the subject site and a 50 metre buffer to account for any indirect impacts.

Locality – for the purposes of this report, the “locality” is defined as the area within a five kilometre radius of the perimeter of the study area.

Region – the region and sub-region in which the project would be located, as defined by the Interim Biogeographic Regionalisation of Australia. The Interim Biogeographic Regionalisation of Australia is based on Thackway and Cresswell (1995) and Morgan and Terry (1992) and periodically updated by Parks Australia. Interim Biogeographic Regionalisation of Australia Version 6.1 was current at the time of this study. The project is located in the Illawarra sub region at the southernmost portion of the Sydney basin bioregion.

Threatened biota – threatened species, populations and ecological communities, or their potential habitats, as listed under the TSC Act or the EPBC Act.

Subject species, populations or ecological communities – those threatened species, populations or ecological communities that are known or considered likely to occur in the locality. Subject species have been determined from desktop assessments and field surveys by Biosis Research, or are specifically included as a result of consultation with OEH and are included in Attachment 2 of the OEH correspondence dated 31 January 2011.

1.4.2 Location and description

The project is 11.6 kilometres in length and is located west of Gerringong, between the intersection of the Princes Highway and Toolijooa Road, and the intersection of the Princes Highway and Schofields Lane. The project traverses Toolijooa Ridge, bypasses Foxground, crosses Broughton Creek in three locations and bypasses the town of Berry. The project lies partly within the Kiama LGA and partly within the Shoalhaven LGA.

An overview of the study area is provided in **Figure 1.1**. The study area mainly comprises the existing road reserve, privately owned rural agricultural, rural residential and suburban (Berry) properties. Patches of native vegetation and isolated remnant trees are scattered throughout the majority cleared agricultural landscape. The main agricultural land use in the study area is cattle grazing.

Conservation reserves that occur in the locality include the Cambewarra Range Nature Reserve, the Seven Mile Beach National Park, the Barren Grounds Nature Reserve and the Saddleback Mountain Reserve. None of these reserves are directly impacted by the project.

The project deviates from the existing Princes Highway corridor in two locations:

- Across Toolijooa Ridge and the Broughton Creek floodplain between Toolijooa Road and east of Austral Park Road.
- To the north of Berry, where a northern bypass of Berry is proposed between the ridgeline to the east of Woodhill Mountain Road and the south of Berry, where it would rejoin the existing route south-west of Kangaroo Valley Road.

Remaining portions of the project follow the existing route of the Princes Highway.

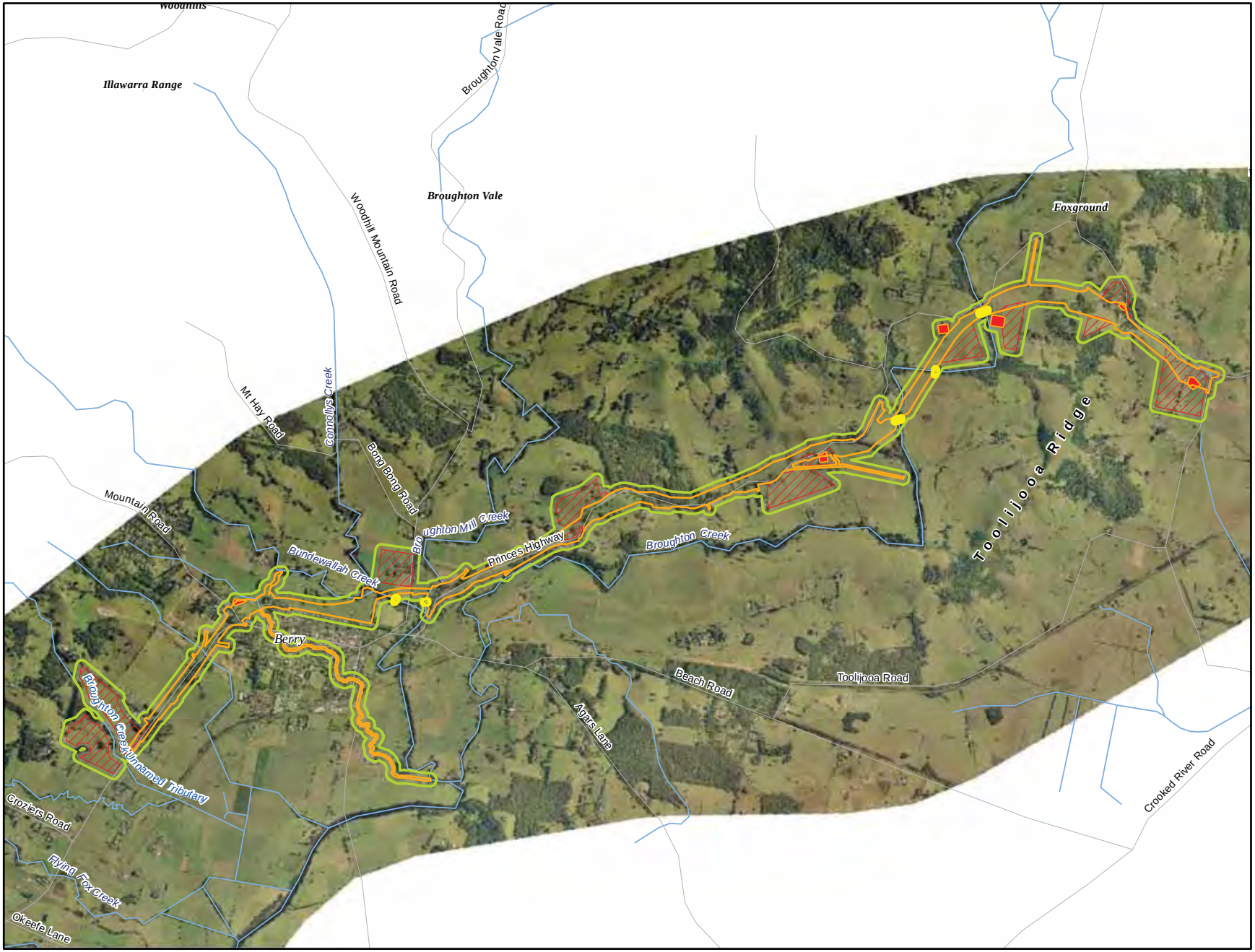
1.4.3 Extent of the study area

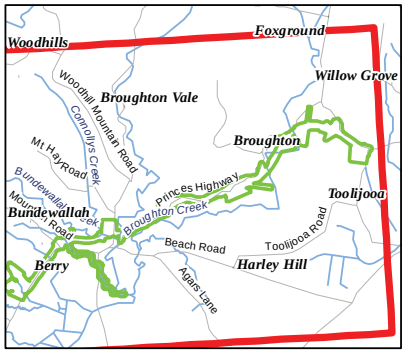
The study area is defined by the extent of direct and indirect impacts on flora and fauna that are likely to occur as a result of the project. Potential impacts on flora and fauna may occur during the construction and/or the subsequent operation of the project. Direct impacts are likely to be limited to the subject site. The proposed location and land take for ancillary facilities such as construction compounds, site offices and stockpile areas (shown in **Figure 1.2**), and land downstream of the proposed Town Creek diversion point, have been considered as part of the subject site in addition to the highway footprint.

Areas that may be indirectly affected by the project include adjoining flora and fauna habitats within 50 metres of either side of the subject site. The subject site and the 50 metre buffer area make up the study area for the project. A distance of 50 metres was chosen for the buffer as this is the average distance that edge effects are likely to be seen and recorded from the edge of a road (Biosis Research 2000, Bali 2005). Although edge effects (indirect impacts) can extend much further than 50 metres, native vegetation patches immediately surrounding the project are already subject to edge effects, and therefore, a relatively small study area was chosen. Edge effects associated with road developments can be summarised as the degradation of adjacent habitat through:

- Changes in microclimate, hydrology or floristics (flora species mix).
- Alteration to the pattern and frequency of fire.
- Invasion by exotic flora and fauna species.
- Increase in sedimentation, tree death or rubbish and water pollution.
- Improved access for predators (Bali 2000).

Further discussion of the potential direct and indirect impacts relating to the project including impacts on wildlife corridors is included in Section 4.1. While the study area includes the subject site and a 50 metre buffer, extensive surveys were carried out within the locality as part of the route options investigations for the project. Surveys carried out within the locality provide important contextual information in relation to the potential impacts of the preferred route.





Legend

- Study Area
- Subject Site - Footprint
- Subject Site - Temporary Creek Crossings

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile

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Figure 1.2 Ancillary Facilities

Date: 16 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F1-2_Ancillary Facilties_Overview_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 350 700 1,050 1,400 1,750
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Scale: 1:35,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 1.2

2 Methods

2.1 Approach

The location and extent of the study area is shown on **Figure 1.1**. The study involved three key stages including a desktop examination, field surveys, and impact assessment reporting. The desktop study involved gathering and reviewing existing information regarding the flora and fauna of the study area. Field surveys were undertaken for the purpose of ground-truthing information obtained during the desktop examination and to gather additional data from parts of the study area selected for further investigation. The combined information from field and desktop studies was then used to assess the impacts of the upgrade on terrestrial flora and fauna values within the study area.

2.2 Desktop study

Existing information regarding the flora and fauna of the study area was obtained from a range of sources, including: databases; aerial photographs and maps; previous studies carried out in the vicinity of the study area; and consultation with experts, government agencies, land owners and land managers, local volunteer organisations and natural heritage clubs. A list of documents cited in this report is located in Chapter 8.

Database records were obtained for the study area and the landscape within a 10 kilometre radius of the perimeter of the study area. Database searches were conducted in April 2011 and included:

- Records of threatened flora and fauna species listed on the schedules of the TSC and EPBC Acts obtained from the NSW Office of Environment and Heritage (OEH) NSW National Parks and Wildlife Service (NPWS) Atlas of NSW Wildlife.
- Records of MNES listed under the provisions of the EPBC Act obtained from the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) Protected Matters Database.
- Records of threatened and migratory bird species obtained from the Birds Australia New Atlas of Australian Birds.
- Records of threatened flora and fauna species and plant communities from the OEH Illawarra sub-region database.

Spatial information from previous studies carried out in the vicinity of the study area that was examined included:

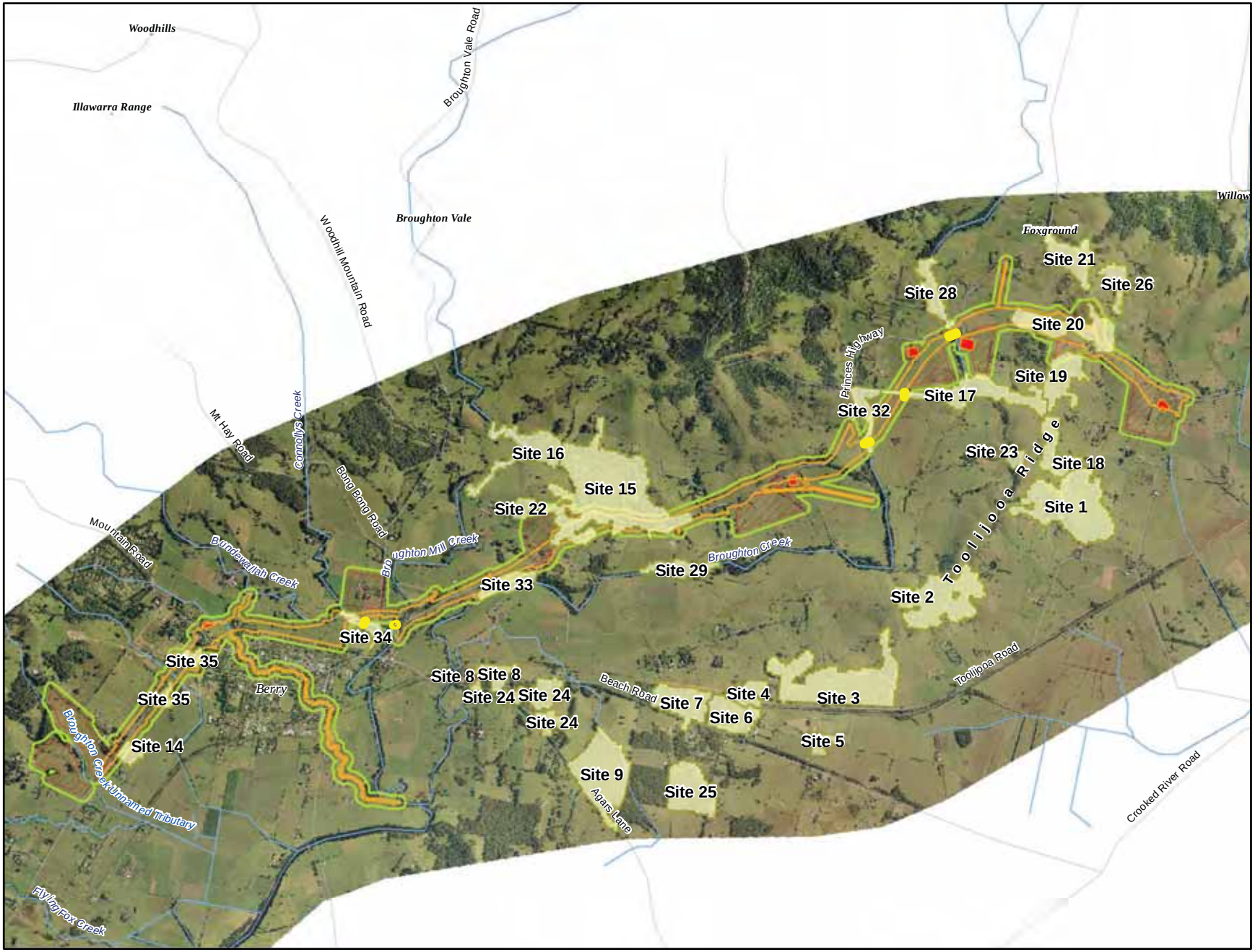
- Aerial photographs of the study area and surrounds, sourced by AECOM.
- Topographic and orthophoto maps (Land and Property Management Authority, (formerly Department of Lands), 1:25,000 maps of Gerroa and Kiama).
- Cadastral information, sourced by AECOM.
- Native Vegetation Map Report Series. No. 4 (DEC 2005o).
- *South Coast Regional Conservation Plan* (NSW Department of Environment, Climate Change and Water (DECCW) 2010).
- Shoalhaven City Council on-line vegetation maps (Shoalhaven City Council 2004).
- Vegetation and Fauna Survey and Assessment prepared for the 1991 Gerringong to Berry route selection study (Muston and Associates 1991).
- *Kiama Municipal Council Local Environment Plan 1996*.
- *Illawarra Regional Environment Plan No 1*.
- *The Natural Vegetation in the Municipality of Kiama New South Wales* (Mills 2006b).
- *Threatened Fauna of the Shoalhaven* (NPWS and Shoalhaven Catchment Management Committee 2000).
- *Mammal Survey of Seven Mile Beach National Park and Comerong Island Nature Reserve on the South Coast of New South Wales* (Murphy 1998).
- *Bats of the Illawarra Region* (Robinson 1985).

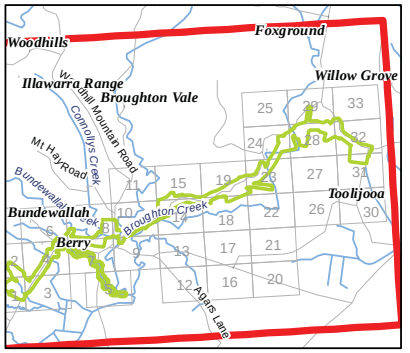
Additional data or information was provided by Mark Tozer (vegetation community expert - DSEWPaC), Ann Goeth (local bird expert – OEH), the Native Animal Network Association, the Berry and District Historical Society Inc., Kerry Withers, Dr Arthur White (frog expert – Frog and Tadpole Study Group) and Garry Daly (herpetologist – NSW National Parks and Wildlife Service (NPWS)).

2.3 Site selection

Sites within the study area were selected for field investigation following roadside reconnaissance and an examination of aerial photographs, topographic maps, existing vegetation maps and threatened species records. Survey sites within the study area included locations containing stands of native vegetation and riparian vegetation along creeks and farm dams. Survey effort previously conducted outside the study area but within the locality as part of the route options assessment has been included for contextual purposes.

Seasonal surveys along the entire upgrade route were conducted in February 2007, November 2008 and May 2009. There were 28 survey sites in the locality of the project (sites 1-9, 14-26, 28-29 and 32-35). The location of survey sites is shown on **Figure 2.1** with survey types shown in **Figure 2.2** and **Figure 2.3** (see Appendix J for mapbooks of these figures at a 1:4000 scale). It should be noted that survey effort was more intensive in areas identified as being of higher conservation significance (Biosis Research 2007). On this basis, survey effort within cleared and disturbed agricultural lands within the study area was limited. Flora surveys and plant community assessments were carried out by one botanist on 28 June 2011 to identify suitable locations for temporary creek crossings during construction. Flora and fauna habitat surveys and plant community assessments were carried out by a botanist and zoologist on 8 November 2011 to assess the proposed diversion of Town Creek.





Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1: Survey sites

Date:13 July 2011	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_Overview_130712.mxd	

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Metres

Scale: 1:35,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 2.1

2.4 Flora surveys

2.4.1 Survey techniques

Flora surveys were carried out by two botanists over a total of 22 days during three split survey periods conducted between 12 to 23 February 2007; 4 to 12 November 2008, and 18 to 22 May 2009. Flora surveys and plant community assessments were carried out by one botanist on 28 June 2011 to identify suitable locations for temporary creek crossings during construction. These surveys were carried out on Bundewallah Creek, Broughton Mill Creek and Broughton Creek. Surveys involved targeted searches for threatened flora species using random meander techniques and ground-truthing of the plant communities mapped by DEC (2005o) using plot-based surveys. An assessment of plant community condition was conducted at all survey sites. Flora surveys and plant community assessments involving random meanders were carried out by one botanist on 8 November 2011 to determine the potential for threatened flora species and populations to occur, and the presence or absence of EECs, within the area potentially affected by the proposed diversion of Town Creek into Bundewallah Creek.

Surveys were conducted in accordance with the draft publication, *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities* (DEC 2004a). Survey effort was most rigorous within areas identified as known or potential habitat for threatened flora species and areas identified as EEC. A description of each of the survey methods is provided below.

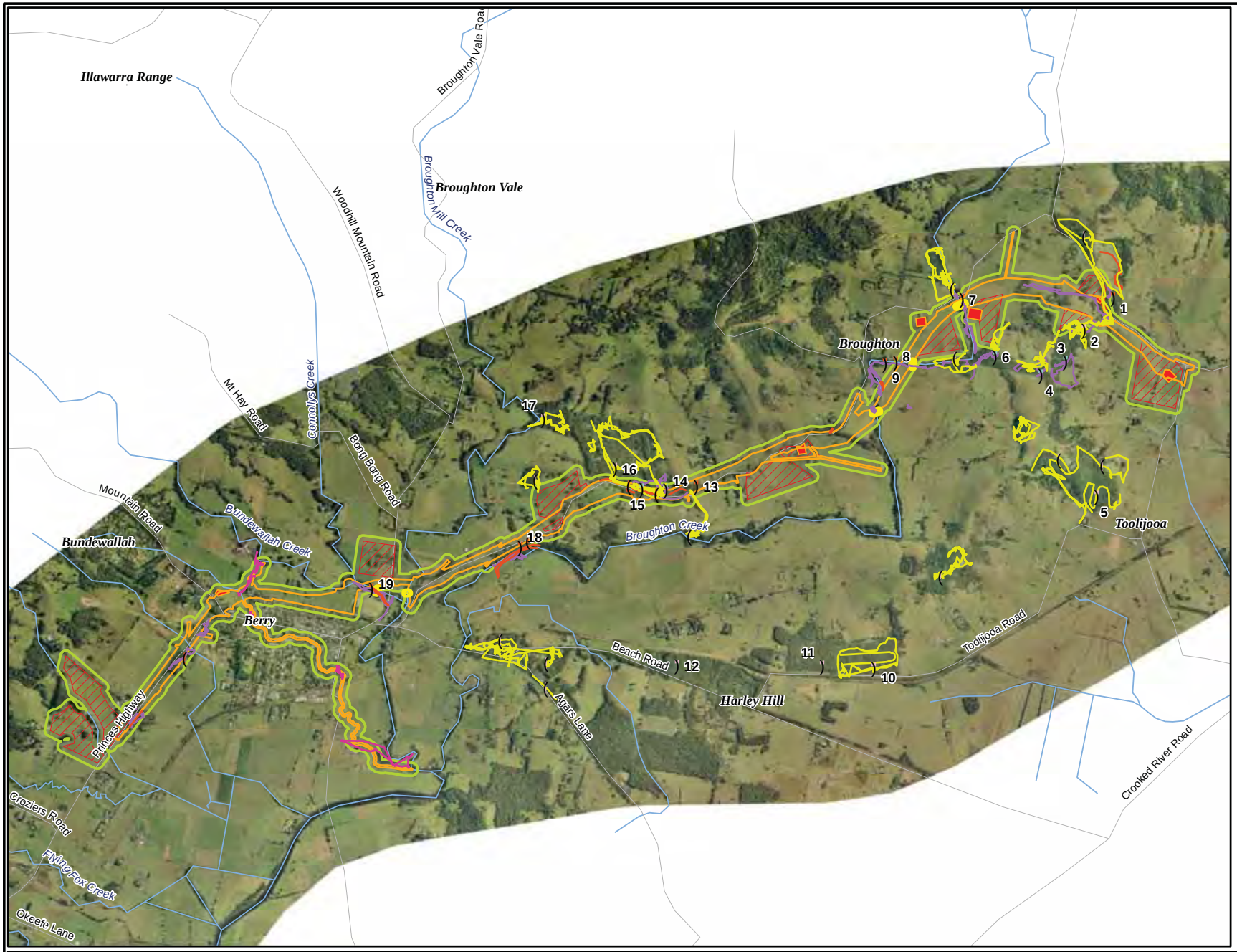
2.4.2 Targeted searches

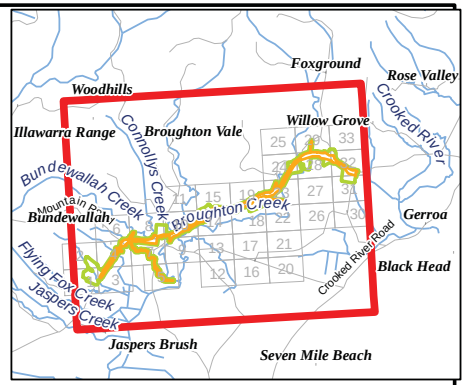
Targeted searches for threatened flora species involved random meander transects as described by Cropper (1993) were carried out in selected areas of known or potential habitat. Random meander transects were undertaken by one or two botanists traversing each site. The locations of random meander transects are shown on **Figure 2.2** (see Appendix J for mapbook at a 1:4000 scale).

During the random meander surveys, an inventory of all observed flora species was recorded at each site (Appendix A). Where threatened flora were detected, the number of individuals present was counted and the extent and geographic location of each population recorded using a hand-held non differential Global Positioning System (GPS). Where flora species could not be identified in the field, a representative sample was collected and preserved for later identification by the Royal Botanic Gardens, Sydney Herbarium.

2.4.3 Plot based surveys (quadrats)

In order to comprehensively describe the structure and floristics of each sampled plant community, plot-based surveys were used. Plot-based surveys also provided a concentrated search area for the detection of inconspicuous flora species that may be present at a particular site. The structure and floristics exhibited by each plant community present in the study area was sampled using one or more 400 square metre quadrats (20 metre x 20 metre). A modified Braun-Blanquet cover abundance scale (Moore 1955) was assigned to each of the species collected within any one quadrat. For this assessment a seven-division cover abundance scale was used (**Table 2.1**).





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Survey period/type

(No. Refers to Quadrats listed in Appendix A)

- (Summer 2007 - Habitat condition assessment
-) Summer 2007 - Quadrat
-) Spring 2008 - Quadrat
- (Autumn 2009 - Habitat condition assessment
-) Autumn 2009 - Quadrat

- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS
File: 13194	Checked by: JC
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Acknowledgements:
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Metres

Scale: 1:35,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 2.2

Table 2.1: Modified Braun Blanquet cover abundance scale (Moore 1955)

Cover abundance score	Cover abundance estimate (per cent cover of any species within each quadrat)
1	Species cover less than five per cent – three or less individuals
2	Species cover less than five per cent – more than three individuals but sparsely scattered consistent throughout plot
3	Species cover less than five per cent – many individuals throughout plot and any number less than five per cent cover abundance
4	Species covers between five per cent and 25 per cent of the plot
5	Species covers between 25 per cent and 50 per cent of the plot
6	Species covers between 50 per cent and 75 per cent of the plot
7	Species covers between 75 per cent and 100 per cent of the plot

Survey data was compared with existing vegetation maps of the study area DEC (2005o) in order to confirm the identification and extent of plant communities, particularly those that correspond to EECs. Any inconsistencies identified in the DEC (2005o) vegetation mapping were checked using the results of both random meander transects and plot-based surveys.

2.4.4 Condition assessments

Habitat condition assessments involved the collection of data regarding the plant communities present at each survey site, including the dominant species within each stratum, the degree of cover and the relative quality or condition of the plant community. The condition of the vegetation was assessed according to the degree to which it resembled relatively natural, undisturbed vegetation using the following criteria:

a) Species composition (species richness, extent of weed invasion).

b) Structure (representation of each of the original layers of vegetation).

Plant community condition was categorised as follows:

Good: containing a high number of indigenous species; no weeds present or weed invasion restricted to edges and track margins; vegetation community containing original layers of vegetation; vegetation layers (ground, shrub, canopy etc) intact.

Moderate: containing a moderate number of indigenous species; moderate level of weed invasion; weeds occurring in isolated patches or scattered throughout; one or more of original layers of vegetation modified; vegetation layers (ground, shrub, canopy etc) largely intact.

Poor: containing a low number of indigenous species; high level of weed invasion; weeds occurring in dense patches or scattered throughout; one or more of the original layers of vegetation highly modified; one or more original vegetation layers (ground, shrub, canopy etc) modified or missing.

Unnatural landscape: highly modified landscape containing few or no indigenous species; exotic species dominant; original native vegetation layers removed; natural soil profile disturbed; unable to be regenerated to natural condition; high input intervention required to revegetate.

2.4.5 Flora survey effort

The details of the flora survey effort for the project are shown in **Table 2.2** and **Table 2.3**. Time invested in each survey technique is based on on-site person hours and does not include travel between locations or flora specimen identification conducted post survey.

Table 2.2: Flora survey details – targeted searches and habitat condition assessments

Task	Details
Aim: to determine presence of threatened flora species and assess habitat condition	
Targeted subject species	Species listed in Appendix C with potential habitat
Survey technique	Random meanders and random meander transects
Time invested in survey technique	138 person hours
Dates of surveys	13 February 2007 to 16 February 2007 19 February 2007 to 23 February 2007 4 November 2008 to 7 November 2008 10 November 2008 to 12 November 2008 18 May 2009 to 22 May 2009 28 June 2011 8 November 2011
Survey point of transect marked on a map	See **Figure 2.2** and Appendix J
Size, orientation and dimensions of quadrat or length of transect for each survey technique	Targeted searches (random meanders) carried out within the study area. This included two persons walking in parallel lines about 20 metres apart and traversing the sample site during field surveys carried out between February 2007 and May 2009. Random meanders during the June and November 2011 surveys were carried out by one botanist and meandering over the potential temporary creek crossing sites and Town Creek.
Survey start times and finish times	Between 8 am and 6 pm

Table 2.3: Flora survey details – plot based sampling

Task	Details
Aim: to describe structure and floristics of each plant community, identify EECs and search for inconspicuous flora species	
Targeted subject species	All flora species and communities
Survey technique	Quadrats
Time invested in survey technique	14.25 person hours
Dates of surveys	13 February 2007 to 16 February 2007 19 February 2007 to 23 February 2007 4 November 2008 to 7 November 2008 10 November 2008 to 12 November 2008 18 May 2009 to 22 May 2009
Description of site location	Stratified within each of the different plant communities
Survey point of transect marked on a map	See **Figure 2.2** and Appendix J
Size, orientation and dimensions of quadrat or length of transect for each survey technique	17 quadrats each measuring 20 metre x 20 metre or 30 metre x 10 metre (400 square metres).
Survey start times and finish times	Between 8.30 am and 4.30 pm

2.5 Fauna surveys

The locations of fauna survey sites are shown in **Figure 2.3** (see Appendix J for mapbook at a 1:4000 scale). Targeted surveys were conducted as described below.

2.5.1 Elliott traps

Elliott traps targeting small, ground-dwelling mammals were deployed at four sites (sites 1, 3, 15 and 19). Both small (size A) and large (size B) traps were used. In 2007 traps were placed along transects with Elliot A and Elliot B traps alternating every five metres (thus, the distance between traps of the same size was about 10 metres). In 2008, pairs of Elliott A and Elliott B traps were placed along a transect every 20 metres (site 19) or 30 metres (site 15). Alternate baits (dog food and a mixture of rolled oats, peanut butter, honey and vanilla essence) were used for both trap sizes. Traps were opened before dusk each night for four consecutive nights and checked each following morning.

2.5.2 Cage traps

Cage traps targeting medium-sized ground-dwelling mammals were deployed at six sites (sites 1, 3, 15, 17, 19 and 20). Traps were placed along a transect and were spaced between 20 metres and 50 metres apart. Traps were baited with chicken necks and a mixture of rolled oats, peanut butter, honey and vanilla essence. Traps were opened before dusk each night for four consecutive nights and checked each following morning.

2.5.3 Hair tubes

Hair tubes targeting small to medium-sized ground-dwelling mammals were deployed at site 15. The hair tubes were placed along a transect and were spaced about 30 metres apart. The hair tubes were baited with a mixture of rolled oats, peanut butter, honey and vanilla essence. The hair tubes were collected after seven consecutive nights.

2.5.4 Harp traps

Harp traps targeting microchiropteran bats were deployed at two sites (sites 3 and 15). Traps were set along potential "flyways" for a maximum of two consecutive nights and checked each following morning.

2.5.5 Ultrasonic call recording

Ultrasonic call detectors (ie Anabats) targeting microchiropteran bats were deployed at eight of the forest remnants (sites 3, 15, 17, just north of 17, 19, 20, 28 and 32). Within site 15, an Anabat unit was deployed at three different locations. Ultrasonic call detectors were left recording for one to two nights at each location.

2.5.6 Diurnal bird survey

Diurnal bird surveys were carried out at 22 sites throughout the study area in patches of native vegetation and also at numerous farm dams (**Figure 2.3** and Appendix J). Surveys involved one or two zoologists traversing forest or woodland patches or scanning an area from a fixed point with binoculars. Birds were identified by direct observation or by call.

2.5.7 Spotlighting

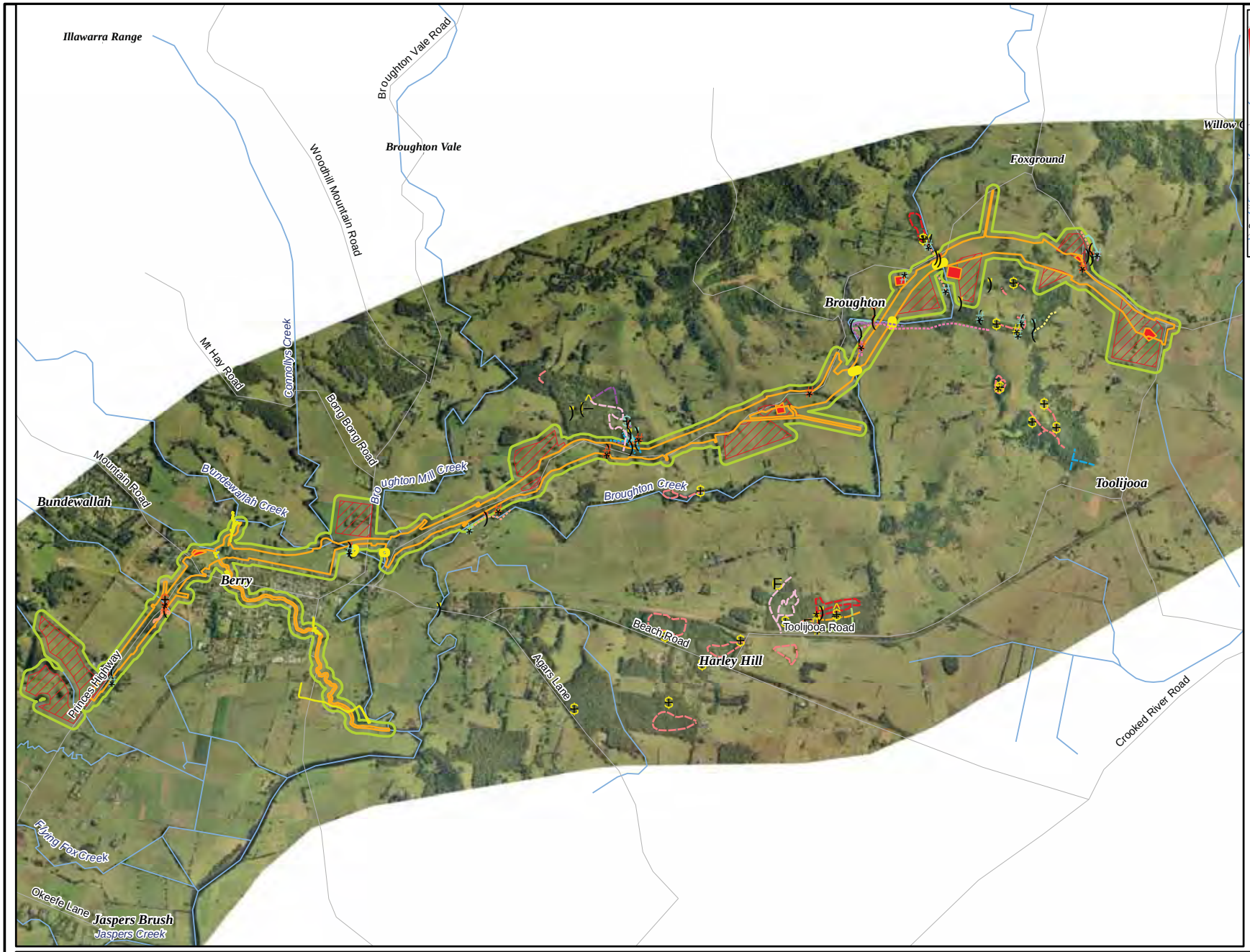
Spotlighting for nocturnal mammals and birds was carried out at six sites (sites 3, 15, 17, 20, 28 and 32) with repeated surveys carried out at three sites (sites 3, 15 and 17). Spotlighting was either undertaken by two zoologists traversing through a site on foot or by driving slowly along tracks and examining the vegetation using a 50-watt spotlight. Spotlighting from a vehicle was also carried out in roadside vegetation along several minor roads and tracks within the study area.

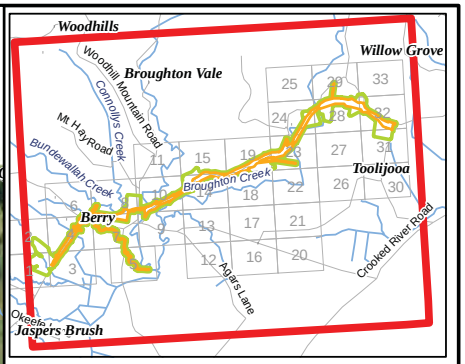
2.5.8 Call playback

Call playback techniques were used to survey for frogs, mammals and/or owls at six sites (sites 3, 15, 17, 20, 28 and 35). Call playback involved repeating recorded calls of target species through a 10 watt TOA megaphone for a period of at least three minutes per call. The playing of each call was followed by a five minute listening period. This process was repeated until each target species' call had been played. Spotlighting (using hand-held 50-watt spotlights) was conducted following the final listening period.

2.5.9 Nocturnal frog survey

In addition to call playback, frogs were surveyed by spotlight searches and aural surveys, which were conducted at night within three to four hours of dusk. Nocturnal frog surveys targeted waterbodies such as creeks, dams and wetlands (sites 17, 32, north of 32 and 35) and were undertaken in spring, summer and autumn (meeting seasonal requirements for target species). Second replicate surveys were conducted at all four sites. Aural surveys involved quietly listening for calling frogs for a period of five minutes at each site. Aural surveys were followed by a spotlight search using hand-held 50-watt spotlights. Spotlight searches were also carried out after rain at numerous dams and creeks adjacent to the Princes Highway, south of Berry and Toolijooa, and Beach Road east of Berry. Call playback for the threatened Green and Golden Bell Frog (*Litoria aurea*) was also undertaken at sites that were considered to provide potential habitat for the species.





Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.3: Location of fauna survey effort

Date:1 August 2012	Drawn by: RS/JMS
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-3_survey_fauna_Overview_010812.mxd	

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0 400 800 1,200 1,600 2,000
Metres

Scale: 1:150,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 2.3

2.5.10 Reptile survey

Habitat for threatened reptile species is not present within the study area and consequently, no systematic searches for reptiles were carried out as part of this study. Reptiles were recorded by opportunistic identification when observed during other surveys or by occasional hand searches under rocks or fallen timber where suitable habitat was present.

2.5.11 Incidental observations

Both indirect and direct evidence of fauna was recorded and used to identify species presence. Direct evidence of fauna species included actual sightings or identification of the species by calls (eg birds, frogs and some nocturnal mammals). Indirect evidence of fauna species included remains (eg skin), scats, diggings or burrows and feeding scars.

Incidental fauna observations were recorded each day over the entire length of the study area.

2.5.12 Fauna habitat assessment

Fauna habitats within the study area were assessed on the presence of one or more of the following features:

- Vegetation cover.
- Size range and abundance of tree hollows.
- Rocky outcrops, overhangs or crevices.
- Abundance of leaf litter and fallen woody debris.
- Freestanding water bodies, ephemeral drainage or seepage areas.
- Disturbances, including weed invasion, clearing, rubbish dumping or fire.
- Potential foraging, nesting or roosting resources.
- Connectivity to off site habitats.
- Surrounding habitat.

The three categories used to evaluate habitat value were Good, Moderate or Poor, as detailed below:

Good: ground flora containing a high number of indigenous species; plant community structure, ground, log and litter layer intact and undisturbed; a high level of breeding, nesting, feeding and roosting resources available; a high richness and diversity of native fauna species.

Moderate: ground flora containing a moderate number of indigenous species; plant community structure, ground log and litter layer moderately intact and undisturbed; a moderate level of breeding, nesting, feeding and roosting resources available; a moderate richness and diversity of native fauna.

Poor: ground flora containing a low number of indigenous species, plant community structure, ground log and litter layer disturbed and modified; a low level of breeding, nesting, feeding and roosting resources available; a low richness and diversity of native fauna species.

Other habitat features, such as the value of the study area as a habitat corridor, the presence of remnant communities or unusual ecological plant community structures were also used to assess habitat quality.

2.6 Fauna survey effort

Fauna surveys were carried out by two zoologists for a total of 22 days from 12 to 21 February 2007 (inclusive), 3 to 11 November 2008 (excluding weekend), and from 18 to 22 May 2009 (inclusive). Fauna habitat surveys (including incidental observations) were carried out by one zoologist over one day on 8 November 2011 within parts of the study area potentially affected by the full diversion of Town Creek. **Table 2.4** and **Table 2.5** show the total survey effort (excluding incidental observations) conducted for the Foxground and Berry bypass project. The locations of fauna survey sites are shown in **Figure 2.3** and **Appendix J**.

Table 2.4: Trapping survey effort

Technique	No. of trap nights
Elliott A traps	360
Elliott B traps	320
Cage traps	176
Hair tubes	175
Harp traps	7
Anabat detectors	21

Table 2.5: Fauna survey effort other than trapping

Survey technique	No. of sites (No. of surveys)	Total transect length in metres	Total person hours
Diurnal bird survey	22 (31)	8317	13.0
Spotlighting (mammals and birds)	6 (13)	8636	15.0
Nocturnal frog survey	4 (7)	1258	7.0
Call playback (owls and mammals)	5 (15)	n/a	9.5
Call playback (frogs)	3 (4)	n/a	0.75
Habitat assessment	34 (34)	n/a	n/a

2.7 Ancillary facility assessment

The locations for ancillary sites were unknown at the time of field survey and therefore have not all been directly surveyed in the field. Consequently, a methodology for assessing the ancillary sites was developed and approved by the RMS. This methodology is based on using agreed criteria as the primary assessment tool to confirm 'no-go' areas and to identify worst case and representative potential impacts on the receiving environment to ensure sufficient flexibility for the future construction contractor.

The criteria for terrestrial ecology were:

- No substantial vegetation clearing (unless required for project alignment) with sites to have low conservation significance for flora and fauna.
- No removal of EEC, unless area is to be cleared for the highway footprint.

No physical disturbance would occur outside the boundaries of the proposed ancillary sites. Further, buffers and temporary fencing would be used if directly adjacent to EECs or areas of medium-high conservation significance to protect 'no-go' areas (in accordance with the RMS 'Biodiversity Guidelines: Guide 2 – Exclusion Zones' (RTA 2011)).

Low conservation significance is defined as:

- An area with no EEC and no native vegetation (although disturbed, poor quality native vegetation may be considered to have low conservation significance in some situations).
- No threatened (or migratory) flora or fauna records/occurrences.
- No (or very poor quality) potential habitat for threatened (or migratory) species.
- No water source.

Generally, within the study area, areas of low conservation significance are considered to be built-up areas, mown lawns and heavily grazed (ie short grass) exotic pastures (with no shrub layer, no trees, no rocks, no logs, no water).

Medium-high conservation significance is defined as:

- An area with native vegetation which may be EEC or not.
- Threatened (or migratory) flora or fauna records/occurrences.
- Moderate to good potential habitat for threatened (or migratory) species including intact soil profile, intact structural layers, mature fruiting trees, hollow-bearing trees and fallen woody debris.
- Water source.

2.8 Threatened and migratory species likelihood of occurrence criteria

The likelihood of occurrence assessment for threatened flora and fauna and migratory species was based on previous records collated from database searches, data collected during the field survey, the current (known) distribution range of these species, and the presence and condition of suitable habitat in the locality. The criteria to assess the likelihood of threatened flora and fauna or migratory fauna species to occur within the locality is presented in **Table 2.6**.

Table 2.6: Criteria used to assess likelihood of occurrence

Likelihood of occurrence	Assessment criteria
Low	Species considered to have a low likelihood of occurrence include species not recorded in the field surveys that fit one or more of the following criteria: • Have not been recorded previously in the study area or locality and the study area is beyond the known distribution or range. • Are dependent on a narrow range or specific habitats that do not or are not likely to occur in the study area. • Are considered locally extinct. • Are a non-cryptic perennial flora species that were targeted during field surveys. • Are flora species that have a very limited range and highly specific dispersal mechanisms.
Moderate	Species considered to have a moderate likelihood of occurrence include species not recorded in the field surveys that fit one or more of the following criteria: • There are infrequent records for the species in the study area and locality. • Preferential habitats of the species are present in the study area but these are mainly in a poor or modified condition. • May use or occur in habitats within the study area opportunistically during seasonal migration but are unlikely to be present on permanent basis as a populations or vagrant individuals. • Are cryptic flowering flora species that were not seasonally targeted during surveys.
High	Species considered to have a high likelihood of occurrence include species recorded during the field surveys or species not recorded that fit one or more of the following criteria: • Have a high incidence of previous records in the study area and locality. • Preferentially use habitats that are present in the study area which are abundant and/or in good condition. • Resident populations are known in the study area or locality. • Are known to regularly use habitats of the site or locality or are highly likely to visit the site during seasonal dispersal or migration.

2.9 Taxonomy

The flora taxonomy (classification) used in this report follows the most recent *Flora of New South Wales* (Harden 1990, Harden 1991, Harden 1992, Harden 1993, Harden 2002). All doubtful species names were verified with the on-line Australian Plant Name Index (Australian National Botanic Gardens 2007). In the text of this report, flora species are generally referred to by their scientific names only. However, threatened species and introduced flora species are referred to by both their common and scientific names when first mentioned. Flora common names where available have been included in threatened species tables and the complete flora list in Appendix A.

Names of vertebrates follow the 'Census of Australian Vertebrates' maintained by the Commonwealth DSEWPaC (DEWHA 2009a). In the body of this report vertebrates are referred to by both their common and scientific names when first mentioned. Subsequent references to these species cite the common name only. Common and scientific names are included in the Appendix B.

2.10 Limitations

Some flora species that occur in the local area are annuals (completing their life cycle within a single season) and are present only in the seed bank for much of the year. While seasonal surveys were undertaken, some species do not appear or flower consistently each season or from one year to the next. Other flora species are perennial, but are inconspicuous unless flowering or in fruit. Furthermore, some fauna species are only detectable at certain times of the year. Therefore, despite seasonal surveys it is likely that some species that are present in the study area were not detected. Despite these limitations, the assessment of impact is based on the presence or absence of suitable habitat for threatened flora and fauna, and as such, species are taken into account during the assessment even though they may not have been detected during the survey.

This assessment has relied on the regional vegetation survey and mapping project *Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands* and as such the limitations of the surveys and mapping by Tozer *et al* (2010) and (DEC 2005o) apply to some extent to this survey and assessment.

This assessment has relied on threatened species data provided for the project by the OEH and publicly available data from the DSEWPaC. The limitations of the collection, processing, management and distribution of the data sourced from these parties are relevant to the current assessment.

Other limitations to the field investigations include site access. Whilst the majority of land owners able to be contacted assisted the field investigations and the study was able to apply recognised sampling techniques to most of the habitat types present within the study area, surveys of some sites were limited by various constraints. These included limitations imposed by land owners on survey techniques or survey times and duration or, in some cases, a refusal of access. Furthermore, a small number of sites were inaccessible as they presented a significant occupational health and safety risk due to steep and unstable terrain.

Based on an assessment of aerial photography and road side reconnaissance, areas subject to access constraints were determined to be of low conservation significance and therefore, access limitation to some parts of the current study area was not a major limitation.

In addition, the proposed locations for construction compounds, site offices and stockpile areas became available after the targeted field surveys were conducted and as a result, not all of these areas have been investigated in the field. However these sites have been assessed according to the RMS assessment methodology for ancillary facilities (see Section 2.7).

Deviations from recommended fauna survey guidelines and/or effort include:

- Targeted frog survey effort did not entirely meet the Department of Environment and Climate Change (DECC) 'Threatened species survey and assessment guidelines: field survey methods for fauna – Amphibians' (DECC, 2009) as these guidelines were issued in April 2009, after the February 2007 and November 2008 surveys were completed. Whilst another field trip was undertaken in May 2009, after the frog guidelines were released, this was outside the seasonal requirements of the target frogs. The Department of the Environment, Water, Heritage and the Arts (DEWHA) 'Survey guidelines for Australia's threatened frogs' (DEWHA, 2010b) was also released after field surveys were completed. However, the survey effort employed during field surveys was consistent with the survey effort recommended for the target frog species in these guidelines.
- Mapping of den sites and feed trees for the Yellow-bellied Glider was not undertaken (although general habitat assessments took note of the presence of such features). Also, mapping the location and size of the areas occupied by Yellow-bellied Glider family groups in the locality was not undertaken. Such a task would be an enormous undertaking and was considered unnecessary for assessing the potential impacts on this species for the current project.
- Cage trapping for Spotted-tailed Quoll was undertaken in May but not March as well. March surveys were considered unnecessary as this species was considered to occur within the study area despite not being recorded during targeted surveys. Mitigation measures specifically targeting the Spotted-tailed Quoll have been included.
- Pit-fall trapping was not undertaken for the Eastern Pygmy-possum or White-footed Dunnart. Ground Elliott trapping and hair tube surveys were undertaken.
- Stag-watching and a detailed hollow-bearing tree survey would be undertaken post-approval to assess the number and type of nest boxes required for the project.
- Habitat-based surveys were undertaken within the Town Creek part of the study area; no targeted surveys such as trapping or spotlighting were carried out.

Systematic flora surveys using evenly spaced transects was not undertaken. Surveys were conducted in accordance with the *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities* (DEC 2004) using random meander techniques and ground-truthing of the plant communities mapped by DECCW (DEC 2005) using plot-based surveys.

In relation to the amount of field survey effort and its timing, a reasonable sample of the spectrum of flora and fauna, their habitats and assessment of the ecological processes that are likely to occur in the locality have been made. The desktop and field survey effort and methods have compiled adequate information to provide a reliable assessment of the presence or absence of threatened species, populations and ecological communities or their habitats that potentially occur in the locality.

3 Results

A list of the flora and fauna recorded during surveys within the Foxground and Berry bypass project study area are provided in Appendix A and Appendix B respectively.

3.1 Geology and soils

The study area encompasses the foothills of the escarpment slopes around Berry and the floodplains associated with Broughton Creek and Shoalhaven River. In more detail the study area consists of the following two main topographic groups:

- The undulating hills and foothills extending north-west from the South Coast Railway Line.
- The Shoalhaven lowland plain, extending south-east of the foothills towards the Shoalhaven Bight.

The elevated north-western portion of the project area is influenced by the Cambewarra Mountain Range (north-west of Berry) which is a narrow low range that runs roughly parallel with the coastline. The lower slopes of this range extend into the project area as the ridge lines approach Berry. Harley Hill and Toolijooa Ridge are situated towards the eastern part of the project area and are disjointed from the Cambewarra Range.

A ridge of moderate elevation, from Foxground to Toolijooa Ridge, and a flatter ridge to the south-west of Toolijooa Ridge, separate the Broughton Creek floodplain from the Crooked River floodplain.

The geology of the study area corresponds to the Permian Shoalhaven Group, which may be divided into the Volcanic Sandstones sub-group (also referred to as the Budgong Sandstone), the Volcanics Facies sub-group and Berry Siltstone formation sub-group.

The *Soil Landscapes of the Kiama 1:100,000 Sheet* (Hazelton, 1992) identifies the presence of the following soil landscape units within the study area:

- Kiama landscape unit, occurring in areas close to Toolijooa Road. The Kiama landscape unit is characterised by sandy clay loams and stiff to hard clays.
- Wattamalla Road landscape unit, occurring in steeper areas around Toolijooa Ridge. The Wattamalla Road landscape unit is characterised by shallow soils consisting of sandy and silt loams, very stiff to hard clays and extremely weathered rock developed in units associated with the underlying rock materials.
- Shoalhaven landscape unit, which corresponds to creeks and floodplain areas at Broughton Creek and Berry. This landscape unit consists of alluvial soils, comprised of gravel, sand, silt and clay derived mainly from sandstone and shale and overlying buried estuarine sediments. The erosion hazard is rated as slight to low.
- Coolongatta landscape unit, which largely corresponds to the undulating hills between Austral Park Road and north of Berry. Coolongatta landscape unit consists of sands, and stiff to hard clays.

In summary soil types of the study area typically support tall open forests and closed forests, most of which have been cleared to make way for agricultural land use.

3.2 Plant communities

3.2.1 Vegetation mapping

The following section provides descriptions of each plant community recorded within the study area as well as a discussion of their conservation status, location and extent. Existing vegetation mapping (DEC 2005o) provided the background and assisted with the planning of field sampling and subsequent analysis; however, occasional inconsistencies with the DEC maps arose in the type and extent of vegetation within the study area. Plant communities as mapped by DEC (2005o) have been amended following ground-truthing during the surveys. All amendments to the DEC mapping are identified within the text in Section 3.2.2 and illustrated in **Figure 3.1** (see Appendix J for mapbook at a 1:4000 scale).

A description of the condition of plant communities and fauna habitats present within the study area is provided in Section 3.3.

3.2.2 Identification of plant communities

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation and have not been mapped or described as a native plant community. Native plant communities that do occur within the study area have been named in accordance with the plant community descriptions provided by DEC (2005o) as part of the NSW native vegetation mapping program. Plant communities conforming to listed EECs were sampled, identified according to their floristic composition and compared to the DEC profiles and relevant scientific committee determinations. The area of each native plant community occurring within the subject site, study area and locality is shown in **Table 3.1**.

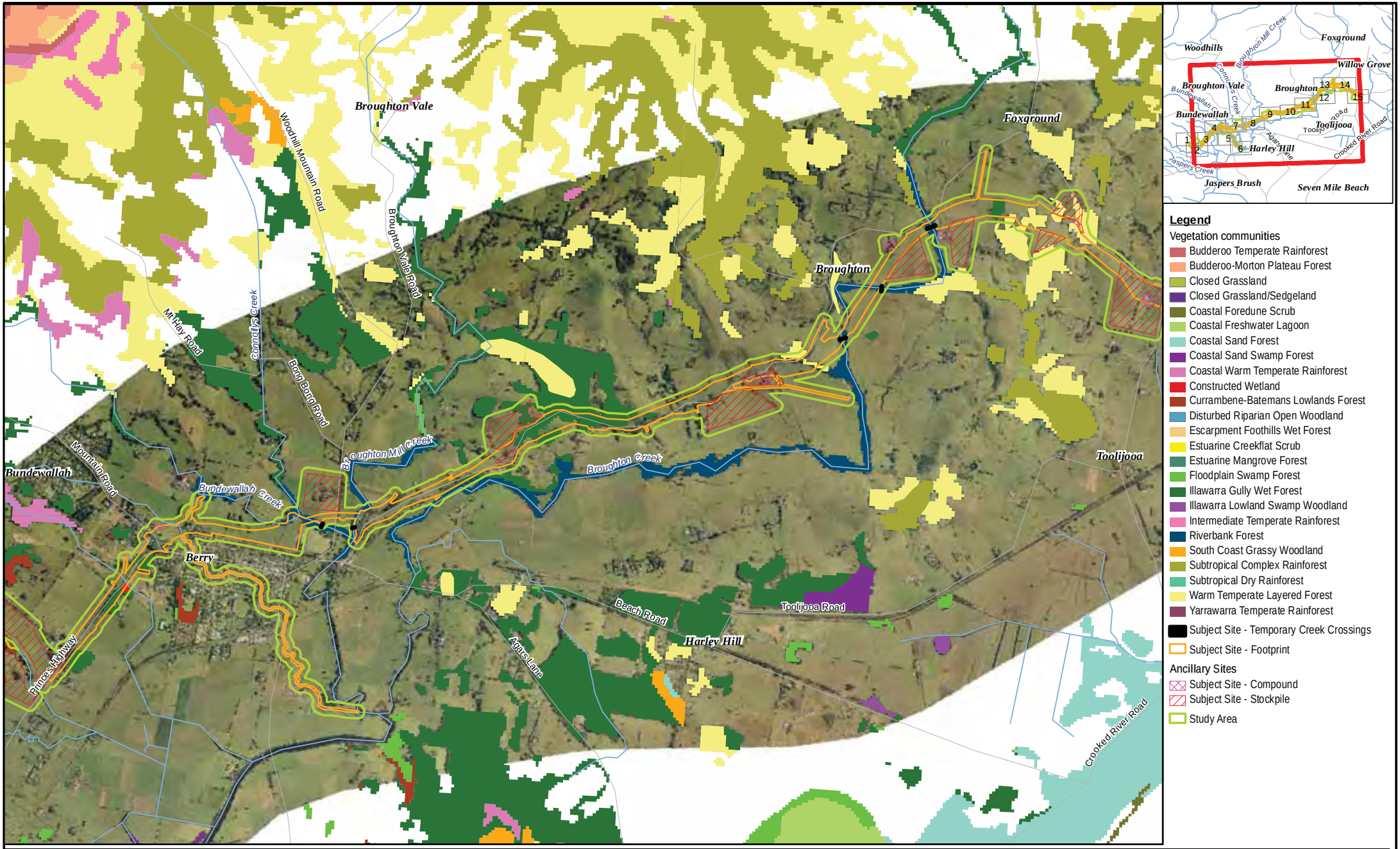
Twenty-five separate plant communities have been mapped as occurring within the locality (five kilometre radius of the study area) (**Figure 3.1** and **Table 3.1**. Twelve of these plant communities are likely to form part of an EEC as listed on the TSC Act (**Table 3.1**).

Eight mapped plant communities occur within the study area including Illawarra gully wet forest, Currambene-Batemans lowlands forest, Riverbank forest, warm temperate layered forest, constructed wetland, closed grassland, closed grassland/sedgeland and riparian open woodland. Another community, subtropical complex rainforest, was mapped about 0.25 kilometres from the study area and occurs in association with warm temperate layered forest. A brief description of vegetation occurring within the study area and adjoining areas is provided below.

Illawarra gully wet forest

Illawarra gully wet forest is a tall eucalypt forest with a moist open understorey. This community is scattered along coastal lowlands south from the Hacking River catchment, including areas near Berry, Nowra and Batemans Bay (DEC 2005o). Illawarra gully wet forest occurs on sheltered slopes and gullies with loamy soils. In areas of increased fertility and soil moisture the community grades into warm temperate layered forest. More than a third of its original range has been cleared, mainly in the Illawarra lowlands.

A total of 25.5 hectares of this community was mapped within the study area (**Table 3.1**). The most significant stand occurs to the north-east of Berry adjacent to Tindalls Lane and the Princes Highway (site 15) (**Figure 2.1**, **Figure 3.1** and Appendix J). Small stands were recorded within the study area immediately south-west of Berry, adjacent to the Princes Highway. Large remnants of Illawarra gully wet forest were surveyed within the locality and include remnants adjacent to Agars Lane and Beach Road (sites 6, 7, 9 and 25).



Biosis Research Pty. Ltd.
18-20 Mandible Street
Alexandria
NEW SOUTH WALES
2015

Figure 3.1: Vegetation mapping of the study area (modified from DECCW, 2005)

Date: 16 July 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_Overview_160712.mxd	

Acknowledgements:
Vegetation mapping from DECCW
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 430 860 1,290 1,720
Metres

Scale: 1:250,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 3.1

Flora species identified during the field survey were consistent with the diagnostic flora species described for this community (DEC 2005o). Dominant species included a canopy of *Eucalyptus pilularis*, *E. paniculata, E. saligna* X *botryoides* and *Syncarpia glomulifera* with an understorey of *Acacia binervata*, *Pittosporum undulatum, Breynia oblongifolia*, *Persoonia linearis* and a ground layer including *Tylophora barbata*, *Pteridium esculentum*, *Carex longebrachiata* and *Poa labillardieri*.

Currambene-Batemans lowlands forest

Currambene-Batemans lowlands forest is a eucalypt forest with an open shrub layer and a dense grassy groundcover, found on coastal lowlands on sandstones and shales below 100 metres above sea level (ASL). Its distribution is primarily between Bomaderry and Cudmirrah, with the largest stands around Currambene State Forest between Nowra and Culburra. Small woodlots and remnant trees suggest the distribution may have extended northward along the extensively cleared footslopes between Bomaderry and Berry and on the lower slopes of Kangaroo Valley. There are isolated records to the south, from Tabourie and Termeil Lakes, Batemans Bay and Mogo areas (DEC 2005o).

There are several stands of the community mapped in the locality on the south western outskirts of Berry township (**Figure 3.1** and Appendix J). This includes a total of 2.4 hectares within the study area, of which 0.0002 hectares occurs within the subject site (**Table 3.1**). No field surveys were carried out in areas mapped as Currambene-Batemans lowlands forest of the study area for the current assessments (see limitations section 2.10).

Riverbank forest

Riverbank forest is a tall *Casuarina cunninghamiana* forest with an open shrub layer and dense to patchy groundcover of grass species. This community is found on sand and gravel alluvium often with cobbles. The community has a wide distribution and occurs along major creeks and rivers including the Coxs, Abercrombie, Wollondilly, Shoalhaven and Deua Rivers (DEC 2005o). During the current surveys of the study area, this community was identified along the riparian corridors of freshwater creeks including Broughton Creek (sites 17, 28 and 29) and Bundewallah Creek (**Figure 2.1** and Appendix J).

DEC (2005t) did not map Riverbank forest within the study area and mapped this community as floodplain swamp forest, part of the EEC *swamp oak floodplain forest of the NSW North Coast, Sydney Basin and South East Corner bioregions*. Floodplain swamp forest occurs in areas with brackish groundwater and is dominated by *Casuarina glauca*. Vegetation mapping by Shoalhaven City Council (Shoalhaven City Council, 2004) and discussions with one of the authors of the DEC (2005t) vegetation mapping (M. Tozer, pers. comm. 2007) support the interpretation of the area as maintaining Riverbank forest.

A total of 10 hectares (**Table 3.1**) of this community is mapped within the study area (**Figure 3.1** and Appendix J). Native flora species identified during the field survey were consistent with the diagnostic flora species described for Riverbank forest (DEC 2005o). Dominant flora species include a largely monospecific canopy of *Casuarina cunninghamiana* within understorey species including *Hymenanthera dentata* and ground layer of *Sigesbeckia orientalis*, *Lomandra longifolia*, *Microlaena stipoides*, *Dichondra repens* and *Commelina cyanea*. This community is frequently highly disturbed and weed species are often dominant in the understorey.

Despite difficulties categorising this community due to the highly altered species composition and structure, it is considered that Riverbank forest within the study area is consistent with the EEC *River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions*.

Warm temperate layered forest

Warm temperate layered forest is a tall eucalypt forest characterised by an open emergent canopy and dense small tree layer with a moist shrubby understorey (DEC 2005o). The distribution ranges from the Hacking River along the Illawarra escarpment to Nowra and within Kangaroo Valley. A total of 12.2 hectares of this community was mapped within the study area (**Table 3.1**), where it occurs on sheltered slopes, low ridges (including Toolijooa Ridge) and gullies scattered between Berry and Toolijooa Road (sites 8, 16, 17, 20 and 21) (**Figure 2.1** and Appendix J). Significant stands of the community have been mapped by DEC (2005o) within the locality between Broughton Vale and Gerringong (**Figure 3.1** and Appendix J).

This community occurs in association with the EEC subtropical complex rainforest (as described below) and intergrades between the two communities are likely to be present within the locality. Each of these intergrading communities contain a similar suite of rainforest species (DEC 2005o). Areas where eucalypt species were the dominant canopy have been attributed to warm temperate layered forest following ground surveys.

Flora species identified during the field survey were consistent with the diagnostic flora species described for this community (DEC 2005o). Dominant species included a canopy of *Eucalyptus botryoides* X *saligna*, *E. quadrangulata* with a mid storey tree layer co-dominated by *Acmena smithii*, *Cryptocarya glaucescens*, *Pittosporum undulatum* and *Livistona australis*, and a shrub layer of *Notelaea venosa*, *Clerodendrum tomentosum*, *Eupomatia laurina* with climbers and ground cover species including *Adiantum formosum, Pandorea pandorana*, *Eustrephus latifolius*, *Tylophora barbata*, *Stephania japonica*, *Doodia aspera*, *Oplismenus imbecilis, Pseuderanthemum variable*, *Gymnostachys anceps* and *Blechnum cartilagineum*.

Subtropical complex rainforest

This community is characterised as a closed forest with a dense and diverse tree canopy supporting a variety of lianas, a sub-canopy layer of small trees, a sparse shrub layer and ground layer dominated by ferns (DEC 2005o). Subtropical complex rainforest is distributed between Scarborough and Cambewarra with an outlying patch to the south at Milton. The community is restricted to volcanic soils on slopes and benches of the Illawarra escarpment. Subtropical complex rainforest is included within the *Illawarra subtropical rainforest in the Sydney Basin bioregion*, an EEC listed under the TSC Act.

This community does not occur within the study area, but was identified in surveys of the locality as part of the route options assessment and is largely restricted to a band of scattered fragments along and near Toolijooa Ridge (sites 1, 2, 17, 18, 23) (**Figure 2.1** and Appendix J). DEC (2005s) has also mapped a significant stand of subtropical complex rainforest at Barren Grounds Nature Reserve within the locality to the north of Berry (**Figure 3.1** and Appendix J). Further isolated fragments have been mapped in the locality between Foxground Road and Gerringong.

Flora species identified during the field survey were consistent with the diagnostic flora species described for this community (DEC 2005q). Dominant species included a canopy of *Doryphora sassafras*, *Dendrocnide excelsa*, *Ficus* spp., *Alectryon subcinereus* and *Toona ciliata*, a small tree layer of *Cassine australis*, *Eupomatia laurina*, *Acronychia oblongifolia*, shrub layer of *Pittosporum multiflorum* with climbers and ground covers including *Arthropteris tenella*, *Piper novae-hollandiae, Marsdenia rostrata*, *Pandorea pandorana*, *Gymnostachys anceps* and *Doodia aspera*.

Constructed wetland

A constructed wetland is mapped at the western end of the project and near the southern end of Town Creek (**Figure 3.1** and Appendix J). Aquatic and semi-aquatic vegetation has established following the construction of the western waterbody and following the construction of the access track causeway of the Berry sewage treatment works, adjacent to Town Creek. Constructed wetland habitats cover 0.7 hectares within the study area (**Table 3.1**). At the time of survey the constructed wetland in the west was dominated by *Typha orientialis* with groundcovers of the banks dominated by pasture grasses such as *Pennisetum clandestinum* and *Paspalum dilatatum*. A stand of regenerating shrubs and trees consisting of *Acacia* and *Eucalyptus* species occurs on the southern margin. The constructed wetland near the southern end of Town Creek is characterised by patches of *Typha orientialis* and sparse cover of other emergent macrophytes. The banks are dominated by pasture grasses such as *Pennisetum clandestinum* and *Paspalum dilatatum* and patches of *Persicaria strigosa*. Exotic trees and shrubs around the banks include *Erythrina crista-galli*, *Lantana camara*, *Ligustrum sinense* and *Solanum mauritianum*.

Closed grassland/closed sedgeland

Closed grassland, closed sedgeland and intergrades of these communities dominate the channel of Town Creek on the northern and southern margins of Berry township (**Figure 3.1** and Appendix J). The closed grassland between Town Creek north to Bundewallah Creek over the alignment of the proposed constructed channel covers 0.9 hectares (**Table 3.1**) and is dominated by *Pennisetum clandestinum*, other introduced pasture species such as *Trifolium repens* and *Paspalum dilatatum* and colonising weeds including *Cirsium vulgare* and *Rumex crispus*. Native herbs and rushes include scattered occurrences of *Ludwigia peploides* ssp *montevidensis* and *Persicaria strigosa*.

Intergrades of the closed grassland and closed sedgeland are present in Town Creek between North and George Streets and from the South Coast Rail Line to the confluence with Broughton Mill Creek adjacent to the Berry sewage treatment works (**Figure 3.1** and Appendix J). These intergrades cover a total area of 2.5 hectares (**Table 3.1**). Structure and floristic composition are similar to that described above for the closed grassland with *Cyperus eragrostis*, *Pennisetum clandestinum* and *Trifolium repens* dominating the suite of exotic species and native *Persicaria* spp and patches of *Typha orientalis* common in the lower channel terraces. The closed grassland and closed sedgeland plant communities represent an unnatural landscape and have established as a result of the substantial clearing of native vegetation and a long history of agriculture.

Riparian open woodland

A disturbed riparian open woodland occurs along Town Creek through the Berry urban area (**Figure 3.1** and Appendix J), covering 3.8 hectares (**Table 3.1**). This plant community is characterised by areas of revegetation, regrowth native vegetation, planted exotic trees with invasive woody weeds and areas of managed open space in public and private land tenure. The canopy consists of local and non-locally occurring native trees and exotic tree species occurring mainly as landscape plantings. Common native and exotic trees include *Araucaria heterophylla*, *Casuarina cunninghamiana* ssp *cunninghamiana*, *Cinnamomum camphora*, *Eucalyptus robusta*, *Grevillea robusta* and *Syncarpia glomulifera* ssp *glomulifera*. Other native and introduced trees present as a sparse midstorey/understorey are *Callistemon viminalis*, *Jacaranda mimosifolia*, *Melaleuca quinquenervia*, *Salix babylonica* and *Tristaniopsis laurina*. The groundcover and aquatic/semi-aquatic vegetation is dominated by exotic herbs and grasses with native species present as minor occurrences or plantings in revegetation areas. Common exotic species are *Anagallis arvensis*, *Bromus catharticus*, *Cyperus eragrostis*, *Myriophyllum* sp, *Rumex crispus* and *Tradescantia fluminensis*. Common native species recorded include *Commelina cyanea*, *Lomandra longifolia*, *Ludwigia peploides* ssp *montevidensis* and *Persicaria strigosa*.

Other areas of the riparian open woodland on the northern and southern sections of Town Creek are primarily stands of exotic shrubs and trees such as, *Erythrina sykesii*, *Ligustrum sinense* and *Salix babylonica* with the groundcovers dominated by introduced pasture species.

The riparian open woodland is a derived plant community that has been subject to clearing of native vegetation, management of urban stormwater and weed invasion. This is an unnatural landscape with resilience in a depleted state.

Cleared land and paddocks

Cleared paddocks dominate the foothills, slopes and floodplains throughout the study area. The majority of the cleared land and paddock areas are considered an unnatural landscape, with limited or no capacity for regeneration to a native plant community.

The cleared land and paddocks are typically comprised of grasslands dominated by exotic pasture species, including Prairie Grass *(Bromus catharticus),* Yorkshire Fog *(Holcus lanatus),* Kikuyu Grass *(Pennisetum clandestinum)*, Panic Veldtgrass *(Ehrharta erecta)* and Paspalum and Vasey Grass *(Paspalum* spp). Introduced annual and perennial herbs and shrubs are also a typical feature of this community, including Curled Dock *(Rumex crispus),* Paddy's Lucerne *(Sida rhombifolia),* Mistflower *(Ageratina riparia),* Fireweed *(Senecio madagascariensis),* Lamb's Tingues *(Plantago lanceolata)* and White clover *(Trifolium repens)*. Large patches of woody weeds including Lantana *(Lantana camara)* and Weeping Willow *(Salix babylonica)* are present along the cleared and disturbed drainage lines and at the interface of bushland remnants.

Scattered trees occur in varying densities across the landscape and include a range of remnant native trees and exotic plantings. Some of the older trees are likely to provide habitat (such as tree hollows or perch sites) for native fauna and, as such, are an important feature within an otherwise denuded landscape.

Native plant communities of the subject site, study area and locality are detailed in **Table 3.1.**

Table 3.1: Native and derived plant communities of the subject site, study area and locality

Plant community (DEC 2005o)	Conservation status		Equivalent EEC	Area within subject site (hectare)	Area within study area, excluding subject site (hectare)	Area within locality (hectare)
	TSC Act	EPBC Act				
Budderoo temperate rainforest	-	-	-	-	-	17.9
Budderoo-Morton plateau forest	-	-	-	-	-	26.4
Closed grassland*	-	-	-	0.4	0.5	1.0
Closed grassland/sedgeland	-	-	-	2.2	0.3	2.5
Coastal foredune scrub	-	-	-	-	-	8.5
Coastal freshwater lagoon	V	-	Freshwater wetlands on coastal floodplains of the NSW North Coast, Sydney Basin and south-east corner bioregions	-	-	124.4
Coastal sand forest	V	-	Bangalay sand forest, Sydney Basin and south-east corner bioregions	-	-	419.1
Coastal sand swamp forest	V	-	Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and south-east corner bioregions	-	-	17.1
Coastal warm temperate rainforest	V	-		-	-	87.3
Constructed wetland	-	-	-	0.4	0.3	0.7
Currambene-Batemans lowlands forest	-	-	-	0.0002	2.4	27.7
Disturbed riparian open woodland	-	-	-	2.6	1.2	3.8
Escarpment foothills wet forest	-	-	-	-	-	42.6
Estuarine creekflat scrub	V	-	Swamp oak floodplain forest of the NSW North Coast, Sydney Basin and south-east corner bioregions	-	-	0.2
Estuarine mangrove forest	-	-	-	-	-	1.1
Floodplain swamp forest	V	-	Swamp oak floodplain forest of the NSW North Coast,	-	-	47.7

Plant community (DEC 2005o)	Conservation status		Equivalent EEC	Area within subject site (hectare)	Area within study area, excluding subject site (hectare)	Area within locality (hectare)
	TSC Act	EPBC Act				
			Sydney Basin and south-east corner bioregions			
Illawarra gully wet forest	-	-	-	15.4	10.05	583.6
Illawarra lowland swamp woodland	V	-	Illawarra lowlands grassy woodland in the Sydney Basin bioregion	-	-	9.7
Intermediate temperate rainforest	-	-	-	-	-	62.7
Riverbank forest	V	-	River-flat eucalypt forest of the NSW North Coast, Sydney Basin and south-east corner bioregions	2.9	7.1	65.7
South coast grassy woodland	V	-	Illawarra lowlands grassy woodland in the Sydney Basin bioregion	-	-	37.9
Subtropical complex rainforest	V	-	Illawarra subtropical rainforest in the Sydney Basin bioregion	-	-	914.0
Subtropical dry rainforest	V	-	Illawarra subtropical rainforest in the Sydney Basin bioregion	-	-	0.5
Warm temperate layered forest	-	-	-	6.9	5.3	1278.7
Yarrawarra temperate rainforest	V	-	Robertson rainforest in the Sydney Basin bioregion	-	-	24.5
Totals (hectare)				**30.8**	**27.2**	**3805.3**

** Not considered to be a native plant or derived native plant community.*

3.3 Flora and fauna habitats

The following section provides a description of the condition of flora and fauna habitats within the study area (reference to survey sites outside the study area have been made where they provide important contextual information, such as being part of a potential local wildlife corridor). The following habitat descriptions are largely unchanged from those in the preliminary biological report (Biosis Research 2007). Updates to the descriptions provided in the Biosis Research (2007) report include specific reference to sites that are subject to potential impacts (those within the study area), additional information based on seasonal survey effort conducted since the 2007 surveys, and additional information based on the November 2011 surveys of Town Creek.

3.3.1 Toolijooa Ridge and Harley Hill (sites 1-4, 6-7, 9, 17-21, 23 and 25-26)

Native vegetation along Toolijooa Ridge (sites 1-2, 17-21, 23 and 26) and Harley Hill (sites 3-4, 6-7, 9 and 25) is now confined to about 12 discontinuous patches of remnant and regrowth vegetation from the uppermost hilltops and steep rocky and inaccessible slopes (Toolijooa Ridge) down to the plateau (Harley Hill). Vegetation communities along Toolijooa Ridge include subtropical complex rainforest which grades into warm temperate layered forest further down slope and along edges. Isolated stands of Illawarra gully wet forest are also present, sometimes represented by scattered remnant trees only. The dominant vegetation community at Harley Hill includes Illawarra gully wet forest. Ongoing disturbances such as grazing and a high degree of weed invasion continue to threaten the integrity of flora and fauna habitats at each of these sites.

Study area

Native vegetation at site 20 (**Figure 2.1** and Appendix J) would be impacted by the project. Vegetation at site 20 is represented by disturbed stands of warm temperate layered forest. The condition of vegetation at site 20 was considered to be in poor condition along edges where large infestations of the noxious weed Lantana *(Lantana camara)* are present and have displaced most native species. These edges are likely to have little or no capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation. Patches of Lantana *(L. camara)* were also dispersed within the native remnants, especially where disturbances have created gaps in the remnant canopy. Isolated small pockets of warm temperate layered forest at site 20 were considered to be in moderate condition and included a dense native canopy which excluded Lantana invasion.

Some large hollow-bearing trees were present and provide potential nesting and roosting resources for birds, arboreal mammals and microchiropteran bats.

Down slope to the east of site 20, native vegetation is represented by a sparse stand of mature *Eucalyptus pilularis* with a heavily grazed and cleared understorey. Prior to clearing and grazing, this area was probably represented by Illawarra wet gully forest and is now in poor condition.

Adjoining areas

Vegetation condition outside the study area across Toolijooa Ridge (sites 1, 18, 19, 21 and 26) is highly variable and ranges from very poor in the cleared exotic pasture to good in areas of highly diverse native vegetation. As with site 20, the condition of vegetation at each site was considered in poor condition along edges and in canopy gaps where large infestations of *L. camara* are present and have displaced most native species. These edges were considered to have little or no capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation.

The core areas of remnant vegetation at sites 1, 17 and 18 contained subtropical complex rainforest, often in good condition. Although evidence of previous disturbances such as logging was evident, the dense canopy layers have helped reduce the dispersal of weeds within each remnant. Subtropical complex rainforest present at each site varied in its structure and diversity. The core of the remnant patch at site 23, although relatively small, was considered to be in good condition with all structural layers intact and a high diversity of native species present. A large proportion of site 1, the largest remnant of this community surveyed in the study area covering about 20 hectares, is also in good condition.

The condition of fauna habitats at each of these sites was also highly variable from poor to good condition. Although many sites were in poor condition, a variety of feeding and sheltering resources were observed. A large proportion of surface rock and outcropping is present at each of these sites, particularly under the sheltered rainforest canopy at site 1. Such rock outcrops are likely to provide shelter for a variety of native mammals including the Bush Rat (*Rattus fuscipes)* and Brown Antechinus (*Antechinus stuartii)*. Hollow-bearing trees were scarce, but were present and may provide nesting and roosting habitat for various birds, bats and small mammals. Flora species within the warm temperate layered forest and subtropical complex rainforest remnants are also likely to provide feeding resources. Myrtaceaeous trees (mostly *Eucalyptus* species) within the warm temperate layer forest canopy, provide direct (foliage, nectar, exudates) and indirect (arthropods) food for a range of vertebrates, particularly birds and arboreal mammals. Flowering and fruiting trees such as Figs *(Ficus* spp.) and Cabbage Palm *(Livistona australis)* are common at each site and are likely to provide important feeding resources for a range of insects and nectivorous and frugivorous vertebrates.

3.3.2 Broughton Creek (sites 17, 28-29, and 32-33)

Native vegetation along Broughton Creek is now largely restricted to a thin riparian corridor with patches of remnant and regrowth. Ongoing disturbances such as grazing, erosion and a high degree of weed invasion have had a major impact on habitat condition at each of these sites.

Study area

The project crosses Broughton Creek at sites 17, 28 and 32 and is located upslope in the study area of site 33. Vegetation alongside Broughton Creek at each of these four sites is represented by Riverbank forest in poor condition. Each site has a tall native canopy of *Casuarina cunninghamiana* and an understorey completely dominated by a high density weed infestation. Natural structural layers are no longer intact and in most areas the mid storey and ground layers are completely dominated by weed species including *Ligustrum sinense, Lantana camara, Solanum mauritianum, Ageratina riparia* and *Tradescantia fluminescens*.

These weed-infested areas were considered to have little capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation. Obvious disturbances at each of these sites include heavy grazing and erosion.

Vegetation located on the steep slopes along the existing Princes Highway at site 33 ranges from warm temperate layered forest in protected areas lower down the steep slope, up to Illawarra gully wet forest at the top along the roadside edge. Warm temperate layered forest along the lower stopes is dominated by an extensive infestation of *Ligustrum lucidum* and other woody weed species. Illawarra gully wet forest along the roadside edge was in a moderate to good condition with most natural structural layers of vegetation remaining intact and scattered areas of weed infestation. At least six large hollow-bearing *Casuarina cunninghamiana* (site 17 and 32) and six large hollow-bearing *Eucalyptus pilularis* (site 33) are located within the study area.

Adjoining areas

Adjoining vegetation to the north of the study area at site 28 is similarly impacted by weed infestations in addition to some areas where grazing and trampling by stock has left the creek bank bare and eroded. Vegetation upslope and to the western side of site 28 was identified as the EEC subtropical complex rainforest and warm temperate layered forest. These remnants were also in poor condition and subject to disturbances and a high degree of weed infestation. As with the adjacent riparian vegetation, these areas have little capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation.

Adjoining vegetation to the east of the study area at site 17 is in moderate condition and, despite competition from weeds, the natural layers of vegetation appear relatively intact. A suite of native rainforest species are present on the site and vegetation upslope and to the east of Broughton Creek is represented by warm temperate layered forest and the EEC, subtropical complex rainforest, which is in moderate to good condition away from its disturbed edges.

Regardless of the degraded nature of much of the area observed along Broughton Creek, many sites contained mature casuarinas with small hollows. These trees provide potential roost sites for fauna, particularly microchiropteran bats.

3.3.3 Princes Highway at Tindalls Lane (sites 15-16 and 22)

Adjacent to Tindalls Lane and on the north and south sides of the Princes Highway is an area of remnant vegetation that covers about 60 hectares (sites 15 and 16) and is one of the largest contiguous areas of native vegetation present in the study area. Historic disturbances such as logging have altered the structure of these communities and weed infestations are scattered across each site.

Study area

The project impacts upon vegetation on both the north and south of the existing Princes Highway at site 15. Native vegetation at site 15 is represented by Illawarra gully wet forest in a moderate to good condition with a largely intact native tree, shrub and ground layer and along with infestations of woody weeds such as *Lantana camara*. Where dense patches of lantana were absent, the native shrub layer remains intact.

The fauna habitats at this site were varied. Hollow-bearing trees were scarce, but those present (large eucalypts) may provide nesting and roosting habitat for various birds, bats and arboreal mammals. Small scale habitat features such as logs, dense undergrowth and leaf litter were also present, offering further habitat opportunities to a range of species. Flora species within the remnant are also likely to provide feeding resources.

Myrtaceaeous trees (mostly eucalypt species) dominate the canopy, providing direct (foliage, nectar, exudates) and indirect (arthropods) food for a range of vertebrates, particularly birds and arboreal mammals.

Adjoining areas

Native vegetation adjoining the study area at site 15 is largely dominated by Illawarra gully wet forest in moderate condition due to dense infestations of *Lantana camara* scattered throughout. Where dense patches of lantana were absent the native shrub layer remains intact. Despite lantana infestation, this vegetation exhibited a reasonable capacity for the regeneration of natural vegetation provided weed control practices are implemented.

A small drainage line runs along the south-west of site 15 and vegetation along this portion of the site is represented by warm temperate layered forest in moderate condition. Warm temperate layered forest is also present to the north-west on site 16. Vegetation on site 16 is in a moderate to good condition with patchy infestations of *Lantana camara* and *Tradescantia fluminensis*. Despite these weed infestations the vegetation across site 16 exhibited a reasonable capacity for the regeneration of natural vegetation, provided weed control practices are implemented. The northern and eastern edges of site 16 grade into Illawarra gully wet forest which is also in moderate condition.

3.3.4 Broughton Mill and Bundewallah creeks (site 34)

Immediately north-east of Berry township, the project crosses Broughton Mill and Bundewallah Creeks. Native vegetation along these creeks is now largely restricted to a highly disturbed riparian corridor.

Study area

Vegetation in the study area at site 34 is represented by Riverbank forest in a highly disturbed, poor condition. Site 34 has a tall native canopy of *Casuarina cunninghamiana* and an understorey completely dominated by a high density weed infestation. Natural structural layers are no longer intact and in most areas the mid storey and ground layers are completely dominated by weed species including *Ligustrum lucidum, L. sinense, Solanum nigrum, Ehrharta erecta* and *Tradescantia fluminescens*. These weed infested areas were considered to have little capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation. Obvious disturbances at each of these sites includes clearing, nutrient enrichment, sedimentation and erosion.

Regardless of the degraded nature of much of the area observed along each creek, many sites contain mature casuarinas with hollows.

3.3.5 Bundewallah Creek (proposed receiving point for Town Creek diversion)

Bundewallah Creek at the northern end of Rawlings Lane, is proposed as the receiving water for the full diversion of Town Creek from where it crosses North Street, Berry.

Study area

Native flora species identified during the field survey were consistent with the diagnostic flora species described for Riverbank forest (Tozer 2010). Dominant flora species include a canopy of *Casuarina cunninghamiana* ssp *cunninghamiana* with understorey species including *Hymenanthera dentata* and ground layer of *Commelina cyanea, Dichondra repens, Lomandra longifolia, Microlaena stipoides* and *Sigesbeckia orientalis*. This community is frequently highly disturbed and weed species are often dominant in the understorey (Tozer 2010). Riverbank forest at the proposed receiving location on Bundewallah Creek includes a sparse canopy between 15 and 25 metres of *Casuarina cunninghamiana* ssp *cunninghamiana*, *Cinnamomum camphora* and *Erythrina sykesii*. The woody weeds *Lantana camara* and *Ligustrum sinense* form dense understorey thickets in places. Elsewhere the understorey is absent or characterised by scattered woody weeds. The groundcover stratum is dominated by exotic annual and perennial grasses and herbs with minor patches and occasional occurrences of native groundcovers. Common exotic species are *Anagallis arvensis*, *Bromus catharticus*, *Pennisetum clandestinum*, *Rumex crispus*, *Senecio madagascariensis* and *Trifolium repens*. Native groundcovers include *Dichondra repens*, *Geranium homeanum*, *Sigesbeckia orientalis* ssp *orientalis*, *Persicaria strigosa* and *Urtica incisa*.

Bundewallah Creek at the proposed receiving point varies in width from approximately 3 metres to 10 metres. The creek was slow-flowing at the time of survey and supported wide pools and rocky riffle areas. Fringing vegetation consisted largely of weedy grasses. Common frogs and ducks are likely to utilise these habitats. Deposited concrete slabs provide basking and shelter habitat for common reptiles such as Eastern Water Dragon (*Physignathus lesueurii*) and Eastern Water Skink (*Eulamprus quoyii*). Small tree hollows provide potential roosting habitat for microbats. Fauna habitats at this location range from poor to moderate in condition.

Adjoining areas

A farm dam is present just north-west of the proposed receiving location on Bundewallah Creek and provides habitat for waterbirds and common frogs, such as Pacific Black Duck (*Anas superciliosa*) and Striped Marsh Frog (*Limnodynastes peronii*). No emergent or fringing sedges were present at the time of survey, with the bank dominated by weedy grasses. A few large stags are present on the edge of the dam providing perch sites for waterbirds and raptors.

3.3.6 Town Creek diversion

Where Town Creek meets North Street, heading downstream, it is proposed to be diverted across land adjacent to Rawlings Lane and into Bundewallah Creek. See Section 3.3.5 for description of Bundewallah Creek.

Study area

Closed grassland occurs between Town Creek north to Bundewallah Creek over the alignment of the proposed constructed channel and is dominated by *Pennisetum clandestinum*, other introduced pasture species such as *Trifolium repens* and *Paspalum dilatatum* and colonising weeds including *Cirsium vulgare* and *Rumex crispus*. Native herbs and rushes include scattered occurrences of *Ludwigia peploides* ssp *montevidensis* and *Persicaria strigosa*. The closed grassland represents an unnatural landscape and has established as a result of the substantial clearing of native vegetation and a long history of agriculture.

Fauna habitat is limited within the closed grassland. However, the land is prone to flooding and small, shallow wetlands were present at the time of survey. Common frogs, common and migratory waterbirds may utilise this resource from time to time. Fauna habitat is subject to trampling by cattle, observed drinking from the wetlands during the survey.

Town Creek south of the proposed diversion point on North Street consists of intergrades of closed grassland and closed sedgeland, and disturbed riparian open woodland. Further south, shortly before the confluence with Broughton Mill Creek, a constructed wetland occurs on Town Creek. Structure and floristic composition of the closed grassland/sedgeland are similar to that described above for the closed grassland with *Cyperus eragrostis*, *Pennisetum clandestinum* and *Trifolium repens* dominating the suite of exotic species and native *Persicaria* spp and patches of *Typha orientalis* common in the lower channel terraces. The disturbed riparian open woodland occurs along Town Creek through the Berry urban area. This plant community is characterised by areas of revegetation, regrowth native vegetation, planted exotic trees with invasive woody weeds and areas of managed open space in public and private land tenure. The canopy consists of local and non-locally occurring native trees and exotic tree species occurring mainly as landscape plantings. The constructed wetland has formed as a result of aquatic and semi-aquatic vegetation becoming established following the construction of the access track causeway of the Berry sewage treatment works.

The constructed wetland is characterised by patches of *Typha orientialis* and sparse cover of other emergent macrophytes. The banks are dominated by pasture grasses such as *Pennisetum clandestinum* and *Paspalum dilatatum* and patches of *Persicaria strigosa*. Exotic trees and shrubs around the banks include *Erythrina crista-galli*, *Lantana camara*, *Ligustrum sinense* and *Solanum mauritianum*. These plant communities represent an unnatural landscape.

Fauna habitats along Town Creek south of the proposed diversion point on North Street are reasonably disturbed however provide foraging and breeding resources for a range of common birds, frogs, reptiles and mammals. The creekline itself and constructed wetland provide habitat for threatened and migratory birds such as Black Bittern (*Ixobrychus flavicollis*) and Latham's Snipe (*Gallinago hardwickii*). The constructed wetland, with fringing Typha and emergent rushes, may provide limited potential habitat for the threatened Green and Golden Bell Frog however, was shallow and stagnant at the time of survey. Whilst a number of preferred Koala (*Phascolarctos cinereus*) feed trees occur, they are planted individuals, occurring in low numbers, and provide less than 15 per cent canopy cover. Therefore, these trees are unlikely to provide core habitat for Koalas. Fauna habitats along Town Creek range from poor to moderate in condition.

3.3.7 Broughton Mill Creek (confluence with Town Creek)

Town Creek discharges into Broughton Mill Creek about 1.5 kilometres south-east of the intersection of Queen Street and Prince Alfred Street, Berry. Broughton Mill Creek is tidal-influenced at this location.

Study area

Broughton Mill Creek at the confluence with Town Creek consists of riparian open woodland containing stands of exotic shrubs and trees such as, *Erythrina sykesii*, *Ligustrum sinense* and *Salix babylonica* with the groundcovers dominated by introduced pasture species. Fauna habitats are disturbed and subject to trampling by cattle (observed at time of survey). No sedges are present but patches of the reed *Phragmites australis* provide potential habitat for common frogs and birds. Instream habitats such as logs are largely absent; exposed and fringing rocks occur infrequently.

Adjoining areas

A large effluent storage pond occurs within the Berry sewage treatment plant property. This pond is the last step in the filtration process before the water discharges into Broughton Mill Creek. The pond is predominantly surrounded by weedy grasses and does not contain fringing or emergent sedges, rushes or reeds. The pond provides habitat for waterbirds such as Australasian Grebe (*Tachybaptus novaehollandiae*), Great Cormorant (*Phalacrocorax carbo*) and Pied Cormorant (*Phalacrocorax varius*).

3.3.8 Hitchcocks Lane (site 35)

Two separate stands of vegetation occur on the south side of the existing Princes Highway within site 35, one opposite Hitchcocks Lane and the second within a small reserve at the western end of Victoria Street.

Study area

Vegetation at site 35, opposite Hitchcocks Lane is represented by Illawarra gully wet forest and includes mature hollow-bearing *Eucalyptus saligna* X *botryoides* and *E. pilularis* with a patchy understorey including both native shrubs and groundcovers along with large patches of weed species including *Tecoma capensis* and *Lantana camara.* The condition of Illawarra gully wet forest at the Hitchcocks Lane site was considered to be moderate. Native vegetation within this portion of site 35 exhibited good capacity for natural regeneration, provided competing weed species are removed.

A small drainage line crosses under the existing Princes Highway at site 35 and flows into a constructed wetland supporting native rushes such as *Typha orientialis*. The drainage line and wetland provide habitat for common frogs and birds.

Vegetation at site 35, at the western end of Victoria Street is represented by isolated remnant trees with a mown grassy understorey. This area was considered highly modified and in poor condition. The native canopy layer is all that remains intact.

3.3.9 Schofields Lane (site 14)

South-west of Berry township and directly opposite Schofields Lane occurs a stand of native vegetation. The stand would be largely unaffected directly by the Foxground and Berry bypass project however indirect impacts are possible.

Study area

Vegetation at site 14 is represented by Illawarra gully wet forest and includes mature hollow-bearing *Eucalyptus pilularis* and *E. saligna X botryoides* with a degraded understorey. The native understorey was sparse with *Pteridium esculentum* dominating. Large patches of weed species including *Rubus fruticosus, Senecio madagascariensis*, and *Onopordum acanthium* were scattered throughout the site. The condition of Illawarra gully wet forest at the site 14 was considered to be moderate, based on the amount of mature eucalypt trees present.

No drainage lines or water bodies were present at the site.

There were few logs and scattered stags (dead trees) with hollows on the site. There is potential for microbat breeding and roosting habitat.

3.4 Flora species

A total of 513 vascular flora species were recorded within the study area and adjoining areas, comprising 402 (78 per cent) locally indigenous species and 111 (22 per cent) exotic weed species. A list of flora species recorded is provided in Appendix A. Weeds and significant flora species are discussed below.

3.4.1 Noxious weeds

Seven exotic weed species recorded in the study area and surrounds are listed as noxious weeds in the Shoalhaven LGA with three of these listed as noxious in the Kiama LGA as identified in **Table 3.2**.

Table 3.2 Noxious weeds recorded in the study area

Weed species	Common name	Noxious weed class
Ageratina riparia	Mistflower	4
Lantana camara[#]	Lantana	4
Ligustrum lucidum	Large-leaved privet	4
Ligustrum sinense	Small-leaved privet	4
Lycium ferocissimum[#]	African boxthorn	4
Rubus fruiticosus[#]	Blackberry complex	4
Senecio madagascariensis	Fireweed	4

[#] *Listed as noxious in Kiama LGA*

The legal requirements of these noxious weed classes include:

a) Class 4 - The growth and spread of the flora must be controlled according to the measures specified in a management plan published by the local control authority.

b) Class 5 - The requirements in the *Noxious Weeds Act 1993* for a notifiable weed must be complied with.

Given that survey effort was focussed within areas of native vegetation, it is considered highly likely that further noxious weed species would occur within cleared and disturbed portions of the study area.

3.4.2 Weeds of national significance

Twenty Weeds of National Significance (WONS) have been identified by Australian governments because of their invasiveness, impacts on primary production and the environment, potential for spread and socioeconomic impacts. Two WONS, *Lantana camara* and *Rubus fruiticosus* were recorded in the study area during the current surveys. Other than the requirements of the NSW *Noxious Weeds Act 1993* there are no additional legal obligations to control WONS.

3.4.3 Environmental weeds

Environmental weeds are present in all areas of native vegetation and dominate cleared and disturbed areas throughout the study area. The environmental weed suite includes annual and perennial grasses and herbs such as *Bidens pilosa*, *Cirsium vulgare*, *Ehrharta erecta*, *Pennisetum clandestinum*, *Sida rhombifolia* and *Rumex crispus* in cleared and disturbed paddocks and along the edges of native plant communities. Perennial species such as *Protasparagus aethiopicus* and *Solanum pseudocapsicum* have invaded areas under canopy with dense patches of groundcover species such as *Ranunculus repens* and *Tradescantia fluminensis* present in damp areas and riparian zones.

Woody environmental weeds such as *Cinnamomum camphora* and *Solanum mauritianum* generally occur on the edges of native vegetation with cleared and disturbed areas as small stands or scattered individuals. Exotic vines including *Araujia hortorum*, *Delairea odorata* and *Passiflora subpeltata* occur on disturbed edges and under the canopy of patches of native vegetation.

3.4.4 Significant flora

A total of 17 vascular flora species listed on the TSC Act and/or the EPBC Act, or their habitat have been previously recorded within a 10 kilometre radius of the study area. Threatened flora records extracted from the OEH Atlas of NSW Wildlife within the 10 kilometre radius of the study area are mapped in **Figure 3.2**. An additional 14 species are recorded from the OEH Atlas of NSW Wildlife Illawarra sub region search with a further four species specified for consideration in correspondence from OEH (Appendix C).

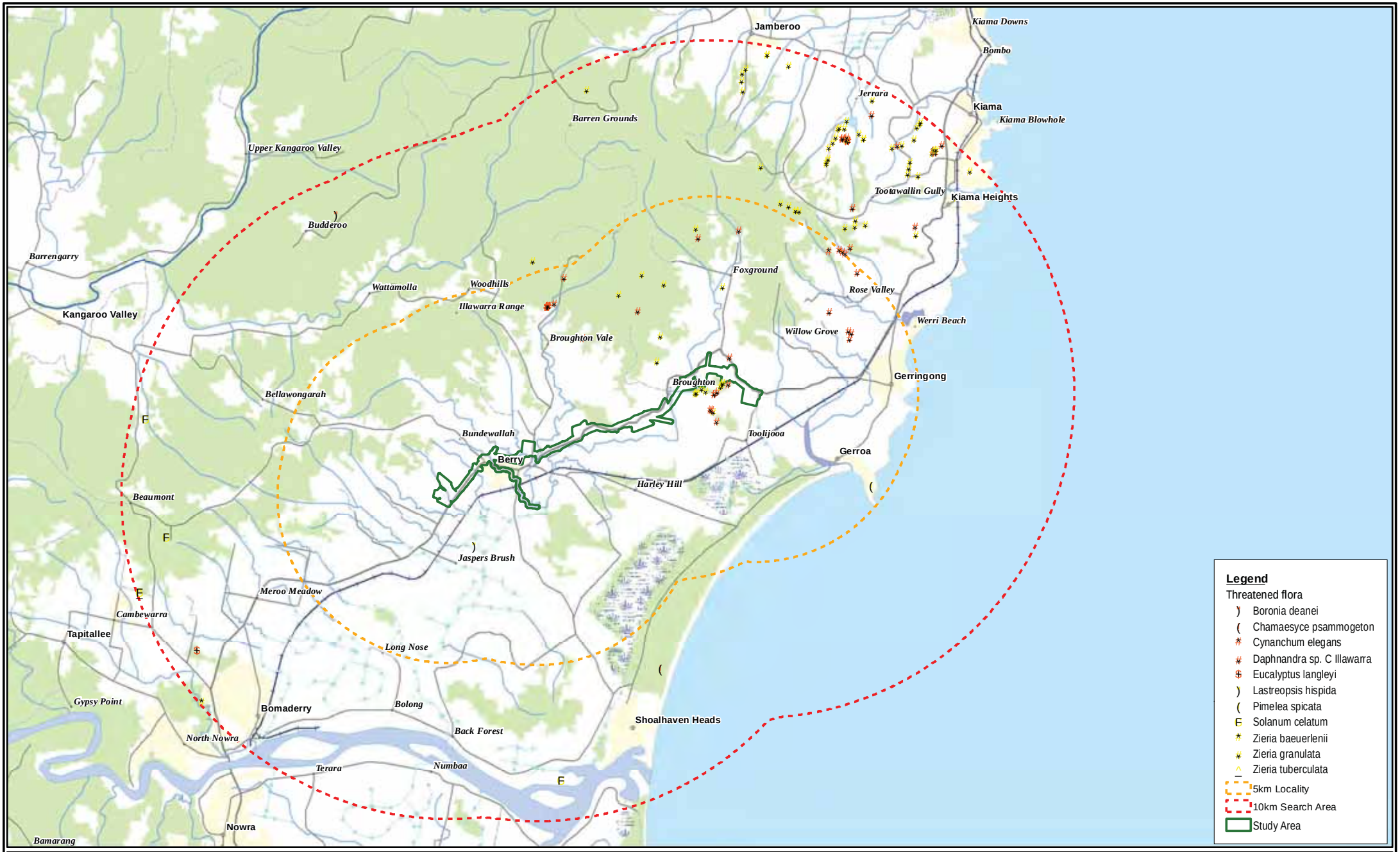
No threatened flora species were recorded in the study area during the survey. Two threatened species, *Daphnandra* sp. 'Illawarra' and *Zieria granulata* were recorded in adjoining areas. *Daphnandra* sp. 'Illawarra' occurred in warm temperate layered forest and subtropical complex rainforest in sites 17, 19 and 23, with the closest record about 600 metres south of the study area. *Zieria granulata* occurred in and adjoining subtropical complex rainforest and warm temperate layered forest, associated with rocky outcrops, in sites 17, 19 and 23. The closest record of *Zieria granulata* to the study area was about 200 metres to the south.

Due to the proximity of previous records and/or the presence of identified habitat preferences, potential habitat may exist within the study area for four threatened flora species: *Cynanchum elegans, Daphnandra* sp. 'Illawarra', *Irenepharsus trypherus* and *Zieria granulata*. Letter correspondence from OEH (then DECCW), dated 31 January 2011 which accompanied the DGRs has specified five flora species to be assessed as subject species for the project including two of the species cited above (*Daphnandra sp. '*Illawarra' *and Zieria granulata*) and an additional three species (Appendix C).

The additional three flora subject species are:

- *Pterostylis gibbosa.*
- *Cryptostylis hunteriana*.
- *Genoplesium baueri*.

All subject species listed in Appendix C and highlighted above have been considered further in Chapter 6 (assessment of impacts) of this report.



Biosis Research Pty. Ltd.
18-20 Mandible Street
Alexandria
NEW SOUTH WALES
2015

Figure 3.2: Threatened flora, listed on the TSC and EPBC Acts, recorded within 5 and 10km of the Study Area

Date: 16 July 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JER
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194 S2_F6 flora.mxd	

Acknowledgements:
Species data from DECCW and Biosis Research Pty. Ltd.
This product contains Data which is copyright to the Commonwealth of Australia (c. 2003)

0 1 2 3 4
Kilometers

Scale: 1:110,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 3.2

3.5 Fauna species

A list of fauna recorded within the study area is provided in Appendix B and includes 125 species of bird (including nine introduced species), 34 species of mammal (including five introduced species), nine species of frog and nine species of reptile.

The fauna surveys generally focused on habitats with a greater potential to contain native species, eg remnant native forest/rainforest, waterbodies (wetlands, creeks, farm dams) and rocky outcrops. Highly modified areas such as grazing paddocks and cropped pastures were routinely observed throughout the course of the field work.

3.5.1 Significant fauna

A total of 114 threatened, migratory and/or preliminarily listed fauna species or their habitat have been previously recorded within a 10 kilometre radius of the study area (OEH Atlas of NSW Wildlife and DSEWPaC Online EPBC Database) or the Illawarra sub-region of the Southern Rivers Catchment Management Authority (CMA) (Appendix D). Of these, 73 fauna species are listed under the TSC Act and 69 fauna species are listed (or nominated for listing) under the EPBC Act (20 threatened species and 51 migratory species)[1]. Eighty-nine threatened and/or migratory species have been previously recorded within 10 kilometres of the study area (**Figure 3.3**). Marine and pelagic species have been excluded (except those that may forage on land).

Nine threatened species and six migratory species were recorded during the field surveys for the project:

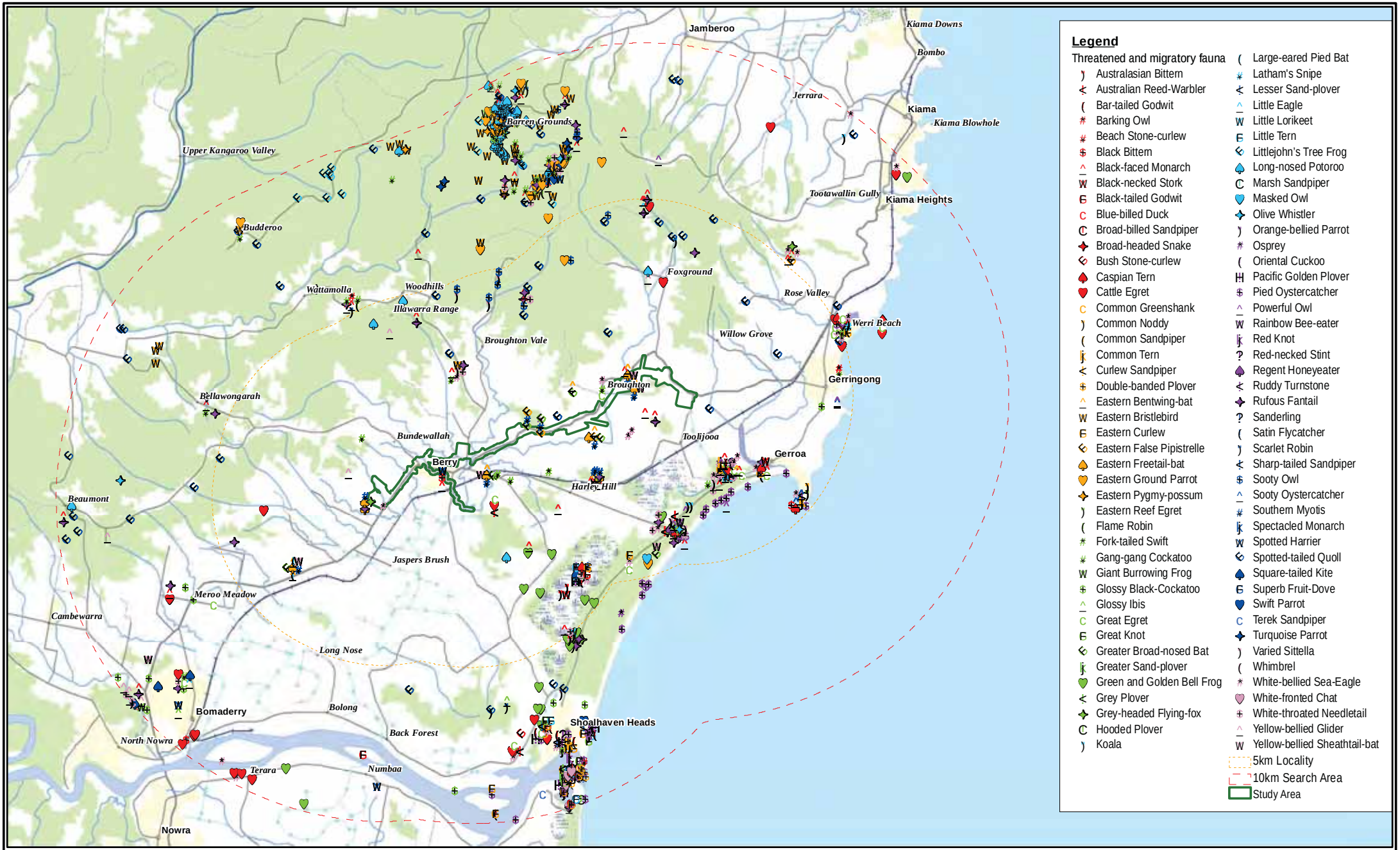
Threatened species present were:

- Gang-gang Cockatoo (*Callocephalon fimbriatum*).
- Powerful Owl (*Ninox strenua*).
- Yellow-bellied Sheathtail bat (*Saccolaimus flaviventris*).
- Eastern Freetail Bat (*Mormopterus norfolkensis*).
- Grey-headed Flying-fox (*Pteropus poliocephalus*).
- Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis*).
- Eastern False Pipistrelle (*Falsistrellus tasmaniensis*).
- Southern Myotis (*Myotis macropus*).
- Greater Broad-nosed Bat (*Scoteanax rueppellii*).

Migratory species present were:

- White-bellied Sea-eagle (Haliaeetus leucogaster).
- Fork-tailed Swift (Apus pacificus).
- Cattle Egret (Ardea ibis).
- Black-faced Monarch (Monarcha melanopsis).
- Rufous Fantail (Rhipidura rufifrons).
- Australian Reed-warbler (Acrocephalus stentoreus).

[1] An individual species may be listed under one or both Acts and may be listed as threatened and/or migratory.



Legend

Threatened and migratory fauna

- Australasian Bittern
- Australian Reed-Warbler
- Bar-tailed Godwit
- Barking Owl
- Beach Stone-curlew
- Black Bittern
- Black-faced Monarch
- Black-necked Stork
- Black-tailed Godwit
- Blue-billed Duck
- Broad-billed Sandpiper
- Broad-headed Snake
- Bush Stone-curlew
- Caspian Tern
- Cattle Egret
- Common Greenshank
- Common Noddy
- Common Sandpiper
- Common Tern
- Curlew Sandpiper
- Double-banded Plover
- Eastern Bentwing-bat
- Eastern Bristlebird
- Eastern Curlew
- Eastern False Pipistrelle
- Eastern Freetail-bat
- Eastern Ground Parrot
- Eastern Pygmy-possum
- Eastern Reef Egret
- Flame Robin
- Fork-tailed Swift
- Gang-gang Cockatoo
- Giant Burrowing Frog
- Glossy Black-Cockatoo
- Glossy Ibis
- Great Egret
- Great Knot
- Greater Broad-nosed Bat
- Greater Sand-plover
- Green and Golden Bell Frog
- Grey Plover
- Grey-headed Flying-fox
- Hooded Plover
- Koala
- Large-eared Pied Bat
- Latham's Snipe
- Lesser Sand-plover
- Little Eagle
- Little Lorikeet
- Little Tern
- Littlejohn's Tree Frog
- Long-nosed Potoroo
- Marsh Sandpiper
- Masked Owl
- Olive Whistler
- Orange-bellied Parrot
- Osprey
- Oriental Cuckoo
- Pacific Golden Plover
- Pied Oystercatcher
- Powerful Owl
- Rainbow Bee-eater
- Red Knot
- Red-necked Stint
- Regent Honeyeater
- Ruddy Turnstone
- Rufous Fantail
- Sanderling
- Satin Flycatcher
- Scarlet Robin
- Sharp-tailed Sandpiper
- Sooty Owl
- Sooty Oystercatcher
- Southern Myotis
- Spectacled Monarch
- Spotted Harrier
- Spotted-tailed Quoll
- Square-tailed Kite
- Superb Fruit-Dove
- Swift Parrot
- Terek Sandpiper
- Turquoise Parrot
- Varied Sittella
- Whimbrel
- White-bellied Sea-Eagle
- White-fronted Chat
- White-throated Needletail
- Yellow-bellied Glider
- Yellow-bellied Sheathtail-bat

5km Locality
10km Search Area
Study Area

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Figure 3.3: Threatened and migratory fauna, listed on the TSC and EPBC Acts, previously recorded within 5 and 10km of the Study Area

Date: 16 July 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-3_Fauna_160712.mxd	

Acknowledgements:
Species data from DECCW, Birds Australia and Biosis Research Pty. Ltd.

This product contains Data which is copyright to the Commonwealth of Australia (c. 2003)

0 1 2 3 4
Kilometers

Scale: 1:110,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 3.3

A letter from the OEH (then DECCW), dated 31 January 2011 which accompanied the DGRs, has specified 18 threatened fauna species to be assessed as subject species for the project (seven of which were recorded during the current surveys). An additional 33 threatened fauna species (two of which were recorded during the current surveys) have been assessed as subject species due to the presence of known and/or potential habitat and/or previous records (Appendix D). All subject species listed in Appendix D have been considered further in Chapter 6 (assessment of impacts) of this report. Further, 29 migratory species with known and/or potential habitat in the study area are also considered further in Chapter 6.

3.6 Endangered populations

Part 2 of Schedule 1 of the TSC Act lists endangered populations of flora and fauna. There are no endangered fauna or flora populations listed that occur within the project study area.

3.7 Critical habitat

Critical habitat can be declared under both the EPBC Act and the TSC Act. Under the EPBC Act, it is an offence for a person to take an action that the person knows will significantly damage the critical habitat of a listed threatened species. Under the TSC Act, the declaration of critical habitat serves primarily as a guide for planning under Part 3 of the EP&A Act and a trigger which ensures a rigorous environmental assessment of all activities and development proposals and any other action that has the potential to damage the species or its habitat (NPWS 2002).

No areas of critical habitat for flora or fauna have been declared within the project study area under either the EPBC Act or the TSC Act (DECC 2008a, DEWHA 2009d). The NPWS has prepared a recommendation for the identification of critical habitat for the Bomaderry Zieria (*Zieria baeuerlenii*), listed under both the TSC Act and EPBC Act, within the Bomaderry bushland (NPWS 2002). A final declaration has not yet been made for this proposed area of critical habitat. This area lies about 10 kilometres to the south-west of the project. It would not be impacted by the project.

3.8 Corridors

3.8.1 Introduction

Wildlife corridors can be best defined as “retained and/or restored systems of (linear) habitat which, at a minimum, enhance connectivity of wildlife populations and may help them overcome the main consequences of habitat fragmentation” (Wilson and Lindenmayer 1995). Alternatively, they can be defined as “linear habitats that differ from a more extensive surrounding matrix; frequently they link one or more patches of habitat in the landscape, but they may also occur as isolated lines of habitat” (Bennett 1990).

A corridor serves a number of different functions in terms of wildlife conservation:

- Providing increased foraging area for wide-ranging species.
- Providing cover for movement between habitat patches, and enhancing the movement of fauna through sub-optimal habitats.
- Reducing genetic isolation.
- Facilitating access to a mix of habitats and successional stages to those species which require them for different activities (eg foraging or breeding).
- Providing refuge from disturbances such as fire.
- Providing habitat in itself.
- Linking wildlife populations and helping to maintain immigration and recolonisation between otherwise isolated patches. This in turn may help reduce the risk of population extinction (Wilson and Lindenmayer 1995).

Vegetation cover in a corridor may not always be continuous. Corridors may include smaller remnants, wetlands, roadside vegetation, groups of trees, and even individual trees. Corridors may be broken, or fragmented, by currently degraded or cleared areas but still contribute to landscape connectivity. Discontinuous corridors can provide important stepping-stone links (Scotts *et al*. 2000).

The functioning of a corridor can be best described in terms of its connectivity, of which there are two components:

- Structural connectivity. This is the mappable spatial continuity of the corridor. This can include the distance over which the corridor extends, the width, the number of gaps and the presence of habitat nodes.
- Functional connectivity. This is a measure of the ability of a species to move between two habitats. The functional connectivity of a corridor depends not only on its spatial continuity, but also on factors such as behaviour of the species, the scale of the species' movements, and its response to the width and quality of habitat in the corridor (Bennett 1990).

3.8.2 Corridors in the region

Large corridors in the Shoalhaven link national parks, nature reserves and other large areas of natural vegetation. These corridors have a high value for conservation purposes as they consist of large tracts of relatively undisturbed vegetation linking coastal areas with the escarpment of the Budawang Range and extending west into the Southern Tablelands. These include the Jervis Bay – Morton National Parks corridor, the Conjola – Morton National Parks corridor, the Five Lakes – Morton National Parks corridor and the Murramarang – Morton National Parks corridor. These corridors are primarily protected through their tenure as national park or other crown reserves, although there is some freehold land and land managed by State Forests (Shoalhaven City Council 2005).

Corridors with cleared sections exist also in the Shoalhaven. These corridors link protected national parks and nature reserves. Cleared sections occur mainly on freehold land and therefore management of existing and re-established vegetation within these corridors relies primarily on private landholders. Of particular concern for this project is the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. Remnant bushland in the Seven Mile Beach and Coomonderry Swamp area is isolated by several kilometres of cleared land from the escarpment forests to the north of Berry. Scattered patches of bushland exist between these two areas, including Toolijooa Ridge, Harley Hill, Moeyan Hill, along Broughton Creek and along public roads (Shoalhaven City Council 2005).

A broader wildlife corridor has been identified by the Southern Rivers CMA. This corridor represents a long term restoration goal which would see a revegetated corridor extending east from the escarpment to the coast. It represents areas of interest for the Southern Rivers CMA and the Berry Landcare group in which efforts towards restoring the native landscape and improving connectivity should be focused. Within the study area, this corridor includes the section of the project between the proposed embankment at Broughton Creek bridge 1 and just east of Tindalls Lane interchange. It is mostly made up of cleared agricultural land and includes most of the wildlife corridors as shown in **Figure 3.4**. The assessment concentrates on connectivity impacts associated with the project. Therefore it focusses on the most vulnerable areas within this corridor which are located along creeks and ridgelines, and which have existing remnant vegetation.

The *Illawarra Regional Environmental Plan No. 1* (as of July 2009) a deemed State Environmental Planning Policy - SEPP also identifies the above wildlife corridors. Under the SEPP, the consent authority must not grant development consent to an application to carry out development on land shown on the map as a wildlife corridor that, in the opinion of the consent authority, will involve significant tree felling or vegetation clearance unless it is satisfied that: (a) the development will be managed so as to not have any long-term detrimental impact on opportunities for wildlife movement; or (b) the development is designed to enhance the retention and augmentation of vegetation native to the area (NSW legislation website 2009). The project crosses the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor, which is mapped as a wildlife corridor under the deemed SEPP (discussed in section 3.8.3) and as such, the SEPP applies.

3.8.3 Corridors in the study area

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation and have not been mapped or described as a native plant community. Therefore, wildlife corridors in the study area are limited, however the Princes Highway does cross the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor discussed in section 3.8.2. Vegetation remnants at Toolijooa Ridge, Broughton Creek, Site 15, Broughton Mill Creek and Bundewallah Creek are discontinuous parts of this corridor and are thus important to wildlife in the area. Creeks provide dispersal habitat for aquatic fauna and vegetation along creeks (such as Town Creek) and some road reserves within the study area would also provide limited value as local corridors for some species. These smaller corridors are important in linking the larger corridors, and also provide the added values of protecting riverbanks, improving water quality and flows, controlling soil erosion and increasing land productivity through shelterbelts, windbreaks and screens (Shoalhaven City Council 2005). Fauna can use road reserves as habitat in which to live as well as movement corridors facilitating local movements, dispersal and migration (Bennett 1990). Within highly modified landscapes, remnant patches and strips of vegetation within road reserves are often the only remaining vegetation links. A number of studies have indicated the importance of such roadside vegetation (Breckwoldt 1990, Middleton 1980). Corridors in the study area are shown in **Figure 3.4**.

3.8.4 SEPP 14 wetlands

The nearest SEPP 14 wetland to the project area is Coomonderry Swamp in the southern section of the locality (**Figure 3.4**). The majority of Coomonderry Swamp occurs in private land tenure with some areas included in the boundary of Seven Mile Beach National Park. Drainage of the study area is ultimately to Broughton Creek which is part of the Coomonderry Swamp catchment. Coomonderry Swamp is about five kilometres southeast of Berry.

3.8.5 SEPP 44 Koala habitat protection

SEPP 44 aims to encourage the proper conservation and management of areas of natural vegetation that provide habitat for Koalas, ensuring a permanent free living population over their present range and attempting to reverse the current trend of Koala population decline. Under this policy the distinction is made between 'potential' and 'core' Koala habitat.

"Potential Koala habitat" means areas of native vegetation where the trees of the types listed in Schedule 2 of the Policy constitute at least 15 per cent of the total number of trees in the upper or lower strata of the tree component. "Core Koala habitat" means an area of land with a resident population of Koalas, evidenced by attributes such as breeding females (that is, females with young) and recent sightings of and historical records of a population.

The Koala has been previously recorded north and south of the study area. Although some SEPP 44-listed feed tree species were recorded during the field surveys (eg *Eucalyptus microcorys, E. racemosa, E. robusta and E. tereticornis*), none were dominant within the forest/woodland patches of the study area. Based on the low density of preferred feed trees (ie less than 15 per cent of the total number of trees in the upper or lower strata of the tree component) and the absence of records of this conspicuous species within the study area, the study area does not constitute "potential" or "core" Koala habitat as defined under the SEPP. However, it is possible that the species moves through the study area on occasion between areas of potential habitat. Potential impacts to the Koala have been further assessed in Chapter 6 (assessment of impacts).

3.8.6 Groundwater-dependent ecosystems

Groundwater-dependant ecosystems (GDEs) have been defined by the Department of Land and Water Conservation (DLWC 2002) as ecosystems which have their species composition and natural ecological processes determined by groundwater. GDEs vary in the degree of their dependency on groundwater from having no apparent dependence to being entirely dependent on it.

Terrestrial vegetation such as native plant communities including forests, woodlands and wetlands in riparian zones and on coastal floodplains may be dependent on shallow groundwater either permanently or seasonally. River or stream flow is often maintained by groundwater which provides base flow emerging as springs or diffusely from sediments and rock strata underlying a stream and stream banks. Base flow groundwater can be crucial in maintaining in-stream and near-stream ecosystems such as native plant communities (DLWC, 2002).

The NSW *State Groundwater Dependant Ecosystems Policy* (DLWC, 2002) defines five main types of groundwater systems in NSW. Shallow Alluvial Groundwater Systems are associated with coastal rivers and are often in direct connection with surface water bodies such as rivers and wetlands. This type of groundwater system is likely to support base flows and associated terrestrial ecosystems such as riparian forests, riparian woodlands and wetlands. Based on a review of the topographic and physiographic features of the locality the fluvial landscapes of the locality are likely to be characterised by Shallow Alluvial Groundwater Systems.

Riverbank forest occurs in the study area and locality (**Figure 3.1** and Appendix J) and this is discussed in Section 3.2.2. As described by Tozer *et al* (2010) the community is found on sand/gravel alluvium strewn with cobbles along swift-flowing reaches of streams, at elevations from 20-800 metres ASL. Riverbank forest in the current assessment is considered to be part of the EEC River-flat eucalypt forest. The Final Determination for River-flat eucalypt forest (NSW Scientific Committee, 2004) states that the EEC:

- Is associated with silts, clay-loams and sandy loams, on periodically inundated alluvial flats, drainage lines and river terraces associated with coastal floodplains.
- Generally occurs below 50 metres elevation.
- Forms mosaics with other floodplain forest communities and treeless wetlands.
- Floristic composition is primarily determined by the frequency and duration of waterlogging and the texture, nutrient and moisture content of the soil.

Impacts to River-flat eucalypt forest are discussed in Chapter 4. Details on groundwater issues within the study area in general can be found in the technical paper *Princes Highway upgrade - Foxground and Berry bypass - Surface water, groundwater and flooding assessment* by AECOM (August 2012).

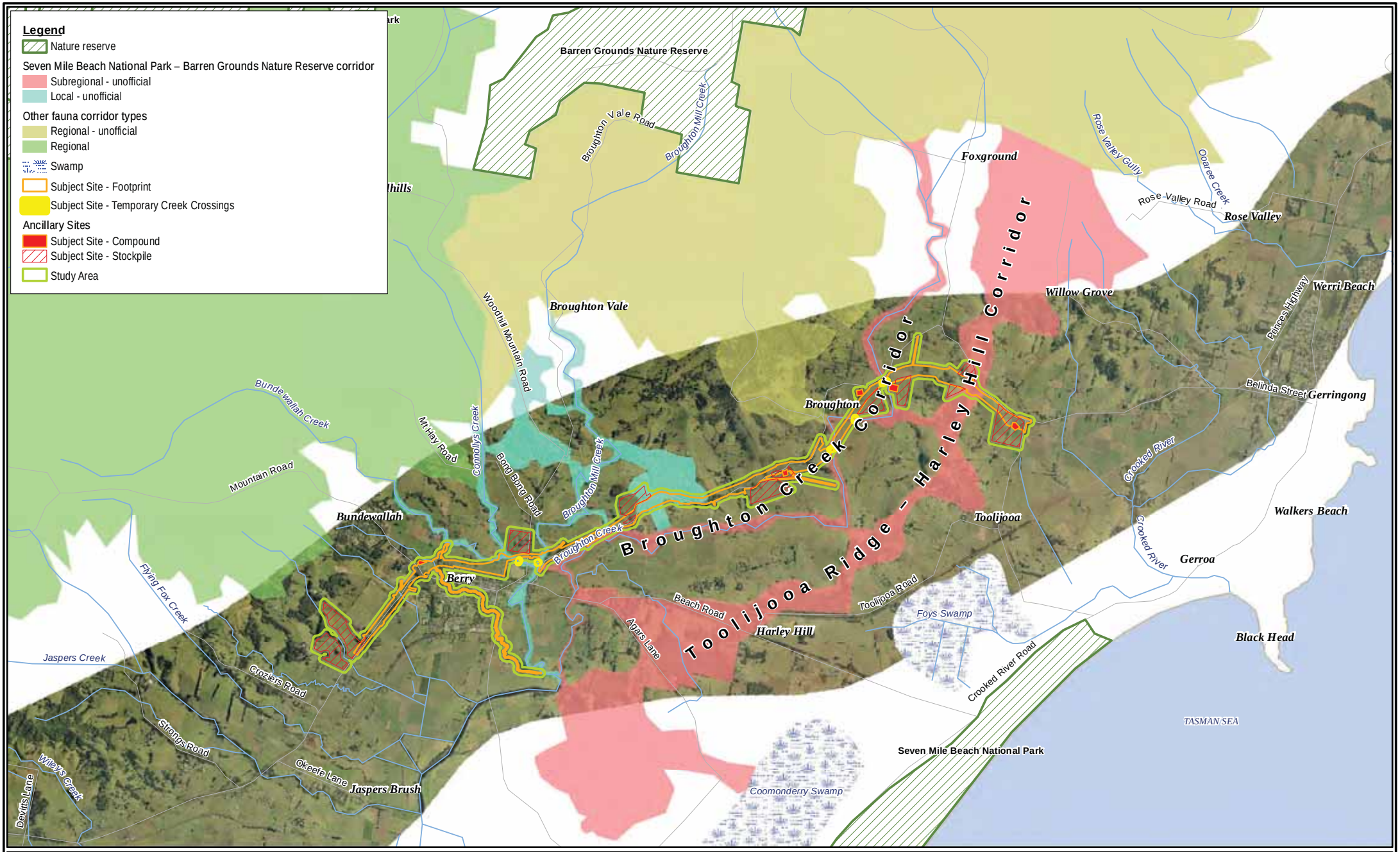

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Figure 3.4: Wildlife corridors

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Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-4_Corridors_160712.mxd	

Acknowledgements:
Habitat corridors based on 2008 aerial photography and the Illawarra Regional Environmental Plan (April 1982)
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 0.6 1.2 1.8 2.4 3
Kilometres

Scale: 1:50,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 3.4

4 Potential impacts

This chapter assesses the types of impacts that may result as a consequence of the construction and operation of a road, with specific reference to the Princes Highway between about the junction of Toolijooa Road and the Princes Highway and about the junction of Schofield's Lane and the Princes Highway. The assessment focuses on the most likely or representative scenarios based on the current project design, terrestrial flora and fauna field survey and desktop analysis. The impacts estimated from representative scenarios can be mitigated, greatly reducing or eliminating the impacts, thereby avoiding the worst case scenario where no mitigation would be implemented possible leading to local extinctions.

Worst case scenarios have been addressed by adopting a conservative approach in the terrestrial biodiversity assessments. In addition, worst case scenarios have been considered by proceeding with assessments of significance on the basis of potential habitats for threatened terrestrial biodiversity and which is required by impact assessment guidelines. However despite the definition of the construction footprint and ancillary facilities areas, project management systems, operational controls and work methods during construction, potential exists for impacts on native vegetation and terrestrial flora and fauna habitats. Potential worst case scenarios and possible impacts have been addressed in the following sections.

4.1 Potential impacts

Potential impacts resulting from road developments on terrestrial ecological values include the following:

- Vegetation clearance and habitat loss.
- Increased fragmentation including edge effects.
- Increased mortality.
- Weed invasion.

Each of these potential impacts is discussed below.

4.1.1 Vegetation clearance and habitat loss

Impacts of vegetation clearing and the proposed full diversion of Town Creek can result in the loss of flora species and fauna habitat features that occur in the area. In the study area, this would include nesting habitat and roosting hollows, watery habitats, as well as feeding and shelter resources.

Direct impacts would occur for the construction and operation of the project including the roadway, temporary creek crossings, Town Creek diversion and areas for ancillary facilities. The indirect impacts are calculated based on the 50 metres average extent of edge effects, calculated by buffering the area that would be directly impacted by construction of the project by 50 metres (see Section 1.4). Overall, eight different plant communities (including the predominantly exotic 'closed grassland') would be impacted by the project, including fragmentation of linear patches. Such fragmentation would result in new edges being created by the project. The impacts of this vegetation clearing on threatened species habitat are discussed in Section 6.1 and Section 6.2.

The full range of potential impacts due to the diversion of Town Creek into Bundewallah Creek are described in *Princes Highway upgrade - Foxground and Berry bypass Surface water, groundwater and flooding assessment* (AECOM 2012). Potential impacts to flora and fauna habitats as a result of diverting Town Creek into Bundewallah Creek include:

- Increased frequency, volume and velocity of flows in Bundewallah Creek from the receiving point, leading to erosion.
- Increased flows in Bundewallah, Connollys and Broughton Mill Creeks.
- Bundewallah Creek, Connollys Creek and Broughton Mill Creek will have less than 5 per cent change in catchment area due to the proposed diversion.
- Reduced flows in Town Creek south of the project alignment leading to loss of vegetation and fauna habitat (including both native and exotic vegetation).
- Town Creek's catchment would be reduced by 100 per cent at the diversion point and by 47 per cent at the downstream end before the confluence with Broughton Mill Creek.
- The proposed diversion could lead to sediment accumulating in Town Creek downstream of the diversion as a result of reduced flushing efficiency.

Despite the comprehensive assessment methodology the potential exists for a greater level of impact to vegetation and habitats than has been assessed. In this instance a worst case scenario may arise as a result of:

- Accidental clearing of native and derived plant communities and associated habitat for threatened and non-threatened terrestrial biodiversity.
- Project modifications resulting in additional vegetation clearing and habitat loss that fail to adequately further assess impacts that are discrete to the project and at a broader cumulative scale.
- Additional vegetation clearing either approved or accidental that results in residual loss of threatened biodiversity or its potential habitat and which is not compensated for by an offset.

Table 4.1 shows the area of each plant community recorded in the subject site and study area that would be impacted by the project.

Table 4.1: Area of each plant community potentially impacted by the project

Plant community	Impacted area (hectare)					Total impacted area (hectare)
	Direct				Indirect (edge effects)	
	Roadway	Ancillary facilities	Temporary crossings	Town Creek diversion		
Closed grassland*	-	-	-	0.4	0.5	0.9
Closed grassland/ sedgeland	0.1	-	-	2.1	0.3	2.5
Constructed wetland	0.2	-	-	0.2	0.3	0.7
Currambene-Batemans lowlands forest	-	0.0002	-	-	2.4	2.4
Disturbed riparian open woodland	-	-	-	2.6	1.2	3.8
Illawarra gully wet forest	13.7	1.7	-	-	10.05	25.5
Riverbank forest**	2.6	-	0.2	0.1	7.1	10.0
Warm temperate layered forest	5.0	1.9	-	-	5.3	12.2
Total	**21.6**	**3.6**	**0.2**	**5.4**	**27.2**	**58.0**

**Not considered to be a native plant or derived native plant community*
***Equivalent to EEC River-flat eucalypt forest*

4.1.2 Fragmentation

Habitat fragmentation is the division of a single area of habitat into two or more smaller areas, with a new habitat type occurring in the area between the fragments. This new dividing habitat type is often artificial and inhospitable to the fauna species remaining within the fragments (MacNally 1999) and can provide suitable conditions for weed species to establish, which may out-compete native flora species. Although the newly created habitat would be used by some species, they are usually generalist species and are often considered aggressive (eg noisy miners *Manorina melanocephala* (Loyn *et al*. 1983), further decreasing population levels of the species remaining in the fragments.

In addition to the loss of total habitat area, the process of fragmentation can impact on the species within the newly created fragments in a number of ways (eg barrier effects, genetic isolation and edge effects). The degree to which these potential impacts affect the flora and fauna within the newly created fragments depends on a number of variables including distance between fragments, local environmental conditions, the species present and mitigation measures implemented (Chapter 5).

The project without mitigation measures could result in a significant impact to some threatened fauna species (eg Spotted-tailed Quoll and Long-nosed Potoroo) due to the fragmentation of wildlife corridors (worst case scenario). However, given that the mitigation measures detailed in Chapter 5 (ie fauna crossing structures and vegetation corridor enhancement) would be implemented, fragmentation of habitat is unlikely to result in a significant impact to threatened biota. The specific impacts of habitat fragmentation on threatened species are discussed in Section 6.1, Section 6.2 and associated assessments of significance which are provided in Appendices 3 and 4 to this report.

Barrier effects

Barrier effects occur where particular species are either unable or are unwilling to move between suitable areas of fragmented habitat. This could result in either a complete halt to movement or a reduced level of movement between fragments. Roads through areas of native vegetation can act as barriers, with barrier effects greater for some species than others (Goosem 2002). Species most vulnerable to barrier effects include rare species (even a small reduction in movements can reduce genetic continuity within the population hence reducing the effective population size), smaller ground-dwelling species and species with low mobility. Species most likely to be impacted include small birds, terrestrial and arboreal mammals, and reptiles. Species least vulnerable to barrier effects tend to be those that are highly mobile (eg birds and bats), although even these species can vary in their response to barriers.

The project without mitigation measures could result in a significant impact to some threatened fauna species (eg Spotted-tailed Quoll and Long-nosed Potoroo) due to the creation and/or exacerbation of barrier effects (worst case scenario). However, given that the mitigation measures detailed in Chapter 5 (ie underpasses, overpasses and vegetation corridor enhancement) would be implemented, barrier effects are unlikely to result in a significant impact to threatened biota. The specific impacts of barrier effects on threatened species are discussed in Section 6.1, Section 6.2 and associated assessments of significance which are provided in Appendices 3 and 4 of this report).

Corridors and connectivity

As discussed in Section 3.8 the project would cause some impact on local and regional wildlife corridors, particularly where the project crosses Toolijooa Ridge (once) and Broughton Creek (three times), despite the existing degree of clearing and fragmentation.

The project would potentially impact upon habitat connectivity/wildlife corridors in two ways:

1. The barrier to fauna movement across the existing road would increase from two lanes (average width 12.5 metres) to four lanes with a median separation (average width 25 metres). In addition, both the existing and proposed highway would act as barriers to fauna movement where the new highway deviates from the existing alignment for a total of about 6.6 kilometres.
2. Habitat connectivity such as riparian vegetation would be impacted by removal of vegetation, or loss of vegetation due to reduced flow within Town Creek. The removal and/or loss of such vegetation would also create barriers to fauna movement between the fragmented patches.

Currently the existing Princes Highway crosses Toolijooa Ridge once, however the project would widen the existing highway as well as deviate to the west, resulting in a wider and an additional barrier to fauna movement along the ridge. Currently the existing Princes Highway crosses Broughton Creek once with a bridge. The project would cross Broughton Creek just south of the current crossing, also with a bridge. The two new crossings of Broughton Creek and single crossings of Broughton Mill Creek and Bundewallah Creek, on the northern fringe of Berry would also have bridge crossings. In addition, five temporary creek crossings would be required for the construction phase of the project. Vegetation removal for the creek crossings would fragment riparian connectivity along Broughton Creek, Broughton Mill Creek and Bundewallah Creek.

Most threatened species that have been recorded in the study area and/or locality are highly mobile, and would not be averse to crossing cleared areas. These include owls, parrots, cockatoos, raptors and bats. However, the project would create new barriers and exacerbate existing barriers to other threatened species with the potential to occur in the study area, such as the Black Bittern, Bush Stone-curlew, Eastern Pygmy-possum, Spotted-tailed Quoll, Yellow-bellied Glider, Koala and Long-nosed Potoroo.

Non-threatened terrestrial and arboreal mammals recorded in the study area whose movements are limited by the presence of the Princes Highway include Brown Antechinus, Bush Rat, Eastern Grey Kangaroo, Swamp Wallaby, Sugar Glider, Common Ringtail Possum, Common Brushtail Possum, Short-beaked Echidna and Common Wombat. Non-threatened birds whose movements may be limited include small birds such as thornbills, gerygones, treecreepers, scrubwrens and robins. Reptiles such as snakes and lizards would also have their movements limited.

The project without mitigation measures could result in a significant impact to corridors and connectivity (worst case scenario). However, given that the mitigation measures detailed in Chapter 5 (ie underpasses, overpasses and vegetation corridor enhancement) would be implemented, the project is unlikely to significantly impact corridors and connectivity overall. The specific impacts to wildlife corridors and habitat connectivity are discussed in Section 6.1, Section 6.2 and associated species assessments of significance (Appendices F and H).

Edge effects

Edge effects are zones of changed environmental conditions (ie altered light levels, wind speed, temperature) occurring along the edges of habitat fragments. These new environmental conditions along the edges can promote the growth of different vegetation types (including weeds) and allow invasion by pest fauna species specialising in edge habitats. Edge zones can be subject to higher levels of predation by introduced mammalian predators and native avian predators (Berry 2002). This new zone of habitat inside the edge of a fragment can also exacerbate barrier effects.

Biosis Research (2000) noted that there are limitations to edge effect studies, with a study by Murcia (1995) noting that it is unrealistic to expect all variables to vary equally with distance from the edge. As edge effects varied between community types and abiotic effects were the most consistent indicator of edge effects (measuring less than or equal to 50 metres in most studies), Biosis Research (2000) concluded that average edge effects generally occur up to 50 metres away from the road edge.

Specifically, edge effects associated with roads can include the degradation of adjacent habitat through:

- Changes in microclimate (eg temperature, wind, light humidity).
- Changes in hydrology (eg surface and sub-surface water flows).
- Changes in floristics (eg species composition and abundance).
- Alteration to the pattern and frequency of fire.
- Invasion by exotic flora and fauna species.
- Increase in sedimentation.
- Increase in tree death (eg dieback, impact on root zone).
- Increase in rubbish and water pollution.
- Improved access for predators (Bali 2000).

Edge effects may not affect both sides of the road equally and may be greater if they are downslope, downwind or surrounded by more suitable habitat (Biosis Research 2000).

Using the estimate of edge effects of 50 metres proposed by Biosis Research (2000), the subject site was buffered by 50 metres to calculate new edge effects from the project. It is calculated that the project including the permanent roadway, ancillary facilities required during construction, and diversion of Town Creek would directly impact 30.4 hectares of native vegetation (**Table 4.1**). An additional 26.7 hectares of native vegetation would be indirectly impacted by new edge effects. No OEH estates, crown land or State forests would be impacted by edge effects from the project.

4.1.3 Mortality

Fauna injury or death can occur as a result of highway construction and operation in two ways:

- During the break-out phase of construction (when all vegetation is removed to expose a natural earth substrate).

  Habitat clearance may result in the injury or death of resident or visiting fauna. Some species can more readily evade injury by flying (birds) or 'running' away (eg the larger mammals). Many species, however, are unlikely to move quickly enough to avoid being caught. For example, many nocturnal species (possums, gliders, bats) shelter during the day and smaller ground-dwelling species, such as lizards and snakes, are unable to move rapidly and over large distances.

- Road kills.

  Mortality due to road kill during operation of the project has the potential to affect local fauna species at the sub-population level. In general, rates of road kill mortality are likely to be directly proportional to the distance of native vegetation/fauna habitat crossed by the highway (Forman and Sperling 2002). However, other factors such as the design of the road (eg raised or not, presence of walls and fences) also influence road kill mortality. Generally, the effects of road kill mortality on sub-populations cannot be accurately predicted without more detailed demographic data than is available for species in the local area.

The RMS has policies and guidelines in place to manage the risk of fauna mortality during both construction and operation of the highway (Chapter 5). Despite the inclusion of mortality mitigation measures (eg staged habitat clearance during construction, and underpasses with fencing to funnel fauna under the road during operation), road kill may still occur. However, these mitigation measures would reduce the likelihood of road kill causing a significant impact on a species.

A comprehensive assessment has been carried out to determine the potential impacts of the project on native fauna including the likelihood of fauna mortality during the construction phase and ongoing operation. Despite measures to avoid, mitigate and manage the predicted direct and indirect impacts other potential sources of impact may occur as the project progresses. A worst case scenario for fauna mortality may evolve if one or a combination of the following occurs:

- Accidental clearing of native and derived plant communities and associated habitat for threatened and non-threatened terrestrial fauna resulting in additional fauna mortalities during construction.
- Project modifications resulting in additional vegetation clearing and habitat loss for threatened and general fauna that fail to adequately further assess impacts that are discrete to the project and at a broader cumulative scale.
- Project modifications resulting in elimination of some of the proposed fauna friendly crossing structures.
- Improvements in corridor connectivity and habitat quality as a result of mitigation works and biodiversity offset arrangements that expose a greater number and range of threatened or non-threatened fauna to mortality on the roadway.

4.1.4 Weed invasion

Weed invasion can be a significant problem along the edges of habitat fragments. Along these boundaries there are changes in the environment (edge effects) including altered light levels, wind speed, temperature, humidity and runoff. These altered conditions allow the colonisation and growth of weeds which would themselves result in further environmental changes that promote the colonisation and growth of weed species within the area. Due to these environmental changes, weeds may be able to out-compete native flora species and (at worst) could result in the loss of the native plant community in that area.

All areas of native vegetation recorded in the study area had existing weed infestation, with the weediest areas adjoining Broughton and Bundewallah Creeks, where the understorey of Riverbank forest was completely dominated by weed species including *Ligustrum sinense, Lantana camara, Solanum mauritianum, Ageratina riparia* and *Tradescantia fluminescens*.

Given the small size, fragmentation and poor condition of vegetation that would be impacted, the project is not likely to increase the impact of weed invasion in the study area. Although mitigation measures are recommended to reduce the existing weed infestation and the likelihood of increased weed invasion in the impacted patches and manage the potential for introduction of additional weed species (Chapter 5), there remains some potential for a worst case scenario arising as a result of:

- The accidental introduction of a WONS or noxious weed species not currently known from the locality on construction plant and equipment. In particular the introduction of a Class 1 or Class 2 noxious species.
- Project modifications resulting in additional vegetation clearing and habitat loss for threatened and general fauna that fail to adequately further assess impacts that are discrete to the project and at a broader cumulative scale.

4.2 Cumulative impacts

Assessment of the potential cumulative effects on threatened species values arising from the project includes consideration of the following:

- Impacts of other existing or proposed development projects in the locality.
- Impacts of the entire upgrade of the highway between Mount Pleasant and Bomaderry (about 30 kilometres in total), which is the last remaining two lane section of the Princes Highway between Sydney and Nowra (Section 1.4).

4.2.1 Existing and proposed development projects

The project occurs in a largely rural landscape. Consequently, much of the native vegetation in the local area has been cleared and many of the remaining remnants are small, isolated and fragmented. Furthermore, a large proportion of land in the locality is located on the floodplain, which largely precludes further development.

Existing and proposed development projects are predominately located on already cleared land within or adjacent to existing development, such as near Berry township and in the north of Bomaderry. Recent residential development within the study area at Berry includes the Arbor Retirement Village and Huntingdale Park, both of which are located in previously cleared areas. Further temporary housing and tourist park development applications have recently been submitted to Kiama Municipal Council and Shoalhaven City Council, for areas such as Toolijooa and Gerringong, however, the majority are largely within cleared areas with little impacts upon threatened species values.

Approved development in the locality includes expansion of an existing sand quarry at Gerroa (Land & Environment Court 2008), about five kilometres east of the project, adjacent to Seven Mile Beach National Park. Based on the flora and fauna assessment undertaken for the quarry expansion (Mills 2006a), a total of about 4.2 hectares of native coastal vegetation would be cleared including 1.7 hectares of Blackbutt Banksia forest, 1.6 hectares of disturbed Bangalay sand forest and 0.9 hectare of littoral rainforest. No cumulative impacts on these vegetation types are considered likely given that these coastal vegetation types are unlikely to be impacted by the project. Given the lack of habitat connectivity and distance between the quarry and the project, the magnitude of cumulative impacts on threatened fauna populations is considered to be low. Further proposed development adjoining the quarry site, including a tourist resort and golf course, have not received approval.

Approximately 20 kilometres south-west (via the Princes Highway) of Schofields Lane begins the South Nowra project: Princes Highway upgrade, Kinghorne Street to Warra Warra Road, to Forest Road, South Nowra. The South Nowra project involves approximately 6.3 kilometres of Princes Highway upgrades including the construction of a four lane divided carriageway (RTA 2009a; RTA 2009b). Based on the flora and fauna assessments undertaken for the Kinghorne Street to Warra Warra Road section (NGH 2009) and Warra Warra Road to Forest Road section (Hayes Environmental cited in RTA 2009a), the following native vegetation would be cleared: 2.2 hectares of Currambene-Batemans lowlands forest, 2.6 hectares of Southern lowland wet forest, 0.05 hectares of Floodplain swamp forest (EEC), 0.08 hectares of South Coast lowland swamp woodland (EEC), 1.3 hectares of Disturbed edge vegetation, and 9 hectares of Open eucalypt forest. Minor cumulative impacts would occur for Currambene-Batemans lowlands forest only.

Currambene-Batemans lowlands forest is not an EEC however provides potential habitat for three threatened flora species: *Cryptostylis hunteriana*, *Caladenia tessellata* and *Thesium australe*. Only 0.0002 hectares of Currambene-Batemans lowland forest would be directly impacted by the proposed Foxground and Berry bypass project, which equates to less than 0.01 per cent of the total to be cleared by both projects. Known habitat for the Green and Golden Bell Frog occurs within the South Nowra project (Currambene-Batemans lowland forest) and potential habitat occurs for this species within the proposed Foxground and Berry bypass project (constructed wetlands). Only 0.4 hectares of potential habitat would be directly impacted by the proposed Foxground and Berry bypass project, which equates to 15.0 per cent of the total to be directly affected by both projects. The total area to be directly impacted by both projects (2.6 hectares) equates to approximately 0.02 per cent of the same plant communities available with 30 kilometres (16,336.00 hectares) of the Foxground and Berry bypass project (which includes all of the South Nowra Project). Given the lack of habitat connectivity and distance between the proposed Foxground and Berry bypass project and the South Nowra project, the magnitude of cumulative impacts on threatened fauna populations is considered to be low.

4.2.2 Princes Highway upgrade between Gerringong and Bomaderry

A detailed options and constraints analysis process was used to inform the selection of the preferred option for the project and impacts have largely been avoided where possible by following the existing highway alignment or previously cleared land.

However, the project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek to improve road safety and traffic efficiency, including for freight, on the NSW south coast and needs to be considered in this context.

An assessment of the cumulative impacts associated with the project requires consideration of the proposed overall upgrade of the highway between Mount Pleasant and Bomaderry (about 30 kilometres in total) which, with the recent opening of the Oak Flats to Dunmore upgrade, remains the only two lane section of the Princes Highway between Sydney and Nowra. The highway between Mount Pleasant and Bomaderry would be upgraded in three sections.

Table 4.2 provides a summary of impacts to vegetation (including fauna habitat) within the subject site (area of direct impacts) and study area (area of direct impacts plus areas subject to potential indirect impacts) for each of the three remaining sections of the Princes Highway still to be upgraded as part of the RMS's overall upgrade of the Princes Highway. The remaining sections include the recently determined Gerringong upgrade project, the Foxground and Berry bypass project (this project) and the proposed Berry to Bomaderry upgrade project to the south, which is currently in the planning phase. About 80 per cent of direct impacts on plant communities and fauna habitats associated with the upgrade of these three sections of highway are attributable to this project (as shown in **Table 4.2**).

Consideration of the cumulative impacts on vegetation and fauna habitat for the three remaining sections of the Princes Highway still to be upgraded does not change the conclusions of impact assessments (Section 6.1.4 and Section 6.2.4) undertaken for threatened biota either occurring or potentially occurring in the study area. Impact mitigation measures that have been proposed in Chapter 5 are specific to the Foxground and Berry bypass project and these will maintain or improve biodiversity values for the threatened flora and fauna (or potential habitats) that may be affected by the project. Despite avoidance and mitigation measures, the project would result in a residual impact through the permanent loss of about 2.9 hectares of the EEC River-flat eucalypt forest. The preparation and implementation of an Offset Package based on the Offset Strategy in Appendix E would address the residual impact on River-flat eucalypt forest to achieve a maintain or improve outcome. The Offset Strategy in Appendix E has not considered cumulative impacts to River-flat eucalypt forest for the other two Princes Hwy upgrades.

Table 4.2: Area (hectares) of each plant community impacted by the upgrade of the three remaining two lane sections of the highway between Mount Pleasant and Bomaderry

Plant community	EEC	Gerringong upgrade		Foxground and Berry bypass		Berry to Bomaderry upgrade		Cumulative total (direct and indirect)
		Direct impact	Indirect impact	Direct impact	Indirect impact	Direct impact	Indirect impact	
Closed grassland				0.4	0.5			**0.900**
Closed grassland/sedgeland				2.2	0.3			**2.500**
Coastal saltmarsh	Yes		1.06					**1.062**
Coastal warm temperate rainforest	Yes						0.20	**0.196**
Constructed wetland				0.4	0.3			**0.700**
Currambene-Batemans lowlands forest				0.0002	2.44	3.19	6.87	**12.500**
Disturbed riparian open woodland				2.6	1.2			**3.800**
Illawarra gully wet forest				15.4	10.1	0.24	0.92	**26.66**
Revegetation							0.56	**0.563**
Riverbank forest	Yes			2.9	7.1	0.03	0.44	**10.470**
Subtropical dry rainforest	Yes	0.01	0.52					**0.521**
Warm temperate layered forest				6.9	5.3			**12.200**
Totals (hectare)		**0.01**	**1.58**	**30.80**	**27.24**	**3.46**	**8.99**	**72.080**
% of cumulative total (direct and indirect)		**0.01**	**2.21**	**42.75**	**37.79**	**4.83**	**12.56**	**-**

5 Management and mitigation

The RMS' road development and impact on habitat amelioration policy states that "in principle, the planning and construction of roads should, in order of consideration endeavour to:

1. Avoid impacts on habitat though the planning process.
2. Minimise impacts on habitat through the planning process.
3. Mitigate impacts on habitat, through the use of a range of amelioration measures (RTA 2001)".
4. Offset unavoidable residual impacts.

After implementing the above amelioration policy, any residual impacts would be offset.

Where possible, important ecological features identified in the local area have been **avoided** during the options and route selection stage, such as patches of Illawarra subtropical rainforest. The project has been designed, where feasible, to **minimise** impacts on habitat. In areas where significant vegetation is located, the land area of the subject site incorporating the road footprint and construction access requirements has been reduced to minimise potential impacts.

A number of measures to **mitigate** the potential impacts on biodiversity resulting from the project have been investigated during the preliminary phases of this assessment including construction of fauna overpasses (including a land bridge, glider poles and canopy bridges) and fauna underpasses (including road bridges and fauna-friendly culverts) with fauna exclusion fencing.

The resulting management, mitigation and **offset** measures (discussed in detail below) have been developed to maintain and/or improve biodiversity.

5.1 Vegetation clearing and habitat loss

In order to mitigate the removal or modification of 30.4 hectares of native vegetation in the subject site, including 2.9 hectares of EEC, and potential disturbance to 26.7 hectares, including 7.1 hectares of EEC, in the study area it is recommended that:

- The existing corridor along Broughton Creek would be enhanced through revegetation including connection to Toolijooa Ridge vegetation.
- Department of Primary Industries, Fisheries to be consulted for input, in relation to matters relevant to Fisheries, into relocation of Town Creek.
- The flow along the current Town Creek alignment should be maintained through appropriate design.
- Vegetation clearing is restricted to those areas where it is necessary and opportunities to minimise clearing would be part of the detailed design. Where possible, effort would be made to retain habitat trees within the subject site. In addition, vegetation in proximity to rope bridges would be retained and protected during construction to encourage arboreal fauna to use the rope bridges (see Section 5.3.5).
- Where clearing does occur, the area would be fenced with highly visible temporary fencing to ensure that clearing does not extend beyond the area necessary, in accordance with Guide 2 Exclusion zones of the RMS 'Biodiversity Guidelines' (RTA 2011).

- Clearing of vegetation would comply with RMS 'Biodiversity Guidelines: Guide 1 The pre-clearing process' (RTA 2011). The guidelines cover the felling of both non-habitat and habitat trees and the rescue and relocation of fauna.
- Prior to construction, a hollow-bearing tree/stag survey and stag-watching would be carried out in order to identify the number and type of nest boxes required and where to install them. Installation of bat roost and nest boxes would take place at least one month prior to the commencement of construction. The optimal season for stag-watching is spring; a hollow-bearing tree/stag survey however, can be conducted any time of year. Bat roost and nest boxes would be installed at a ratio of 1:1 for each hollow removed by the project. Prior to construction, a survey of any bridges or culverts scheduled for removal would be carried out in order to detect roosting microbats. If detected, a Bat Management Plan would be prepared.
- Vegetation within the road reserve and adjacent to areas of vegetation clearing would be managed to reduce invasion of noxious weed species; this may include controlling weeds at their point of source (ie the area of clearing) and in accordance with Guide 6 Weed management and Guide 10 Aquatic habitats and riparian zones of the RMS 'Biodiversity Guidelines' (RTA 2011).
- A VMP would be prepared prior to construction, detailing restoration, regeneration and rehabilitation of areas of native vegetation in the vicinity of the project. The VMP would also detail appropriate management for the potential habitat of threatened flora species in the vicinity of the project, including monitoring during and after construction works to ensure impacts are minimised. Appropriate management may include fencing the habitat; signage and educating contractors on the presence of habitats, their significance and no-go zones. In addition sugar cane mulch would not be used for revegetation and/or landscaping works (to minimise risk of cane toad introduction/spread). The VMP would be integrated with the landscape plan for the project and its preparation should involve consultation with local Landcare groups and the CMA. The VMP should recommend the input of these stakeholders to ensure the use of local expertise and resources such as local provenance seed sources.
- Residual impacts resulting from the mitigated removal or modification of vegetation and habitats would be compensated for through the implementation of a biodiversity offset strategy (see Section 5.7).
- During detailed design, refinements may be made to the design features and construction methods to further minimise vegetation clearing.

5.2 Edge effects

Mitigation measures related to edge effects relate generally to reducing impacts outside of the direct development zone, controlling possible impacts at their source within the road reserve and reducing the hardness of the edge between the extent of earthworks and native vegetation. Measures that are relevant to the project include:

- Minimising disturbance to habitat adjacent to construction (eg the use of visible temporary fencing).
- Minimising disturbance wherever possible to stream banks and streambeds through avoidance of the use of instream structures. This would be achieved in the case of permanent and temporary creek crossings (ie bridges with no instream structures will be used), however would be impossible in the case of culverts.
- Locating all ancillary building and works in cleared or otherwise disturbed areas away from waterways and other sensitive areas.
- Avoiding stockpiling materials on adjacent vegetation. Adjacent vegetation would be designated as an 'environmentally sensitive area', and fenced off (in accordance with the RMS 'Biodiversity Guidelines: Guide 2 – Exclusion Zones' (RTA 2011)).
- Managing general construction activities to appropriately store waste material and/or contaminants away from adjacent habitats.
- Implementing soil erosion and sedimentation control measures.
- Implementing a weed management strategy within the road reserve, to be incorporated into the VMP and that references Guide 6 Weed management and Guide 10 Aquatic habitats and riparian zones of the RMS 'Biodiversity Guidelines' (RTA 2011).
- Using locally indigenous (local provenance) species for revegetation and restoration (non-native species would only be used for landscaping where culturally appropriate and in locations identified within the urban and landscape design strategy).

5.3 Corridors and connectivity

In order to minimise and mitigate the potential impacts of habitat/corridor fragmentation, it is proposed to enhance the existing riparian corridor along Broughton Creek through revegetation and connect the Broughton Creek corridor to Toolijooa Ridge through additional revegetation. The preparation of a VMP would detail restoration methods, performance measures and a monitoring programme to ensure restoration works achieve objectives. Optimally the VMP would integrate with the landscape plan for the project and be prepared in consultation with local Landcare groups and the CMA committing to input local expertise and resources during implementation. Residual impacts resulting from the loss of riparian vegetation are discussed in the offset strategy (Appendix E).

In addition, underpasses (eg bridges and culverts) and overpasses (eg rope bridges) will be designed to assist the safe passage of fauna underneath and/or over the highway. Although the inclusion of a land bridge was considered, it was decided in consultation with the former DECCW (now OEH), that the proposed mitigation measures (ie underpasses and rope bridges) and strategic revegetation would have a better long term outcome for biodiversity in the locality.

The following sections provide a description of the various fauna mitigation structures and their ability to mitigate the impacts of roads. They also describe in detail the proposed design and location of these structures in relation to the project.

5.3.1 Background on fauna-friendly crossing structures

Generally fauna underpasses have been found to work well (Bond and Jones 2008, Goosem 2005, AMBS 2002, AMBS 1997). Species that have been found to use underpasses include a range of terrestrial mammals including dasyurids, macropods (mostly large span bridges), rodents, bandicoots and bats as well as reptiles and amphibians (Bond and Jones 2008, AMBS 2002). Monitoring of rope bridges has shown that a range of possum species will utilise these structures (Goosem *et al.* 2005). Gliding mammals are largely dependent on tree cover to traverse a landscape (Ball and Goldingay 2008) and are particularly sensitive to habitat fragmentation (Goldingay and Taylor 2009). Ball and Goldingay (2008) found that wooden poles (ie glider poles) installed across a gap in tree cover (eg highway) have the potential to connect habitat patches for gliding mammals and allow dispersal through a fragmented landscape. Fauna fencing, to funnel animals towards under and over passes (and away from the road), has been found to be extremely effective in preventing most road-kill, except following human-related breaches in the fence (Bond and Jones 2008).

Various studies, within Australia and internationally, looking at the effectiveness of fauna-friendly crossing structures have found different periods of acclimatisation were required before a species utilised an underpass or overpass to make a full crossing. Factors such as the subject species, local environment, size and length of the crossing and proximity to habitat may affect the length of time a species takes to become accustomed to a new crossing structure. A number of studies undertaken within Australia (particularly NSW and QLD) have found that a reasonable diversity of fauna will utilise crossing structures within months of construction, with the number of species (or species groups) utilising a crossing structure increasing over time (Fitzgerald 2005, Veage and Jones 2007, Bond and Jones 2008).

5.3.2 Underpasses

Underpasses (eg bridges and culverts) can be either constructed solely for the purpose of fauna movements or can be modified from existing structures such as box culverts (AMBS 2002). Suitability of the structures as fauna underpasses depends on a number of factors including:

- The regional continuity of habitat in the area.
- Habitat directly on either side of the structure.
- Proximity to vegetation cover either side of the structure.
- Unimpeded view of habitat on the other side of the structure.
- Road width, traffic volume and associated noise.
- The dimensions of the structure (width, height and length).
- The species in the local area.

Ideally, fauna crossing structures should be located where regular crossing and/or migration pathways are identified (Veage and Jones 2007). Structures such as exclusion fences and fauna ‘furniture’ can also increase the effectiveness of underpasses (Bond and Jones 2008) (Goosem *et al.* 2005).

A bridge for each of the three creek crossings at Broughton Creek and one each for Broughton Mill Creek and Bundewallah Creek would provide incidental fauna underpasses. These bridges would help to facilitate fauna movement along the Broughton Creek corridor and other local riparian corridors.

The bridges would be of sufficient height (ranging from 8 to 20 metres) to allow light to filter underneath the bridge for vegetation growth and to provide a suitable environment for fauna crossing. Each bridge would also be of sufficient length (ranging from 80 to 600 metres) to enable a width of at least 10 metres between the embankment and the creek edge. Where appropriate, fauna fencing would be installed at the western end of the bridge at Berry. Due to the reasonable height of the Broughton Creek crossings above the existing riparian vegetation, and that each creek will be crossed perpendicularly within a predominantly cleared area, fauna fencing is not recommended at these crossings. However, should road kill become an issue during the operational phase of the highway upgrade at these locations, fauna fencing may be required.

In addition to the incidental bridge crossings, four dedicated fauna underpasses would be included. As shown in **Table 5.1** dedicated box culvert underpasses would be installed on Toolijooa Ridge and about 300 metres east of Tindalls Lane. A dual use box culvert with dedicated fauna passage would be installed about 600 metres and 1200 metres east of Tindalls Lane. These dedicated box culverts would be designed to serve as fauna underpasses by ensuring sufficient dry passage and clearance. Fauna 'furniture' such as rocks, piping, raised log railings and refuge poles would be included within the dedicated dry passage part of the culverts. Refuge poles are timber poles erected within and/or at the entrances to fauna underpasses to allow arboreal mammals a place to seek refuge should they encounter a terrestrial predator whilst attempting to make a crossing. Fauna fencing would be used on all four dedicated fauna underpasses and extend at least 200 metres either side of the underpass to funnel fauna toward the crossing structure.

The Southern Rivers CMA and Berry Landcare group have been consulted as part of this environmental assessment. The dual use box culvert to be installed about 1200 metres east of Tindalls Lane was included in the design of the project as part of this consultation. The fauna mitigation structures proposed for the project would ensure that the project would support the Southern Rivers CMA and Berry Landcare's long term goal of restoring the 'escarpment to sea' corridor.

5.3.3 Rope bridges

Aerial overpasses (rope/canopy bridges) have been recommended for Australian roads (Goosem and Marsh 1997, QDMR 2000, QDMR 1997, QDMR 1998, AMBS 2001a, Bax 2006). These may comprise simple rope bridges, rope 'ladders' or more elaborate tunnel-like structures, which span the full road width. Recent studies have found that arboreal mammals will use all types of rope bridges however they tend to cross tunnel-like structures across the top surface (Goosem *et al.* 2005 and Bax 2006).

Bax (2006) monitored one of five rope tunnel canopy bridges at the Karuah Bypass (about three hours north of Sydney). During the study (lasting 244 days), an infrared camera recorded 50 crossings, 46 from brushtail possums and four from squirrel gliders, proving that arboreal mammals would cross a road (in this case a distance of 70 metres) using aerial overpasses (Bax 2006). During a study of rope bridges at two locations along the Hume Highway, Victoria, infrared cameras recorded Squirrel Gliders, Brush-tailed Phascogales, Common Brushtail Possums and Common Ringtail Possums all using the rope bridges (in this case a distance of 70 metres). The cameras confirmed complete crossings by both the Squirrel Glider and Common Ringtail Possum (Soanes and Van der Ree).

A number of rope bridges would be included in the design as show in **Table 5.1**. Rope bridges would be located at all creek crossings, on Toolijooa Ridge and east of Tindalls Lane. At Broughton Creek Bridges 1 and 2, rope bridges would extend both over and under each of the bridges.

5.3.4 Glider poles

Glider poles (different to refuge poles discussed above) may assist with the movement of some arboreal mammals across large forest gaps, such as road corridors (eg where existing vegetation is of insufficient height to permit successful and safe gliding across the road corridor). Glider poles consist of a simple timber pole located in a position that allows gliders to breach large gaps or increases the functional take-off height in forest that is insufficient in height to allow safe crossing. Other features may include a 'predator shield' and horizontal cross members to assist launching (Goldingay 2010) or instead of a single pole, an array of poles might be more effective. Glider poles have been installed in a number of road projects in NSW to provide connectivity for gliders. A study of glider poles across a paddock (five 12 metre poles across a 70 metre gap) showed regular usage by Squirrel Gliders (Ball and Goldingay 2008). A recent review of glider pole locations for the Oxley Highway Deviation (about five hours north of Sydney) found that poles 30 metres in height (or 25 metre high poles situated closer to the road) were required for successful glides across distances of up to 56 meters (Goldingay 2010).

Due to the extreme height of glider poles that would be required for successful gliding over the new highway (50 metre tall poles), and the structure-free-median design of the new highway, glider poles are not recommended. Instead additional rope bridges (rope bridges under bridges) have been included in the design. The only glider previously recorded within the study area, the Sugar Glider, is known to successfully utilise rope bridges (RTA 2009c). It is important that barbed wire fencing is not installed within the vicinity of rope bridges and associated poles ("crossing zones") as gliders crossing at these locations can be caught in the wire and killed.

5.3.5 Maintaining connectivity

The functional efficiency of the proposed fauna-friendly bridges and culverts can be improved by retaining roadside vegetation that is in the immediate vicinity with these structures. This would require the retention of vegetation 'fingers' at strategic points along the road corridor that correspond to identified movement corridors. To provide an immediate functional movement corridor across the road corridor it is essential that the vegetation at these points is maintained and allowed to encroach or remain up to the road edge. However, it is also important that fauna have an unimpeded view of underpasses and the habitat or horizon on the other side (Veage and Jones 2007). At crossing structure entrances, fauna fencing must have a wide opening and be directly joined to the crossing structure to encourage usage by fauna (ERM Mitchell McCotter 1999, Abigroup 2007). Given the obvious hazards to traffic from the close proximity of vegetation, it is recommended that fauna exclusion fencing be modified to incorporate a crash barrier component at these points.

Riparian vegetation under bridges, at temporary creek crossing sites, adjacent to ancillary sites and in the vicinity of rope bridges should be retained and protected during construction to maintain access to these structures. Similarly, roadside vegetation in the vicinity of rope bridges should be retained and protected. These areas should be designated as an 'environmentally sensitive area', fenced off and marked up on construction maps, in accordance with the RMS 'Biodiversity Guidelines: Guide 2 – Exclusion Zones' (RTA 2011).

Where vegetation clearance within the subject site is unavoidable, revegetation under bridges, at temporary creek crossings, at ancillary sites and in the vicinity of rope bridges should be undertaken to maintain connectivity.

5.3.6 Site selection

The following combination of bridges and culverts (underpasses), and rope bridges would be installed in order to retain connectivity in vegetated areas that form part of local or regional corridors (corridors discussed in Section 3.8). **Table 5.1** below provides the nominated locations for these structures. These locations are shown in **Figure 5.1** to **Figure 5.4**.

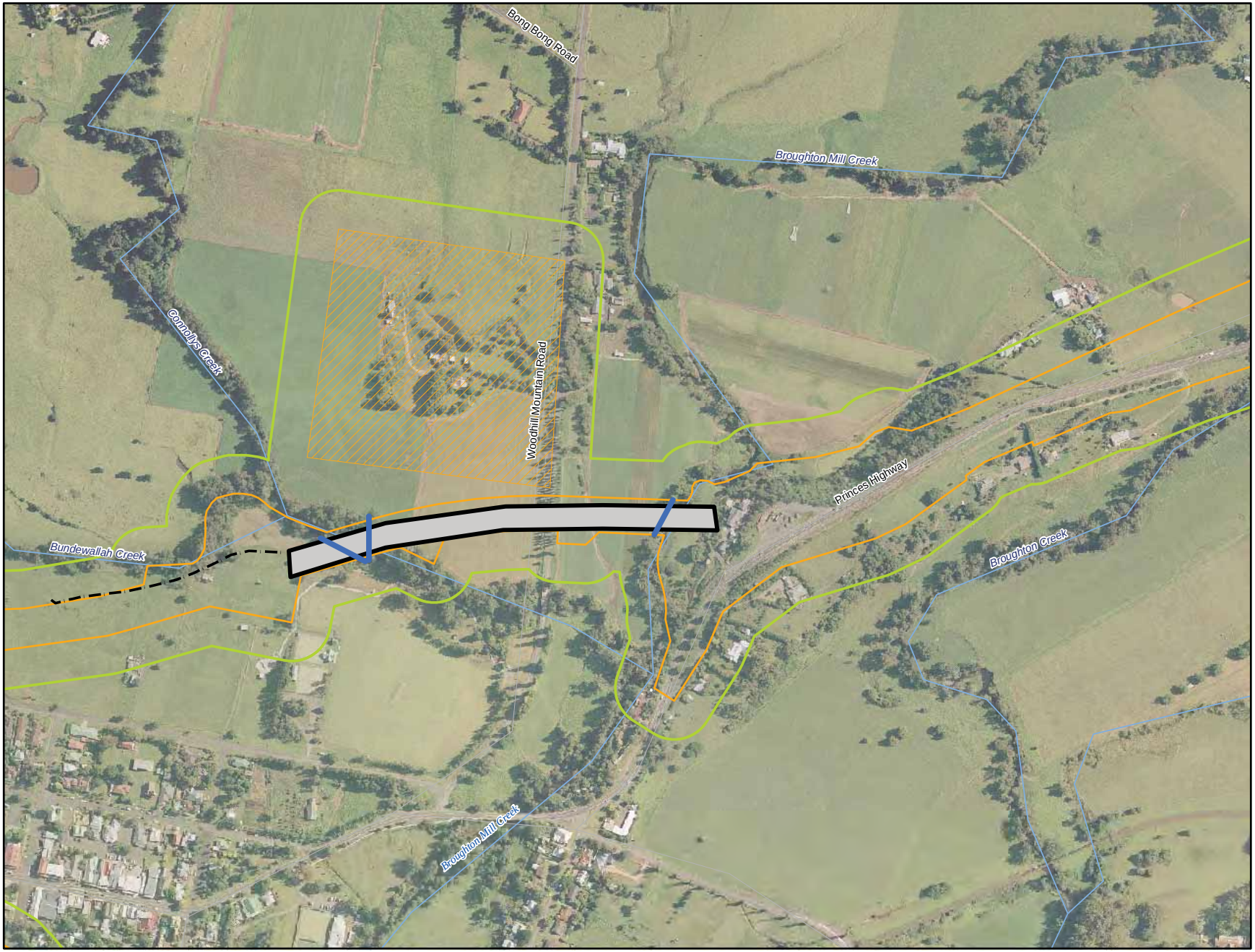
Table 5.1: Fauna mitigation structures

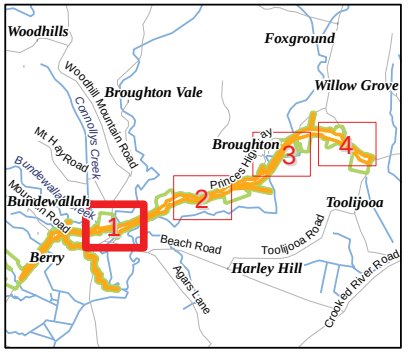
Location	Design chainage (m)	Recommended structures	Target species (* threatened species)
Toolijooa Ridge	8450	• Dedicated fauna underpass (separate to local traffic underpass at chainage 8400) • Fauna fencing • Fauna furniture within underpass	Spotted-tailed Quoll* Long-nosed Potoroo* Bush Stone-curlew* Koala* Brown Antechinus Bush Rat Eastern Grey Kangaroo Swamp Wallaby Short-beaked Echidna Common Wombat
Toolijooa Ridge	8500	• Minimum of three connecting rope bridges: one over existing highway, one over new highway, at least one on south-western side of new highway to nearby stand of vegetation • Exclusion zone fencing during construction to retain and protect existing trees and vegetation in vicinity of rope bridges	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum
Broughton Creek crossings x 3	9950, 10700, 11200	• Bridge (underpass) at each crossing • Scattered hollow logs sourced from approved clearing zones within the subject site, and supplementary metal pipe tunnels (to provide fauna refuge and shelter opportunities)	Spotted-tailed Quoll* Black Bittern* Long-nosed Potoroo* Bush Stone-curlew* Koala* Brown Antechinus Bush Rat Eastern Grey Kangaroo Swamp Wallaby Short-beaked Echidna Common Wombat reptiles amphibians
Broughton Creek bridge 1	9990	• Three connecting rope bridges: one over existing highway, one over new bridge and one under new bridge • Exclusion zone fencing during construction to retain and protect existing riparian vegetation in vicinity of rope bridges	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum

Location	Design chainage (m)	Recommended structures	Target species (* threatened species)
Broughton Creek bridge 2	10700	• Two rope bridges: one over new bridge and one under new bridge • Exclusion zone fencing during construction to retain and protect existing riparian vegetation in vicinity of rope bridges	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum
Broughton Creek bridge 3	11200	• Three rope bridges: two under new bridge (one to each side of creek) and one adjacent to new bridge (crossing the creek) • Exclusion zone fencing during construction to retain and protect existing riparian vegetation in vicinity of rope bridges	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum
Princes Highway about 1200 metres east of Tindalls Lane	12770	• Dual use box culvert underpass (one side raised and dry for dedicated fauna passage) • Fauna fencing • Fauna furniture within underpass	Spotted-tailed Quoll* Long-nosed Potoroo* Bush Stone-curlew* Koala* Brown Antechinus Bush Rat Eastern Grey Kangaroo Swamp Wallaby Short-beaked Echidna Common Wombat Reptiles Amphibians
Princes Highway about 600 metres east of Tindalls Lane	13320	• Dual use box culvert underpass (one side raised and dry for dedicated fauna passage) • Fauna fencing • Fauna furniture within underpass	Spotted-tailed Quoll* Long-nosed Potoroo* Bush Stone-curlew* Koala* Brown Antechinus Bush Rat Eastern Grey Kangaroo Swamp Wallaby Short-beaked Echidna Common Wombat Reptiles Amphibians

Location	Design chainage (m)	Recommended structures	Target species (* threatened species)
Princes Highway about 600 metres east of Tindalls Lane	13360	• One rope bridge over new highway • Exclusion zone fencing during construction to retain and protect existing trees and vegetation in vicinity of the rope bridge	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum
Princes Highway about 300 metres east of Tindalls Lane	13680	• Dedicated fauna underpass • Fauna fencing • Fauna furniture within underpass	Spotted-tailed Quoll* Long-nosed Potoroo* Bush Stone-curlew* Koala* Brown Antechinus Bush Rat Eastern Grey Kangaroo Swamp Wallaby Short-beaked Echidna Common Wombat Reptiles Amphibians
Princes Highway about 300 metres east of Tindalls Lane	13700	• Minimum of two connecting rope bridges: one over new highway and at least one on northern side of highway to nearby vegetation • Exclusion zone fencing during construction to retain and protect existing trees and vegetation in vicinity of rope bridges	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum
Broughton Mill Creek	15900	• One rope bridge joining riparian vegetation under new bridge at Berry • Exclusion zone fencing during construction to retain and protect existing riparian vegetation in vicinity of the rope bridge	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum

Location	Design chainage (m)	Recommended structures	Target species (* threatened species)
Bridge at Berry	16000	• Bridge (underpass) over Broughton Mill Creek & Bundewallah Creek (Connollys Creek) • Scattered hollow logs sourced from approved clearing zones within the subject site, and supplementary metal pipe tunnels (to provide fauna refuge and shelter opportunities) • Fauna fencing (western end of bridge, northern side of bridge only)	Spotted-tailed Quoll* Long-nosed Potoroo* Bush Stone-curlew* Koala* Brown Antechinus Bush Rat Eastern Grey Kangaroo Swamp Wallaby Short-beaked Echidna Common Wombat Reptiles Amphibians
Bundewallah Creek (Connollys Creek)	16250	• Two rope bridges under the new bridge (Bridge at Berry) • Exclusion zone fencing during construction to retain and protect existing riparian vegetation in vicinity of rope bridges	Yellow-bellied Glider* Sugar Glider Common Brushtail Possum Common Ringtail Possum





Legend

- Bridge (underpass)
- Dedicated Fauna Underpass
- Dual Use Underpass
- Fauna Fencing
- Rope Bridge Adjacent to Bridge
- Rope Bridge Over Road
- Rope Bridge Under Bridge
- Rope Bridge Over and Under Bridge
- Subject Site - Footprint
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 5.1: Fauna Mitigation Structures

Date: 11 January 2012	Drawn by: RS/JS
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Acknowledgements:
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Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 55

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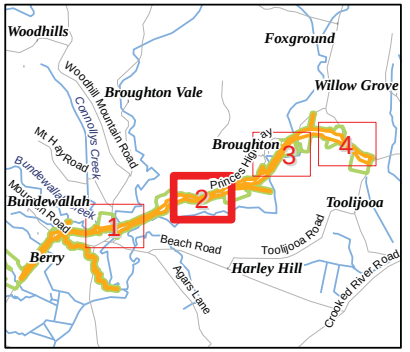

Legend

- Bridge (underpass)
- Dedicated Fauna Underpass
- Dual Use Underpass
- Fauna Fencing
- Rope Bridge Adjacent to Bridge
- Rope Bridge Over Road
- Rope Bridge Under Bridge
- Rope Bridge Over and Under Bridge
- Subject Site - Footprint
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 5.2: Fauna Mitigation Structures

Date: 11 January 2012	Drawn by: RS/JS
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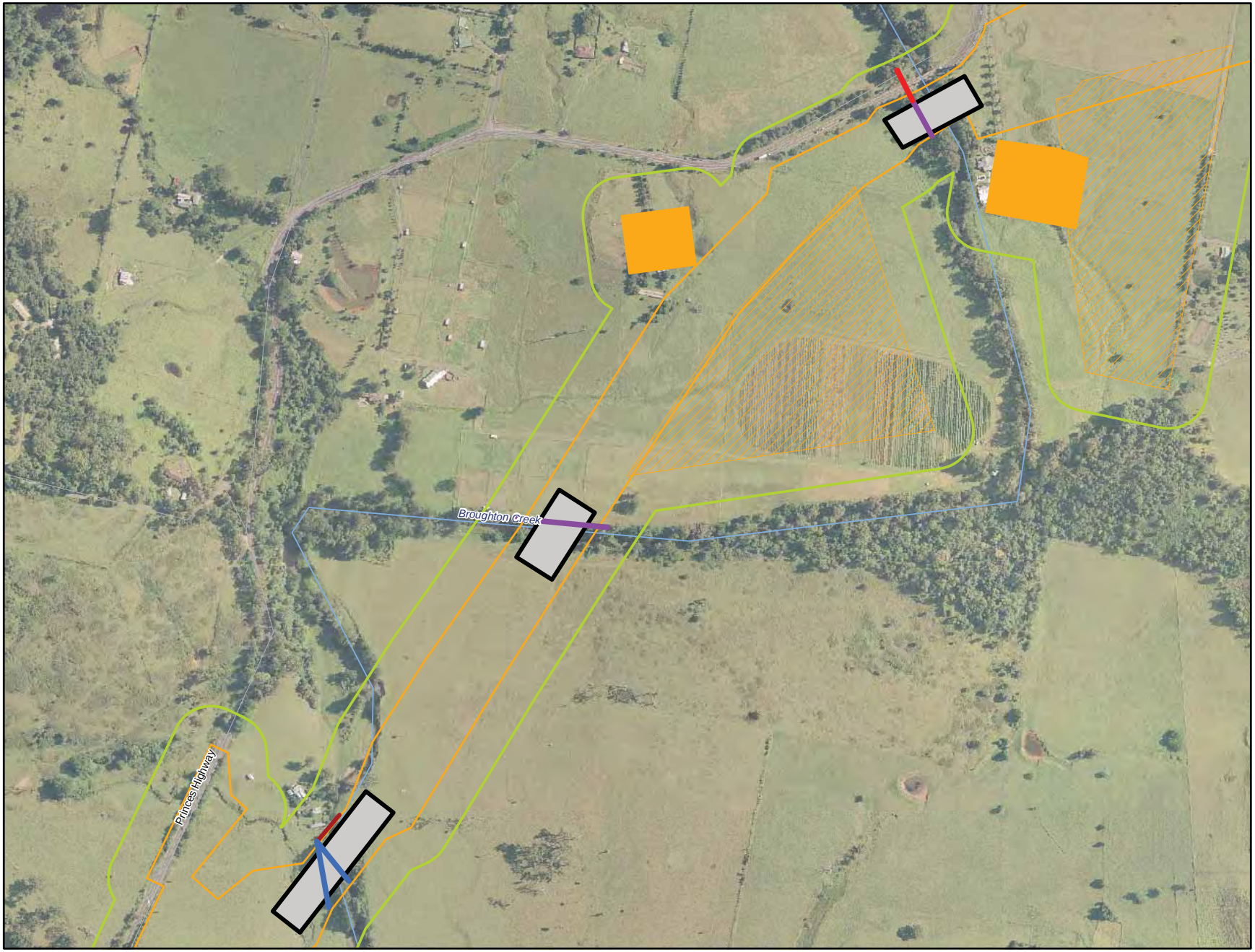
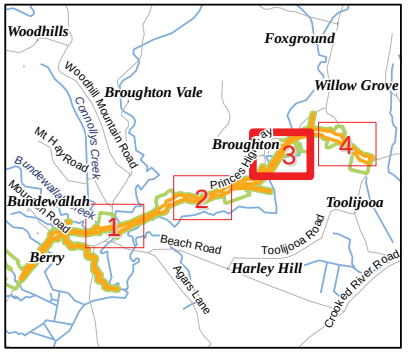
Figure 5.2





Legend

- Bridge (underpass)
- Dedicated Fauna Underpass
- Dual Use Underpass
- Fauna Fencing
- Rope Bridge Adjacent to Bridge
- Rope Bridge Over Road
- Rope Bridge Under Bridge
- Rope Bridge Over and Under Bridge
- Subject Site - Footprint
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 5.3: Fauna Mitigation Structures

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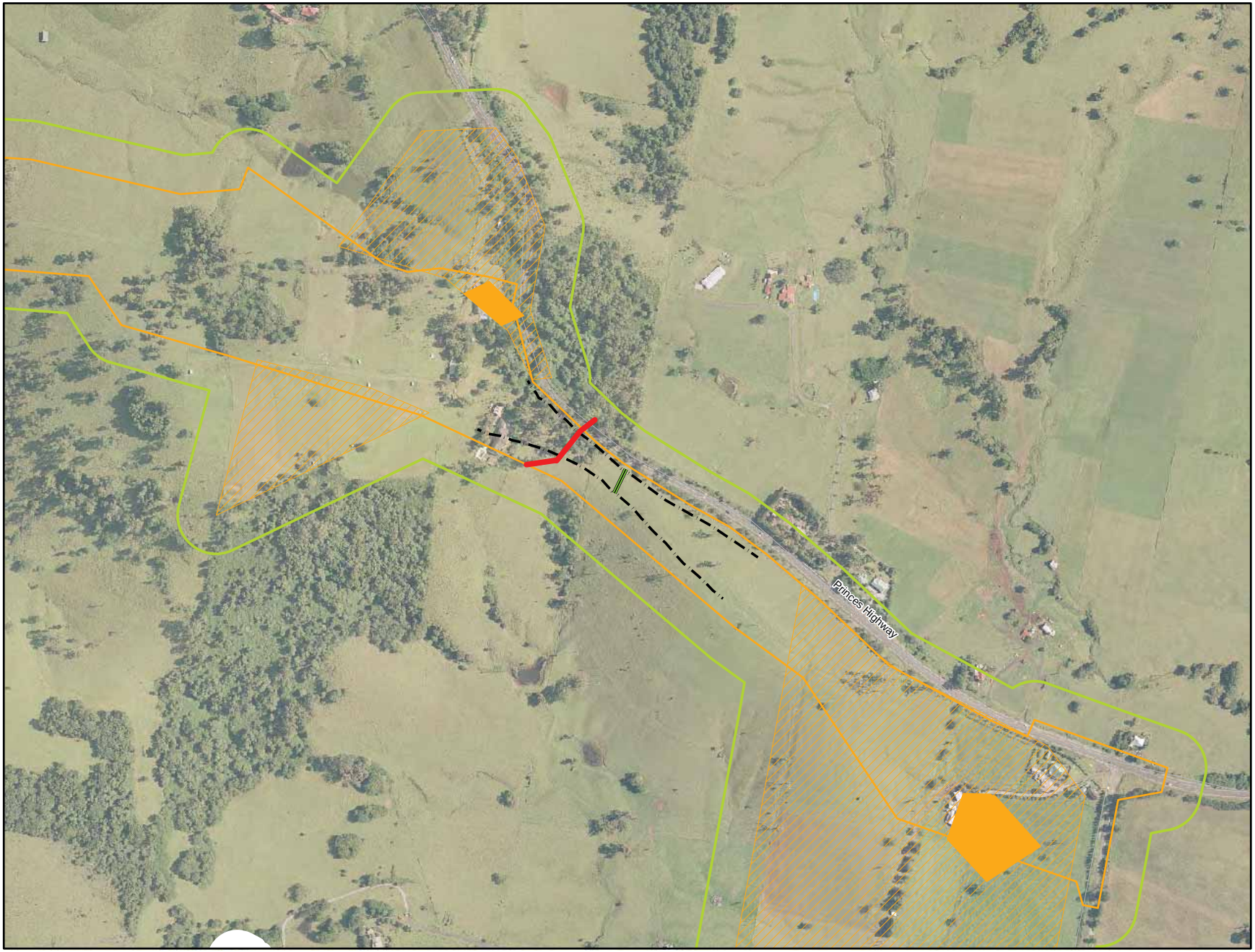
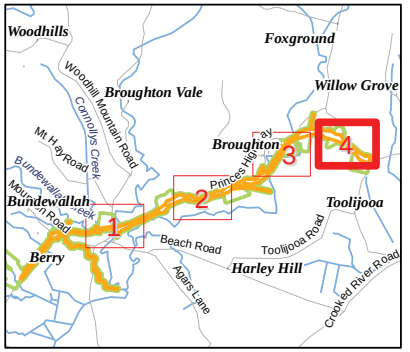
Figure 5.3





Legend

- Bridge (underpass)
- Dedicated Fauna Underpass
- Dual Use Underpass
- Fauna Fencing
- Rope Bridge Adjacent to Bridge
- Rope Bridge Over Road
- Rope Bridge Under Bridge
- Rope Bridge Over and Under Bridge
- Subject Site - Footprint
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 5.4: Fauna Mitigation Structures

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Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 55

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Figure 5.4

5.4 Mortality

It is recommended that the following management measures be implemented to reduce the risk of mortality.

Prior to and during construction

- Minimise clearance and disturbance of fauna habitat, particularly hollow-bearing trees and other habitat features where fauna may be sheltering. Although this may be difficult to achieve in areas where earthworks are to proceed, it should be particularly noted within the road reserve where temporary sites such as stockpiles may be placed.
- Clearing of vegetation would be undertaken in accordance with Guide 1 Pre-clearing process and Guide 4 Clearing of vegetation and removal of bushrock of the RMS 'Biodiversity Guidelines' (RTA 2011). These guides include procedures for clearing of non-habitat and habitat trees, the relocation of rescued fauna and the inclusion of wildlife specialists in the process.

To reduce the risk of roadkill once the highway is operational

- Implementation of fauna fencing as described in Section 5.3 to encourage fauna to cross the road under bridges and/or through culverts as opposed to the across the highway's surface.
- Avoid vegetation overhanging fauna fences that may encourage fauna crossing into the road reserve.
- Carefully consider the location and type of flora species for the verges and median strip so that they do not attract fauna species.
- Avoid the use of barbed wire fencing at glider crossing zones.

The above management measures would be included within the Construction Environmental Management Plan developed for the project.

5.5 Weeds

Management of weeds is outlined in Guide 6 Weed management of the RMS 'Biodiversity Guidelines' (RTA 2011). The objective of the weed management guide is to prevent or minimise the spread of noxious and environmental weed species on all RMS project sites and during maintenance works. In summary the RMS 'Biodiversity Guidelines' outline requirements for management of terrestrial and aquatic environmental and noxious weeds during construction and suggests best practice methods for weed management during maintenance works (RTA 2011).

In addition to the measures and management practices recommended in the RMS 'Biodiversity Guidelines' (RTA, 2011) the following actions should be implemented to reduce the impact of weed invasion on native plant communities:

- Restrict the area of native vegetation disturbed during construction works.
- Restrict stockpiling to areas already cleared of vegetation.
- Control drainage that may contain weed seeds or high levels of nutrients.
- Use weed-free topsoil in landscaping and revegetate disturbed sites with locally indigenous species (local provenance). Revegetation using stockpiled soil would also include planting local native species to stabilise the soil as well as ongoing weed control. Non-native species would only be used for landscaping where culturally appropriate and in locations identified within the urban and landscape design strategy.
- Monitor and control weed populations that establish in disturbed areas, with particular attention to eradication of noxious weeds. Weed invasions would be monitored and controlled by a person experienced in weed management.
- Weed management strategies would be incorporated into the VMP, detailing necessary weed control works, particularly in areas where the weeds may impact on threatened species and/or their habitats.
- Development and implementation of the VMP would be the responsibility of the RMS during the construction phase of the project. The party responsible for the implementation of the VMP during the operational phase of the project (RMS or Council) would be decided prior to commencement of the project.

Further detail on the methods to implement the actions recommended above are suggested in the RMS 'Biodiversity Guidelines' including a reference list of supporting documents and specific detailed weed management guides (RTA 2011).

5.6 Monitoring

Monitoring is an important part of any environmental management/mitigation strategy as there is generally not just one technique that can be applied to achieve any particular ecological goal. Therefore, an iterative and adaptive approach to monitoring provides the basis for updating and fine-tuning any management or mitigation strategy.

Monitoring the effectiveness of mitigation measures in order to evaluate the impact of road construction and operation on target species and their local populations is recommended. It is recommended that a monitoring program be developed for the project which would likely include the following measures:

- Qualified and licensed ecologist/fauna handler present for staged habitat removal and fauna rescue/relocation (in accordance with the RMS 'Biodiversity Guidelines' (RTA 2011)).
- Where existing culverts may be upgraded or extended, undertake pre-decommission surveys for Eastern Bentwing-bat or Southern Myotis using infra-red cameras and anabat call recording devices to determine if microbats present. If microbats are roosting in these culverts, an exclusion program will be required.
- Monitoring of sediment and erosion control measures during construction (usually part of a sediment and erosion management plan).
- Monitoring of edge effect and weed management measures. A monitoring program would be outlined in the VMP.

- Bi-annual monitoring of nest boxes and bat roost boxes by a qualified and licensed ecologist during construction and annual monitoring for three years post completion of construction.
- Monitoring of dedicated fauna underpasses and rope bridges (eg using remote cameras) by a qualified and licensed ecologist bi-annually during construction then at optimal times for detection of target species for a period of three years post completion of construction. Following three years of post construction monitoring consideration would be given to undertaking a further two years of monitoring in the event a negative impact on species is detected.
- A monitoring program would be produced, dictating the frequency of monitoring, however it is suggested that seasonal monitoring (ie spring, summer, autumn, winter) of dedicated fauna underpasses and rope bridges be undertaken using passive infra-red cameras.
- Regular checks of fauna fencing to identify and fix any damage. A monitoring program would be produced, delegating responsibility of fauna fence monitoring and outlining the frequency of monitoring.
- Road kill monitoring. This should occur during operation of the upgrade over a 12 month period at weekly intervals. The monitoring should include a record of the species (if possible) and the GPS location. The local council road cleansing teams may be contracted to undertake the monitoring or alternatively RMS southern region would undertake the monitoring.

5.7 Residual impacts

Residual impacts have been defined in this assessment as 'impacts that remain following actions to avoid and mitigate direct and indirect impacts'. Direct impacts however, are usually permanent and irreversible and mostly result in quantifiable residual impacts. The subject site of the current assessment has been considered as the area to be directly affected by the project (ie the development “footprint”). In addition the subject site is the area most likely to be affected by residual impacts, some of which can be managed by measures to mitigate the adverse effect of the residual impacts. Such mitigation measures are recommended in Section 5.1 - Vegetation clearing and habitat loss.

Indirect impacts occur when project related activities affect species, populations or ecological communities in an inadvertent manner. Indirect impacts can either be permanent or temporary if managed appropriately. This assessment has considered that indirect impacts may occur within the subject site and potentially extending for a 50 metre buffer from the subject site. However this assessment has considered that indirect impacts can be managed through avoidance and mitigation measures to reduce the potential for a residual impact resulting from indirect impacts of the project. These measures are recommended in Section 5.1 Vegetation clearing and habitat loss.

Step 4 of the ‘Guidelines for Threatened Species Assessment under Part 3A of the EP&A Act’ (DEC and DPI 2005) states that 'The extent to which measures avoid, mitigate or offset impacts upon threatened species must reflect the conservation value of the feature including its formal status as a critically endangered, endangered or vulnerable species, population or ecological community.' Therefore based on this statement and in view of the above discussion it is considered that;

- The project would not result in an adverse residual impact on non threatened native plant communities totalling 47.1 hectares inclusive of direct and indirect impacts.
- The project would not result in an adverse residual impact on the 7.1 hectares of the EEC RFEF subject to indirect impacts.
- The project would however, result in an adverse residual impact on the 2.9 hectares of the EEC RFEF subject to direct impacts.

Details of how the adverse residual impact on the 2.9 hectares of the EEC RFEF subject to direct impacts should be addressed is provided in Section 5.8.

5.8 Offsetting

"The most significant impact of the project would be the permanent loss of an estimated 2.9 hectares (direct impact) of River-flat eucalypt forest that despite being in generally poor condition has a high conservation status (ie EEC) (refer Table 4.1). Additionally the project would result in modification of an estimated 7.1 hectares (indirect impact), of River-flat eucalypt forest in similar condition (refer Table 4.1).

As a result of this, a Biodiversity Offset Strategy (to inform the Biodiversity Offset Package) has been prepared (Appendix E) to compensate for unavoidable adverse residual impacts to the EEC and to maintain or improve the long-term viability of the local occurrence of River-flat eucalypt forest and the habitat it may provide for threatened and non-threatened biodiversity.

Investigation of an offset for impacts to River-flat eucalypt forest has included consultation and negotiation with OEH. Offsetting the loss of significant biodiversity would need to consider (but not be limited to) principles such as:

- Ecological sustainability so that the offset measures ensure the long-term viability and functionality of biodiversity. For example commitment to enhancement of existing habitat and securing and managing land of conservation value for biodiversity.
- A net improvement in biodiversity over time.
- Longevity whereby the measures must offset the impact of the development for the period that the impact occurs.
- Agreement of the offset prior to the impact occurring.
- Quantification so that the impacts and benefits can be reliably estimated.
- Offset like-for-like or better. In the first instance it is recommended that all avenues to match the type of biodiversity be investigated. Where there are considerable limitations to this then other options should be considered. For example ecological communities that are of equal or greater conservation status to the type of ecological community lost are used for an offset.

In view of a commitment and subject to a satisfactory agreement of a Biodiversity Offset Package negotiated with the DP&I and OEH, the project could result in an improvement of biodiversity values for River-flat eucalypt forest, fauna subject species and general biodiversity in the locality and region.

6 Assessment of impacts

6.1 NSW Part 3A guidelines for threatened species assessment (EP&A Act)

The impacts of the project on threatened species, populations and ecological communities listed under the TSC Act have been undertaken following the Guidelines for Threatened Species Assessment under Part 3A of the EP&A Act (DEC and DPI 2005). Where threatened species, populations and/or communities are recorded within a study area, an assessment of significance is required under the EP&A Act. When threatened species, populations and/or communities are not recorded during a survey, the presence of potential habitat for a species (or population or community) is used to determine the need to undertake an assessment of significance under the EP&A Act. Where there is no potential habitat in the study area for threatened species, populations and/or communities, there is unlikely to be any impact and therefore these species (or populations or communities) are not required to be considered further.

6.1.1 Endangered ecological communities

One EEC was recorded in the study area (**Table 3.1**): Riverbank forest. Riverbank forest meets the criteria for the EEC *River-flat eucalypt forest on coastal floodplains of the North Coast, Sydney Basin and South East Corner bioregions*.

The project would result in direct impacts to about 2.9 hectares of this community with a further 7.1 hectares potentially subject to indirect impacts (**Figure 3.1** and Appendix J). Areas where River-flat eucalypt forest EEC would be impacted by either direct removal or edge effects for the construction and operation of the project including the permanent roadway, drainage diversions and temporary creek crossings are at:

- Bundewallah Creek north of Rawlings Lane (**Figure 3.1.4**, Appendix J).
- The junction of Bundewallah Creek and Connollys Creek and downstream to Broughton Mill Creek (**Figure 3.1.7**, Appendix J).
- Broughton Creek to the east of Berry on the southern side of the Princes Highway (**Figure 3.1.8**, Appendix J).
- Broughton Creek to the south east and east of the intersection of Tomlins Road and Princes Highway, at Broughton (**Figure 3.1.12**, Appendix J).
- Broughton Creek to the east of the intersection of Thompson Road and Princes Highway, at Broughton (**Figure 3.1.13**, Appendix J).

According to the vegetation mapping a total of 65.7 hectares of this EEC occurs within the locality (**Table 3.1**).

On this basis, an assessment of impact following the Guidelines for Threatened Species Assessment under Part 3A of the EP&A Act has been carried out for this EEC (Appendix G). The assessment of significance for the TSC Act-listed EEC River-flat eucalypt forest concluded that although a significant impact by the project on this EEC would be unlikely (due to the implementation of actions to avoid and mitigate direct and indirect impacts of the project), a residual impact would occur due to the unavoidable loss of/disturbance to the EEC (10 hectares; equivalent to 15.2 per cent of River-flat eucalypt forest in the locality; **Table 3.1**). Therefore, a biodiversity offset strategy (Appendix E) has been prepared to compensate for the unavoidable loss and residual impact on River-flat eucalypt forest from the project.

The project would result in further fragmentation of the riparian vegetation in the study area. However impacts on River-flat eucalypt forest are not considered to be significant, on the basis that:

- River-flat eucalypt forest in the study is highly fragmented.
- River-flat eucalypt forest that will be subject to direct impacts and potential indirect impacts is currently in poor condition.
- Mitigation measures would be implemented to minimise the direct and potential indirect impacts on River-flat eucalypt forest in the study area (see Chapter 5).

A biodiversity Offset Strategy (Appendix E) has been prepared to compensate for the unavoidable loss and residual impact on River-flat eucalypt forest EEC from the project.

6.1.2 Flora

No threatened flora species were recorded in the study area. However, of the 32 threatened flora species considered in Appendix C, five species (*Cynanchum elegans*, *Cryptostylis hunteriana, Daphnandra* sp. 'Illawarra', *Irenepharsus trypherus* and *Zieria granulata*) are considered to have potential habitat in the study area. Based on the number and distribution of previous records of these five species, *Cynanchum elegans*, *Daphnandra* sp. and *Zieria granulata* have a high likelihood of occurring within the study area. Two species, *Cryptostylis hunteriana* and *Irenepharsus trypherus* are considered unlikely to occur in the study area or locality. OEH have specified that *Pterostylis gibbosa*, *Cryptostylis hunteriana* and *Genoplesium baueri* require consideration as subject species.

In view the above, assessments of impact following the' Guidelines for Threatened Species Assessment under Part 3A of the EP&A Act' have been carried out for the seven flora species cited above. These include the four subject species determined by Biosis Research and the additional three species that OEH has required to be specifically considered (OEH correspondence dated 31 January 2011 (Appendix C). The Part 3A threatened species assessments of significance are provided in Appendix G.

Daphnandra (*Daphnandra* sp. 'Illawarra') and Zieria (*Zieria granulata*) were recorded to the south of the study area during broader surveys. The alignment of the project avoids direct and indirect impacts on known records of these species. White-flowered Wax Plant (*Cynanchum elegans*) is recorded in the north eastern sector of the study area about 3.5 kilometres from the eastern end of the project. Delicate Cress (*Irenepharsus trypherus*), Illawarra Greenhood (*Pterostylis gibbosa*), Leafless Tongue-orchid (*Cryptostylis hunteriana*) and Bauer's Midge Orchid (*Genoplesium baueri*) have not been previously recorded within the locality or broader 10 kilometre OEH Atlas of NSW Wildlife searches.

The assessments of significance concluded that the project would have a minimal impact on flora subject species or their potential habitat in the locality based on the following:

- No individuals were recorded in the study area despite targeted surveys, including for those that are considered relatively conspicuous.
- The area of potential habitat impacted within the study area compared to that in the locality is considered small.
- Impacts resulting from the project are largely contained to areas that are already cleared and disturbed and include existing road infrastructure.
- Potential habitat in the study area is currently fragmented and subject to edge effects.
- The project is unlikely to interfere with the pollination and dispersal of native flora species.

6.1.3 Fauna

Where there is potential habitat (foraging or breeding resources) for threatened species in the study area, further consideration must be given to the potential impact of the project on these species. The project may impact on threatened species by causing any of the following:

- Death or injury of individuals.
- Loss or disturbance of limiting foraging resources.
- Loss or disturbance of limiting breeding resources.

Limiting resources are specialised habitat components that species are dependent on for their ongoing survival. Such limiting resources are predominantly associated with specialised breeding habitats (such as tree hollows or suitable nest/maternity roost sites) that occur at low densities, with high levels of competition from a range of species. However, for some species, limiting resources include specialised foraging habitats that have a restricted distribution (eg Koalas feeding only on specific tree species).

Nine threatened species were recorded during the field surveys: Gang-gang Cockatoo, Powerful Owl, Yellow-bellied Sheathtail Bat, Eastern Freetail Bat, Grey-headed Flying-fox, Eastern Bentwing-bat, Eastern False Pipistrelle, Southern Myotis and Greater Broad-nosed Bat. These nine species, along with an additional 42 TSC Act-listed fauna species with potential habitat identified in the study area, have been considered as subject species (Appendix D). Eighteen of the 51 subject species were also specified in correspondence from OEH dated 31 January 2011.

Table 6.1 summarises the possible impacts from the project on the 51 TSC Act-listed threatened fauna with known and/or potential habitat in the study area, and determines the need for Part 3A assessments of significance. Based on the nature of the project (Section 1.4), database interrogation, literature review regarding the ecology of each species, and information gathered during field surveys within the study area, 27 of these species are considered as unlikely to be subject to negative impacts resulting from the project (**Table 6.1**). Accordingly, no Part 3A assessments of significance have been prepared for these species (see Appendix H for more details).

Part 3A assessments of significance have been prepared for the 24 species that may be impacted by the project. These species are: Green and Golden Bell Frog[2], Black Bittern, Bush Stone-curlew, Gang-gang Cockatoo, Glossy Black-cockatoo, Little Lorikeet, Swift Parrot, Turquoise Parrot, Barking Owl, Powerful Owl, Masked Owl, Sooty Owl, Eastern Pygmy-possum, Spotted-tailed Quoll, Yellow-bellied Glider, Koala, Long-nosed Potoroo, Grey-headed Flying-fox, Eastern Bentwing-bat, Southern Myotis, Yellow-bellied Sheathtail-bat, Eastern Freetail Bat, Eastern False Pipistrelle and Greater Broad-nosed Bat (Appendix G).

6.1.4 Conclusions of flora and fauna Part 3A assessments of significance

The assessments of significance (Appendix G) concluded that the project is likely to have minor impacts on threatened flora and fauna species as listed on the TSC Act, provided recommended mitigation measures (Chapter 5) are implemented.

[2] A Part 3A assessment of significance was undertaken for the Green and Golden Bell Frog based on removal/modification of non-limiting dispersal habitat as a precautionary measure given the proximity to the Coomonderry Swamp Key Population.

6.1.5 Key thresholds

The Part 3A Guidelines of the EP&A Act (DEC and DPI 2005) set out a number of key thresholds which need to be addressed to justify the impacts of the project on threatened species, populations and ecological communities. The key thresholds are (DEC and DPI 2005):

- Whether or not the project, including actions to avoid or mitigate impacts or compensate to prevent unavoidable impacts, would maintain or improve biodiversity values.
- Whether or not the project is likely to reduce the long-term viability of a local population of the species, population or ecological community.
- Whether or not the project is likely to accelerate the extinction of the species, population or ecological community or place it at risk of extinction.
- Whether or not the project would adversely affect critical habitat.

Based on the assessments of significance following the Guidelines for Threatened Species Assessment under Part 3A of the EP&A Act (Appendix G), the project is unlikely to reduce the long-term viability of, accelerate the extinction of and/or adversely affect critical habitat for threatened species within the locality.

Maintenance of biodiversity values

Given that 57.1 hectares of native vegetation, including potential habitat for threatened species and an EEC, would be impacted by the project (including 30.4 hectares subject to direct impacts and 26.7 hectares subject to indirect impacts), some biodiversity values of the locality would be lost (**Table 4.1**). The loss of biodiversity values would be minimised by incorporating the mitigation measures detailed in **Chapter 5**, particularly measures to avoid significant habitat features; the provision of fauna under and over passes; rehabilitation of intact native vegetation that would be disturbed by the project; and, revegetation of disturbed areas to improve habitat connectivity. Rehabilitation of disturbed areas is critical to maintaining biodiversity values of the impacted areas.

A biodiversity offset strategy (Appendix E) has been prepared to compensate for the unavoidable loss of and residual impact on River-flat eucalypt forest from the project.

Given the above, the project is considered likely to maintain or improve biodiversity values.

Table 6.1: Potential impact and Part 3A assessment of significance requirements for threatened fauna listed on the TSC Act with potential habitat in the study area.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?	
Green and Golden Bell Frog	V	E1	Unlikely	No	No	**Yes – undertaken as a precautionary measure due to the proximity to the Coomonderry Swamp Key Population**
Spotted Harrier	-	V	Unlikely	No	No	No
Little Eagle	-	V	Unlikely	No	No	No
Square-tailed Kite	-	V	Unlikely	No	No	No
Osprey	M	V	Unlikely	No	No	No
Blue-billed Duck Freckled Duck	-	V	Unlikely	No	No	No
Australasian Bittern	-	V	Unlikely	No	No	No
Black Bittern	-	V	Unlikely	No	No	**Yes**
Bush Stone-curlew	-	E1	Unlikely	No	No	**Yes**
Gang-gang cockatoo	-	V	Possible	No	Yes	**Yes**
Glossy Black-cockatoo	-	V	Possible	Yes	Yes	**Yes**
Greater Sand Plover	M	V	Unlikely	No	No	No
Black-necked Stork	-	E1	Unlikely	No	No	No
Wompoo Fruit- dove	-	V	Unlikely	Yes	No	No

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?	
Rose-crowned Fruit-dove Superb Fruit-dove						
Pied Oystercatcher	-	V	Unlikely	No	No	No
Comb-crested Jacana	-	V	Unlikely	No	No	No
Regent Honeyeater	E	E1	Unlikely	No	No	No
White-fronted Chat	-	V	Unlikely	No	No	No
Varied Sittella	-	V	Unlikely	No	No	No
Olive Whistler	-	V	Unlikely	No	No	No
Eastern Bristlebird	E	E1	Unlikely	No	No	No
Diamond Firetail	-	V	Unlikely	No	No	No
Scarlet Robin	-	V	Unlikely	No	No	No
Flame Robin	-	V	Unlikely	No	No	No
Little Lorikeet	-	V	Possible	No	Yes	**Yes**
Swift Parrot	E	E1	Unlikely	Yes	No	**Yes**
Orange-bellied Parrot	ZM	C1	Unlikely	No	No	No
Turquoise Parrot	-	V	Unlikely	No	Yes	**Yes**
Eastern Ground Parrot	-	V	Unlikely	No	No	No
Australian Painted Snipe	V	E1	Unlikely	No	No	No
Barking Owl Powerful Owl Masked Owl	-	V	Possible	No	Yes	**Yes**

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?	
Sooty Owl						
Eastern Pygmy-possum	-	V	Unlikely	No	No	**Yes**
Spotted-tailed Quoll	E	V	Unlikely	No	Yes	**Yes**
White-footed Dunnart	-	V	Unlikely	No	No	No
Yellow-bellied Glider	-	V	Unlikely	No	No	**Yes**
Koala	V	V	Unlikely	No	No	**Yes**
Long-nosed Potoroo	V	V	Unlikely	No	No	**Yes**
Grey-headed Flying-fox	V	V	Unlikely	No	No	**Yes**
Large-eared Pied Bat	V	V	Unlikely	No	No	No
Eastern Bentwing-bat Southern Myotis	-	V	Unlikely	No	No	**Yes**
Yellow-bellied Sheathtail Bat Eastern Freetail Bat Eastern False Pipistrelle Greater Broad-nosed Bat	-	V	Possible	No	Yes	**Yes**

6.2 Commonwealth significant impact criteria (EPBC Act)

Under the Commonwealth EPBC Act, if the project has the potential to have an adverse impact on threatened species, populations and/or ecological communities as listed under the Act, the project must be referred to the Commonwealth Minister for Sustainability, Environment, Water, Population and Communities for further consideration. The DSEWPaC publication *EPBC Act Policy Statement 1.1 Significant Impact Guidelines: Matters of National Environmental Significance* (DEWHA 2009) was used to assess the likelihood of impact on EPBC Act-listed species.

6.2.1 Endangered ecological communities

No EECs listed under the EPBC Act were recorded in or adjoining the study area.

6.2.2 Flora

No threatened flora species listed under the EPBC Act were recorded in the study area. However, of the 14 EPBC Act-listed threatened flora species considered in Appendix C, four species (*Cynanchum elegans*, *Daphnandra* sp. 'Illawarra', *Irenepharsus trypherus* and *Zieria granulata*) are considered to have potential habitat within the study area as a result of the field surveys and desktop analysis by Biosis Research. In addition to these four species, the OEH have specified a further two EPBC Act-listed threatened flora species, *Pterostylis gibbosa* and *Cryptostylis hunteriana*, that require consideration as subject species. One of these two additional species, *Cryptostylis hunteriana* is considered to have potential habitat in the study area but is unlikely to be present based on the absence of records within the locality.

The impacts of the project on these six species has been assessed against the relevant significant impact criteria (Appendix I) in accordance with the DSEWPaC publication *EPBC Act Policy Statement* (DEWHA 2009). *1.1 Significant Impact Guidelines: Matters of National Environmental Significance*

The project is unlikely to have a significant impact on the five species listed as Endangered under the EPBC Act (*Cynanchum elegans*, *Daphnandra* sp. 'Illawarra', *Irenepharsus trypherus*, *Zieria granulata* and *Pterostylis gibbosa*) as there is not a real chance or possibility that it would:

- Lead to a long-term decrease in the size of a population.
- Reduce the area of occupancy of the species.
- Fragment an existing population into two or more populations.
- Adversely affect habitat critical to the survival of a species.
- Disrupt the breeding cycle of a population.
- Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.
- Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered species' habitat.
- Introduce disease that may cause the species to decline.
- Interfere with the recovery of the species.

The project is unlikely to have a significant impact on the one species listed as Vulnerable under the EPBC Act (*Cryptostylis hunteriana*) as there is not a real chance or possibility that it would:

- Lead to a long-term decrease in the size of an important population of the species.
- Reduce the area of occupancy of an important population.
- Fragment an existing important population into two or more populations.
- Adversely affect habitat critical to the survival of a species.
- Disrupt the breeding cycle of an important population.
- Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.
- Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat.
- Introduce disease that may cause the species to decline.
- Interfere with the recovery of the species.

6.2.3 Fauna

Threatened species

Five species listed as Endangered or Critically Endangered under the EPBC Act have potential habitat in the study area: Regent Honeyeater, Eastern Bristlebird, Swift Parrot, Orange-bellied Parrot and Spotted-tailed Quoll. As shown above (**Table 6.1**), no limiting breeding habitat or foraging habitat is expected to be impacted for the Regent Honeyeater, Eastern Bristlebird or Orange-bellied Parrot. No assessments have been carried out for the Regent Honeyeater, Eastern Bristlebird or Orange-bellied Parrot, in accordance with the Significant Impact Criteria (DEWHA 2009) as the project is unlikely to:

- Lead to a long-term decrease in the size of a population.
- Reduce the area of occupancy of the species.
- Fragment an existing population into two or more populations.
- Adversely affect habitat critical to the survival of a species.
- Disrupt the breeding cycle of a population.
- Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.
- Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat.
- Introduce disease that may cause the species to decline.
- Interfere with the recovery of the species.

The project may impact limiting foraging habitat for the Swift Parrot and/or impact habitat connectivity for the Spotted-tailed Quoll. Therefore, Significant Impact Criteria assessments have been carried out for these two species (Appendix I). The assessments of significance concluded a significant impact on these species by the project to be unlikely provided the mitigation measures detailed in Chapter 5 are implemented.

Six species listed as Vulnerable under the EPBC Act that have known and/or potential habitat in the study area include the Green and Golden Bell Frog, Australian Painted Snipe, Long-nosed Potoroo, Grey-headed Flying-fox (recorded during field surveys), Koala and Large-eared Pied Bat. As shown above (**Table 6.1**), no limiting breeding habitat or foraging habitat is expected to be impacted for the Green and Golden Bell Frog, Australian Painted Snipe or Large-eared Pied Bat. If present within the study area, individuals of Australian Painted Snipe and Large-eared Pied bat are not considered 'important populations' as they are not likely to be key source populations either for breeding or dispersal; populations that are necessary for maintaining genetic diversity; and/or populations that are near the limit of the species range.

However, the project is not likely to:

- Lead to a long-term decrease in the size of an important population.
- Reduce the area of occupancy of an important population.
- Fragment an existing important population into two or more populations.
- Disrupt the breeding cycle of an important population.
- Adversely affect habitat critical to the survival of any of these species.
- Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that any of these species is likely to decline.
- Result in invasive species that are harmful to any of these vulnerable species becoming established in the vulnerable species' habitat.
- Introduce disease that may cause any of these species to decline.
- Interfere substantially with the recovery of any of these species.

As such, no assessments have been carried out for the Australian Painted Snipe or Large-eared Pied Bat, in accordance with the Significant Impact Criteria (DEWHA 2009). The project may, however, impact habitat connectivity for the Long-nosed Potoroo and/or impact known foraging habitat for the Grey-headed Flying-fox. Although the study area is considered unlikely to support limiting breeding resources for the Green and Golden Bell Frog, individuals of this species occurring in the study area may be from 'important populations' and may be key source individuals for dispersal and maintaining genetic diversity. Therefore, Significant Impact Criteria assessments have been carried out for these three species (Appendix I).

Several species of SEPP 44-listed Koala feed trees (*Eucalyptus microcorys, E. racemosa, E. robusta* and *E. tereticornis*) have been recorded in forest and woodland habitats of the study area. Additionally, primary and secondary food tree species (*Eucalyptus amplifolia* ssp*. amplifolia, E. tereticornis* and *Eucalyptus scias* ssp. *scias*) from Appendix 2 of the Recovery Plan (DECC, 2008) have been recorded in the flora surveys. Although the study area is considered unlikely to support a population of Koala it is possible that the species moves through the study area on occasion between areas of potential habitat. On this basis a Significant Impact Criteria assessment has been carried out for Koala and is included in Appendix I. The assessment has considered the criteria for assessing habitat critical to the survival of the species from the *Interim Koala referral advice for proponents* (DSEWPaC, 2012).

The assessments of significance concluded a significant impact on the Green and Golden Bell Frog, Long-nosed Potoroo, Grey-headed Flying-fox and Koala by the project to be unlikely provided the mitigation measures detailed in Chapter 5 are implemented.

Migratory species

The list of migratory species under the EPBC Act is a compilation of species listed under four international conventions: China-Australia Migratory Bird Agreement (CAMBA), Japan-Australia Migratory Bird Agreement (JAMBA), Republic of Korea-Australia Migratory Bird Agreement (RoKAMBA), and the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

Fifty-one migratory species (or their habitat) have been previously recorded within 10 kilometres of the study area. Six of these species were recorded during the field surveys: White-bellied Sea-eagle, Fork-tailed Swift, Cattle Egret, Black-faced Monarch, Rufous Fantail and Australian Reed-warbler. Potential habitat exists in the study area for an additional 23 migratory species (Appendix D).

Migratory waders are the most common migratory species recorded in the locality. While Coomonderry Swamp, Seven Mile Beach National Park, Crooked River Estuary and Black Head are used on occasion or regularly by these species, individuals of these species that have been or may be recorded in the study area are not considered likely to be an ecologically significant proportion of their populations. Similarly, individuals of other migratory birds (eg forest/woodland birds) that have been or may be recorded in the study area are not considered likely to be an ecologically significant proportion of their populations. Known and/or potential habitat in the study area is not considered important for the migratory species listed in Appendix D. Only previously disturbed and/or edge-affected areas of forest and woodland, as well as farmland, would be removed by the project and indirect impacts are not expected to occur beyond 50 metres from the subject site. Habitat/corridor fragmentation is considered unlikely to significantly impact these mobile species. Given the minimal impact expected on the known and/or potential habitat for these species in the study area, no assessments have been carried out for these species, in accordance with the Significant Impact Criteria (DEWHA 2009).

6.2.4 Conclusions of significant impact criteria assessments

The Significant Impact Criteria Assessments under the EPBC Act (Appendix I) concluded that the project is unlikely to have a significant impact on threatened species, populations and/or ecological communities or their habitats listed under the Act, provided the mitigation measures detailed in Chapter 5 are implemented.

A Referral to the Australian Government Minister of the Department of Sustainability, Environment, Water, Population and Communities is not considered necessary.

7 Conclusion

This report assesses the ecological significance of threatened flora and fauna species, endangered populations and EECs that occur, or have the potential to occur, within the area affected by the project, in accordance with the EP&A Act, the TSC Act and the EPBC Act.

Four naturally occurring native plant communities and four derived native plant communities totalling 58 hectares are mapped in the study area. It is estimated the project would directly impact on 30.4 hectares of naturally occurring and derived native plant communities and up to 26.7 hectares may be indirectly impacted.

One EEC was recorded in the study area and would be impacted by the project. About 10 hectares of the EEC River-flat eucalypt forest would be impacted by the project (some 2.9 hectares directly and 7.1 hectares indirectly). This EEC was considered to be in poor condition within the study area, with an understorey completely dominated by invasive weed species. An assessment of significance undertaken for this vegetation community according to the Part 3A Guidelines (DEC and DPI 2005) concluded the project is unlikely to have a significant impact on this EEC, provided the mitigation measures outlined in Chapter 5, and an adequate Offset Package, are implemented.

A further two EECs are present in the locality that have been identified by OEH as EECs to be addressed as subject ecological communities. The EECs Illawarra subtropical rainforest and Illawarra lowlands grassy woodland are mapped in the locality but not on the subject site (DEC 2005o). Neither of these vegetation communities has been recorded in the study area during the field surveys. Assessments of significance according to Part 3A Guidelines (DEC and DPI 2005) concluded the project is unlikely to have a significant impact on these EECs.

No threatened flora species were recorded in the study area, however potential habitat exists for four threatened flora species (all listed under both the TSC Act and the EPBC Act): *Cynanchum elegans*, *Daphnandra* sp. 'Illawarra', *Irenepharsus trypherus* and *Zieria granulata*. Assessments of significance undertaken for each threatened flora species concluded the project was unlikely to have a significant impact on these species.

Although not recorded in the study area in the current surveys or in the locality from database records, an additional three threatened flora species have been assessed as subject species as specified by the former DECCW. Assessments of significance undertaken for *Pterostylis gibbosa*, *Cryptostylis hunteriana* and *Genoplesium baueri* concluded the project is unlikely to have a significant impact on these three flora species.

Nine threatened and six migratory fauna species were recorded during the field surveys. Based on the proximity of current and previous records and the presence of identified habitat preferences, known and/or potential habitat exists within the study area for 51 threatened and 29 migratory fauna species. Impacts to the known/potential habitat of 27 threatened species were considered negligible and therefore, assessments of significance were not conducted for these species. Assessments of significance were carried out for the remaining 24 threatened fauna species (24 listed on the TSC Act and four listed on the EPBC Act). The assessments concluded the project is unlikely to have a significant impact on any TSC or EPBC Act-listed species, provided the mitigation measures outlined in Chapter 5 are implemented.

A referral to the Australian Government Environment Minister is not required for the project.

8 References

Abigroup (2007) 'Bonville Pacific Highway Upgrade Project: Flora and Fauna Management Sub Plan (FFMSP) (incorporating the Weed Management Plan & Translocation Management Plan).' Report for NSW Roads and Traffic Authority No. Abigroup Document No. FFMSP.01.

AECOM (2012). Princes Highway upgrade - Foxground and Berry bypass - Surface water, groundwater and flooding assessment.

AMBS (1997) 'Fauna Usage of Three Underpasses beneath F3 Between Sydney & Newcastle.' Australian Museum Business Consulting, Sydney.

AMBS (2001a) 'An investigation of the use of road overpass structures by arboreal marsupials.' Australian Museum Business Services, Sydney.

AMBS (2001b) 'Fauna Underpass Monitoring Stage One - Final Report - Brunswick Heads.' AMBS for RTA, Sydney.

AMBS (2001c) 'Fauna Underpass Monitoring Stage One - Final Report - Herons Creek.' AMBS for RTA, Sydney.

AMBS (2001d) 'Fauna Underpass Monitoring Stage One - Final Report - Taree.' AMBS for RTA, Sydney.

AMBS (2002) 'Fauna Underpass Monitoring Stage Two, Episode Five. Bulahdelah to Coolongolook.' AMBS Consulting for RTA, Sydney.

ANOS (2008). Genoplsium baueri, http://www.anos.org.au/conservation/genoplsium-baueri/, Australasian Native Orchid Society.

Augee M and Ford D (1999) Radio-tracking studies of Grey-headed Flying-foxes, *Pteropus poliocephalus*, from the Gordon colony, Sydney. *Proceedings of the Linnaean Society of New South Wales* 121**,** 61-70.

Australian Museum (2009). Flame Robin Fact File, http://www.austmus.gov.au/factsheets/flame_robin.htm, Australian Museum

Australian National Botanic Gardens (2007). Australian Plant Name Index, http://www.anbg.gov.au/cpbr/databases/apni.html, Australian National Botanic Gardens, Accessed 2007

Bali R (2000) 'Discussion paper - Compensating for Edge Effects.' Biosis Research for the Roads and Traffic Authority, Sydney.

Bali R (2005) 'Discussion paper - Compensating for Edge Effects.' Report for the NSW Roads and Traffic Authority, Ecosense Consulting., Sydney.

Ball TM and Goldingay RL (2008) Can wooden poles be used to reconnect habitat for a gliding mammal? *Landscape and Urban Planning* 87**,** 140-146.

Barker J *et al.* (1995) 'A Field Guide to Australian Frogs.' Surrey Beatty and Sons, Sydney.

Bax D (2006) 'Karuah Bypass Fauna Crossing Report.' Prepared for RTA.

Belcher C *et al.* (2008) Spotted-tailed Quoll *Dasyurus maculatus*. Pp. 60-62 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Bennett AF (1987). Conservation of mammals within a fragmented forest environment: the contributions of insular biogeography and autecology. In: Saunders, D.A., G.W. Arnold, A.A.

Burbridge & A.J.M. Hopkins, eds. Nature conservation: the role of remnants of native vegetation. Page(s) 41-52. Chipping Norton, NSW: Surrey Beatty & Sons.

Bennett AF (1990) 'Habitat Corridors: Their Role in Wildlife Management and Conservation.' Department of Conservation and Environment, Sydney.

Benson D and McDougall L (2001) Ecology of Sydney Plant Species Part 8: Rutaceae to Zygophyllaceae. *Cunninghamia* 7.

Berry L (2002) Predation rates of artificial nests in the edge and interior of a southern Victorian forest. *Wildlife Research* 29**,** 341-345.

Biosis Research (2000) 'Discussion paper - Compensating for edge effects.' Biosis Research for RTA, Sydney.

Biosis Research (2007) 'Gerringong to Bomaderry Princes Highway Upgrade - Route Options Development, Appendix G - Preliminary Biological Report (Terrestrial Flora and Fauna) November 2007.'

Bird's Australia. (2009). The Atlas of Australian Birds - database search (August 2009)

Bishop T (1996) 'Field Guide to the Orchids of New South Wales and Victoria.' UNSW Press, Sydney.

Blakers M *et al.* (1984) 'The Atlas of Australian Birds.' Melbourne University Press, Melbourne.

Boehm EF (1944) The Fork-tailed Swift in South Australia. *South Australian Ornithology* 15**,** 54-58.

Bond A and JONES DN (2008) Temporal Trends in use of fauna-friendly underpasses and overpasses. *Wildlife Research* 35**,** 103-112.

Braithwaite RW (1995) Southern Brown Bandicoot. Pp. 176-177 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

Breckwoldt R (1990) 'Living Corridors - Conservation & Management of Roadside Vegetation.' Greening Australia Ltd, ACT.

Cameron M (2007) 'Cockatoos.' CSIRO Publishing, Melbourne.

CEL (2012) Aquatic Ecology and Water Quality Management Assessment, Foxground and Berry bypass. Prepared for RTA September 2011. Cardno Ecology Lab Sydney.

Churchill S (1998) 'Australian Bats.' Reed New Holland, Sydney.

Churchill S (2008) 'Australian Bats. Second Edition.' Allen & Unwin, Sydney.

Claridge AW, MT Tanton, JH Seebeck, SJ Cork & RB Cunningham (1992) 'Establishment of ectomycorrhizae on the roots of two species of Eucalyptus from fungal spores contained in the faeces of the long-nosed potoroo (Potorous tridactylus)'. Australian Journal of Ecology. 17: 207-217.

Claridge A *et al.* (2007) 'Bettongs, Potoroos and the Musky Rat-kangaroo.' CSIRO Publishing, Melbourne.

Cogger HG (1992) 'Reptiles and Amphibians of Australia.' Reed Books, Sydney.

Daly G (1996) Observations of the Eastern Owl Frog *Helioporous australiacus* (Anura: Myobatrachidae) in Southern NSW. *Herpetofauna* 26**,** 33-42.

Debus S and Chafer C (1994a) The Powerful Owl *Ninox strenua* in New South Wales. *Australian Birds* 28**,** 21-39.

Debus S and Chafer C (1994b) The Sooty Owl, *Tyto tenebricosa* & Powerful Owl, *Ninox strenua* in NSW. *Australian Birds* 28 Supplement**,** 2.

DEC (1999). Squirrel Glider: Threatened Species Information, http://www2.nationalparks.nsw.gov.au/PDFs/tsprofile_squirrel_glider.pdf, NSW Department of Environment, Climate Change and Water

DEC (2004a) 'Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities - Working Draft.' DEC, Hurstville NSW.

DEC (2004b). Yellow-bellied Glider feed trees, http://www2.nationalparks.nsw.gov.au/PDFs/landholder_notes_03_YellowBelliedGlider.pdf,

DEC (2005a). *Acacia baueri* ssp. *aspera* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10005, Department of Environment and Conservation

DEC (2005b). Barking Owl: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10561, Department of Environment and Conservation

DEC (2005c). Black Bittern: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10441,

DEC (2005d). *Caladenia tessellata* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10124, Department of Environment and Conservation

DEC (2005e). *Cryptostylis hunteriana* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10187, Department of Environment and Conservation

DEC (2005f). Distichlis distichophylla - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10234,

DEC (2005g). Eastern Pygmy-possum: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10155, Department of Environment and Conservation

DEC (2005h). Eucalyptus sturgissiana - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10318,

DEC (2005i). *Genoplesium baueri* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10875, Department of Environment and Conservation

DEC (2005j). Genoplesium vernale - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10343,

DEC (2005k). Green and Golden Bell Frog: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10483, Department of Environment and Conservation

DEC (2005l). Haloragis exalata subsp. exalata - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10392,

DEC (2005m). Koala: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10616, Department of Environment and Conservation

DEC (2005n). Masked Owl: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10820, Department of Environment and Conservation

DEC (2005o) 'Native Vegetation Map Report Series No.4.' Department of Environment and Conservation, Sydney.

DEC (2005p). Pomaderris adnata - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10646,

DEC (2005q). Powerful Owl: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10562, Department of Environment and Conservation

DEC (2005r). Pterostylis *gibbosa* - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10701, Department of Environment and Climate Change and Water

DEC (2005s). *Pultenaea aristata* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10710, Department of Environment and Conservation

DEC (2005t). Regent Honeyeater: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10841, Department of Environment and Conservation (NSW)

DEC (2005u). Rosenberg's Goanna: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10826,

DEC (2005v). *Rulingia prostrata* - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10736, Department of Environment and Conservation

DEC (2005w). Senna acclinis - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10753,

DEC (2005x). Solanum celatum - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10761,

DEC (2005y). Superb Fruit-dove: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10709, Department of Environment and Conservation

DEC (2005z). Swift Parrot: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10455, Department of Environment and Conservation

DEC (2005{). *Syzygium paniculatum* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10794,

DEC (2005‰) White-flowered Wax Plant: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10196, Department of Environment and Conservation

DEC (2005|) 'White-footed Dunnart: Threatened Species Profile.' http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10758, NPWS, Hurstville.

DEC (2005}). *Wilsonia backhousei* - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10838, Department of Environment and Conservation

DEC (2005~). *Wilsonia rotundifolia* - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10839, Department of Environment and Conservation

DEC (2005□). Zieria tuberculata - Threatened Species Profile, http://threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10865,

DEC (2005„). Spotted-tailed Quoll - Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10207_, Department of Environment and Conservation, Accessed 2009

DEC and DPI (2005) 'Draft Guidelines for Threatened Species Assessment - Part 3A of the Environmental Planning and Assessment Act 1979.' NSW Department of Environment and Conservation and Department of Primary Industries.

DECC (2005). Australasian Bittern: Threatened Species Profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10105,

DECC (2007). Orange-bellied parrot - critically endangered species, http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Psittacidae_critically_endangered_species, Department of Environment and Climate Change

DECC (2008). Best Practice Guidelines Green and Golden Bell Frog Habitat, http://www.environment.nsw.gov.au/resources/threatenedspecies/08510tsdsgreengoldbfbpg.pdf, Department of Environment and Climate Change

DECC (2008a). Critical habitat register, http://www.environment.nsw.gov.au/criticalhabitat/CriticalHabitatProtectionByDoctype.htm, Department of Environment and Climate Change, Accessed 2009a.

DECC (2008b). Recovery Plan for the Koala (*Phascolarctos cinereus*), http://www.environment.nsw.gov.au/resources/threatenedspecies/08450krp.pdf, Department of Environment and Climate Change, Accessed 2009b.

DECCW (2005a). Pink Robin *Petroica rodingaster* - Threatened species profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10607, Department of Environment, Climate Change and Water

DECCW (2005b). Sooty Oystercatcher *Haematopus filiginosus* - Threatened species profile, http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10385, Department of Environment, Climate Change and Water

DECCW (2009a). DECCW Atlas of NSW Wildlife: Kiama & Moss Vale 1:100 000 map sheets.

DECCW (2009b). Draft National Recovery Plan for the Grey-headed Flying-fox *Pteropus poliocephalus*. Prepared by Dr Peggy Eby. Department of Environment, Climate Change and Water NSW, Sydney.

DECCW (2010) 'South Coast Regional Conservation Plan.' Department of Environment, Climate Change and Water, Sydney.

DEH (2005). Litoria littlejohni in Species Profile,

DEH (2005a) 'EPBC Act - Principal Significant Impact Guidelines 1.1 Matters of National Environmental Significance.' Department of the Environment and Heritage, Canberra.

DEH (2005b) 'Threat abatement plan for Psittacine Beak and Feather Disease affecting endangered psittacine species.' Department for the Environment and Heritage, Canberra.

DEH (2009) 'EPBC Act Policy Statement 1.1 Significant Impact Guidelines: Matters of National Significance.' Department of Environment and Heritage, Canberra.

DEWHA (2008a). Approved Conservation Advice for Cryptostylis hunteriana (Leafless Tongue-orchid), http://www.environment.gov.au/biodiversity/threatened/species/pubs/19533-conservation-advice.pdf, Department of Environment, Water, Heritage and the Arts

DEWHA (2008b). *Zieria tuberculata* (Warty Zieria) in Species Profile and Threats Database, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=56736, Department of Environment, Water, Heritage and the Arts

DEWHA (2008c). Threat Abatement Plan for Predation by Feral Cats. Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (2008d). Threat Abatement Plan for Predation by the European Red Fox. Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (2009) 'Matters of National Environmental Significance Significant impact guidelines 1.1 *Environment Protection and Biodiversity Conservation Act 1999*.' Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (2009a). Census of Australian Vertebrates, http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/cavs/index.html, Department of the Environment, Water, Heritage and the Arts, Accessed

DEWHA (2009b). Grey-headed Flying-fox - Species Profile and Threats Database, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=744, Department of Environment, Water, Heritage and the Arts, Accessed 2009b.

DEWHA (2009c). Long-nosed Potoroo *Potorous tridactylus tridactylus*: Species Profile and Threats Database, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=75184, Accessed 2009c.

DEWHA (2009d). Register of Critical Habitat, http://www.environment.gov.au/cgi-bin/sprat/public/publicregisterofcriticalhabitat.pl, Department of Environment, Water, Heritage and the Arts, Accessed 2009d

DEWHA (2009e). Spotted-tailed Quoll *Dasyurus maculatus maculatus*: Species Profile and Threats Database, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=75184, Accessed 2009e.

DEWHA (2010a). *Cryptostylis hunteriana* in Species Profile and Threats Database, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=19533, Department of the Environment, Water, Heritage and the Arts

DEWHA (2010b). *Survey guidelines for Australia's threatened frogs. Guidelines for detecting frogs listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*. Department of the Environment, Water, Heritage and the Arts

Dickman CR and Read DG (1992) 'The biology & management of dasyurids of the arid zone in NSW.' NPWS, NSW, No. 11.

Department of Planning (1995). State Environmental Planning policy no 44 - Koala Habitat Protection, http://www.legislation.nsw.gov.au/viewtop/inforce/epi+5+1995+FIRST+0+N/?fullquery=(((%22state%22%20AND%20%22environmental%22%20AND%20%22planning%22%20AND%20%22policy%22))), Department of Planning

DSEWPaC (2010). Litoria littlejohni - Littlejohn's Tree Frog, Heath Frog: Species Profile and Threats Database, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=64733, Department of Sustainability, Environment, Water, Population and Communities

DSEWPaC (2011). Threat abatement plan for the biological effects, including lethal toxic ingestion, caused by cane toads. Department of Sustainability, Environment, Water, Population and Communities

DSEWPaC (2012). *Interim koala referral advice for proponents*. Department of Sustainability, Environment, Water, Population and Communities

Dwyer PD (1995) Common Bentwing-bat. Pp. 494-495 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

Edgar R and Belcher C (1995) Spotted-tailed Quoll. Pp. 67-68 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

Eldridge MDB and Close RL (1995) Brush-tailed Rock-wallaby. Pp. 383-385 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

ERM Mitchell McCotter (1999) 'Karuah to Bulahdelah Pacific Highway Upgrading: Environmental Impact Statement (Section 1).' ERMMM, Report for NSW Roads and Traffic Authority Sydney.

Fairley A and Moore P (2000) 'Native Plants of the Sydney District: An Identification Guide. Revised Edition.' Kangaroo Press, Sydney.

Fitzgerald M (2005) 'Results in Sandtrap Monitoring in 8 Designated Fauna Crossings of the Yelgun to Chinderah Pacific Highway Upgrade: Sample 3 February - April 2005.' Report for AbiRoad Maintenance Pty. Ltd.

Forman RTT and Sperling D (2002) 'Road Ecology: science and solutions.' Island Press.

Forshaw JM and Cooper WT (1981) 'Australian Parrots (2nd Ed).' Lansdowne Press, Melbourne.

Forshaw JM and Cooper WT (2002) 'Australian Parrots (3rd Ed).' Lansdowne Press, Melbourne.

Garnett S (1992) 'Threatened and Extinct Birds of Australia.' York Press, Richmond.

Gibbons P and Lindenmayer DB (1997) Conserving Hollow-dependent Fauna in Timber Production Forest. *Environmental Heritage Monograph* 3**,** 110.

Goldingay R (2008) Yellow-bellied Glider *Petaurus australis*. Pp. 228-230 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Goldingay R and Taylor BD (2009) Gliding performance and its relevance to gap crossing by the squirrel glider (Petaurus norfolcensis). *Australian Journal of Zoology* 57**,** 99-104.

Goldingay RL (2010) 'Review of Glider Pole Locations along the Oxley Highway Deviation Supplementary Report.' Unpublished report prepared for the RTA.

Goldingay RL and Jackson SM (2004) A review of the ecology of the Australian Petauridae. Pp. 376-400 In 'The Biology of Australian Possums and Gliders' (Eds RL Goldingay and SM Jackson). Surrey Beatty & Sons, Chipping Norton.

Goosem M and Marsh H (1997) Fragmentation of a small mammal community by a powerine corridor through tropical forest. *Wildlife Research* 24**,** 613-629.

Goosem M, Western N, and Buchnell S (2005) Effectiveness of rope bridge arboreal overpasses and faunal underpasses in providing connectivity of rainforest habitat. *ICOET 2005 Proceedings* 304-316.

Goosem M (2002) Effects of tropical rainforest roads on small mammals: fragmentation, edge effects and traffic disturbance. *Wildlife Research* 29**,** 277-289.

Harden G (1991) 'Flora of New South Wales Volume 2.' NSW University Press, Kensington.

Harden G (1992) 'Flora of New South Wales Volume 3.' NSW University Press, Kensington.

Harden G and Murray LJ (2000) 'Supplement to Flora of New South Wales, Volume 1.' NSW University Press, Kensington.,

Harden GJ (1993) 'Flora of New South Wales Volume 4.' NSW University Press, Kensington.

Harden GJ (2002) 'Flora of New South Wales Volume 2 (Revised Edition).' University of New South Wales Press Ltd., Kensington.

Hazelton P (1992) 'Soil landscapes of the Kiama 1:100 000 sheet.' Department of Conservation and Land Management (incorporating the Soil Conservation Service of NSW, Sydney.

Higgins PJ (1999) 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 4: Parrots to Dollarbird.' Oxford University Press, Melbourne.

Higgins PJ and Davies SJJF (1996) 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 3: Snipe to Pigeons.' Oxford University Press, Melbourne.

Higgins PJ and Peter JM (2002) 'Handbook of Australian, New Zealand & Antarctic Birds. Volume 6: Pardalotes to shrike -thrushes.' Oxford University Press, Victoria.

Higgins PJ *et al.* (2006) 'Handbook of Australian, New Zealand & Antarctic Birds. Volume 7: Boatbills to Starlings.' Oxford University Press, Melbourne.

Higgins PJ *et al.* (2001) 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 5: Tyrant-flycatchers to Chats.' Oxford University Press, Melbourne.

Hoye GA and Hall LS (2008) Eastern Bent-winged Bat: *Miniopterus schreibersii oceanensis*. Pp. 507-508 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Hoye GA *et al.* (2008) East-coast Free-tailed Bat *Mormopterus norfolkensis*. Pp. 491-492 In 'The Mammals of Australia' (Eds S van dyck and R Strahan). Reed New Holland, Sydney.

Hoye GA and Schulz M (2008) Large-eared Pied Bat: *Chalinolobus dwyeri*. Pp. 531-532 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

IGAE (1992) Intergovernmental Agreement on the Environment.

James T *et al.* (1999) 'Rare Bushland Plants of Western Sydney.' Royal Botanical Gardens.

Johnston PG (2008) Long-nosed Potoroo *Potorous tridactylus*. Pp. 302-304 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Jones D (2006) 'A complete guide to Native Orchids of Australia. Including island territories.' Reed New Holland.

Kavanagh RP, Stanton MA, and Brassil TE (2007) Koalas continue to occupy their previous home-ranges after selective logging in *Callitris-Eucalyptus* forest. *Wildlife Research* 34**,** 94-107.

Land & Environment Court. (2008). Consolidated Conditions of Approval. Gerroa Environment Protection Society Inc (applicant), Minister for Planning (first respondent), Cleary Bros (second respondent).

Law BS and Chidel M (2004) Roosting & foraging ecology of the golden-tipped bat (Kerivoula papuensis) on the south coast of NSW. *Wildlife Res.,* 31**,** 73-82.

Law BS *et al.* (2008) Eastern False Pipistrelle *Falsistrellus tasmaniensis*. Pp. 542-543 In 'Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Lee AK (1995) 'The Action Plan for Australian Rodents.' Australian Nature Conservation Agency, No. Project Number 130.

Loyn RH, Runnalls RG, Forward GY, and Tyers J (1983) Territorial bell miners and other birds affecting populations of insect prey. *Science* 221**,** 1411-1412.

MacNally R (1999) Habitat fragmentation and habitat loss: Secondary, cascading effects and predictability. *Australian Biologist* 12**,** 138-151.

Marchant S and Higgins PJ (1990a) 'Handbook of Australian, New Zealand and Antactic Birds. Volume 1 Ratites to Ducks: Part A Ratites to Petrels.' Oxford University Press, Melbourne.

Marchant S and Higgins PJ (1990b) 'Handbook of Australian, New Zealand and Antarctic Birds. Volume 1 Ratites to Ducks: Part B Australian Pelican to Ducks.' Oxford University Press, Melbourne.

Marchant S and Higgins PJ (1993) 'Handbook of Australian, New Zealand and Antactic Birds. Volume 2 Raptors to Lapwings.' Oxford University Press, Melbourne.

Martin RW *et al.* (2008) Koala *Phascolarctos cinereus*. Pp. 198-201 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Mason, R.J. (1997) Habitat use and population size of the long-nosed potoroo, Potorous tridactylus (Marsupialia: Potoroidae) in a coastal reserve, north-eastern New South Wales. Australian Mammalogy. 20:35-42.

Maxwell S, Burbidge AA, and Morris K (1996) 'The Action Plan for Australian Masupials and Monotremes.' Australian Marsupial and Monotremes Specialist Group, IUCN Survival Commission, Environment Australia Endangered Species Program No. 500, Canberra.

Menkhorst PW and Lumsden LF (1995) Eastern False Pipistrelle.In 'Mammals of Victoria' (Ed. PW Menkhorst). Oxford University Press, Melbourne.

Menkhorst PW, Weavers BW, and Alexander JSA (1988) Distribution, habitat and conservation status of the Squirrel Glider *Petaurus australis* (Petauridae: Marsupialia) in Victoria. *Australian Wildlife Research* 15**,** 59-71.

Middleton WGD (1980) Roadside vegetation, a habitat for wildlife. In 'Roadsides of Today and Tomorrow' Roadside Conservation Committee, Melbourne.

Mills K (2006a) 'Flora and Fauna Assessment - Extension of Cleary Bros (Bombo) Sand Quarry Gerroa, Municipality of Kiama.'.

Mills K (2006b) 'The natural vegetation in the municipality of Kiama NSW.'

Moore MED (1955) The Use of Photosociological Methods in Ecological Investigations. I. The Braun-Blanquet System. *Journal of Ecology* 43**,** 226-244

Morcombe M (2003) 'Field Guide to Australian Birds.' Steve Parish Publishing, Brisbane.

Morgan G and Terry J (1992) 'Natural regions of western New South Wales and their use for environmental management'. *Proceedings of the Ecological Society of Australia* 16**,** 467-473.

Morris AK (1980) The status and distribution of the Turquoise Parrot in New South Wales. *Australian Birds* 14**,** 57-67.

Murcia C (1995) Edge effects in fragmented forests: implications for conservation. *Trends in Ecology & Evolution* 10**,** 58-62.

Murphy MJ (1998) Mammal survey of Seven Mile Beach National Park and Comerong Island Nature Reserve on the south coast of New South Wales. *Australian Zoologist* 30(4)**,** 419-425.

Muston and Associates (1991) 'Gerringong to Berry Highway Route Selection Study: Vegetation and Fauna Survey and Assessment.'

NGH (2009) 'Ecological Assessment: Proposed Princes Highway Upgrade between Kinghorne Street and Warra Warra Road, South Nowra'. Report for the NSW Roads and Traffic Authority.

NPWS (1999a). Australasian Bittern: Threatened Species Information, http://www.nationalparks.nsw.gov.au/PDFs/tsprofile_australasian_bittern.pdf, NSW National Parks and Wildlife Service

NPWS (1999b). Black Bittern: Threatened Species Information, http://www.nationalparks.nsw.gov.au/PDFs/tsprofile_black_bittern.pdf, NSW National Parks and Wildlife Service

NPWS (1999c). Glossy Black Cockatoo: Threatened Species Information, http://www2.nationalparks.nsw.gov.au/PDFs/tsprofile_glossy_black_cockatoo.pdf, NSW National Parks and Wildlife Service

NPWS (1999d). Greater Sand Plover: Threatened Species Information, http://www.environment.nsw.gov.au/resources/nature/tsprofileGreaterSandPlover.pdf, NSW National Parks and Wildlife Service

NPWS (1999e). Green and Golden Bell Frog: Threatened Species Information, http://www.nationalparks.nsw.gov.au/PDFs/tsprofile_green_golden_bell_frog.pdf, National Parks and Wildlife Service

NPWS (1999f) 'Lesser Sand Plover: Threatened Species Information.' NPWS, Hurstville.

NPWS (1999g). Regent Honeyeater: Threatened Species Information, http://www.nationalparks.nsw.gov.au/PDFs/tsprofile_regent_honeyeater.pdf, NSW National Parks and Wildlife Service

NPWS (1999h). Spotted-tailed Quoll: Threatened Species Information, http://www.nationalparks.nsw.gov.au/PDFs/tsprofile_spotted_tailed_quoll.pdf, New South Wales National Parks and Wildlife Service

NPWS (1999i). Threatened Species Information; Square-tailed Kite, http://www2.nationalparks.nsw.gov.au/PDFs/tsprofile_squaretailed_kite.pdf, NSW National Parks and Wildlife Service

NPWS (1999j). Yellow-bellied Glider: Threatened Species Information, http://www2.nationalparks.nsw.gov.au/PDFs/tsprofile_yellowbellied_glider.pdf, NSW National Parks and Wildlife Service

NPWS (2000) '*Acacia baueri* ssp. *aspera*. Threatened Species Information.' NPWS, Hurstville.

NPWS (2002) '*Pterostylis gibbosa (R.Br.) Illawarra Greenhood Orchid Recovery Plan.*' NSW National Parks and Wildlife Service, Hurstville.

NPWS (2003a). NSW Draft Recovery Plan for the Koala (*Phascolarctos cinereus*), http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Koala+-+draft+recovery+plan, NSW National Parks and Wildlife Service, Accessed.

NPWS (2003b). Recovery Plan for the Yellow-bellied Glider (Petaurus australis).

NPWS (2004) '*Pimelea spicata:* Threatened Species Information.' NSW National Parks and Wildlife Service.

NPWS and Shoalhaven Catchment Management Committee (2000) 'Threatened fauna of the Shoalhaven.'

NSW Government (2009). BioNet, http://www.bionet.nsw.gov.au/Area.cfm_, NSW Government

NSW legislation website (2009) 'Illawarra Regional Environmental Plan No 1'.

NSW NPWS (2002). Recommendation for the Identification of Critical Habitat for the Bomaderry Zieria (*Zieria baeuerlenii*), http://www.environment.nsw.gov.au/resources/nature/bomaderryZieriaDraftRecommendation.pdf, NSW National Parks and Wildlife Service, Accessed 21-9-2009.

NSW Scientific Committee (2000) 'Final determination to list Litoria littlejohnii (Littlejohn's Tree Frog) as a Vulnerable species under the TSC Act.' NSW Scientific Committee, Hurstville.

NSW Scientific Committee (2001) 'Final determination to list Pomaderris adnata as an endangered species.' NPWS, Hurstville.

NSW Scientific Committee (2002). Illawarra subtropical rainforest in the Sydney Basin Bioregion - endangered ecological community listing, http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Illawarra+subtropical+rainforest+in+the+Sydney+Basin+Bioregion+-+endangered+ecological+community+listing, Department of Environment and Conservation

NSW Scientific Committee (2004) 'River Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions - Endangered Ecological Community listing.' Department of Environment and Conservation.

NSW Scientific Committee (2008a). Illawarra Lowlands Grassy Woodland in the Sydney Basin Bioregion - endangered ecological community listing, http://www.environment.nsw.gov.au/determinations/IllawarraLowlandsGrassyWoodlandSydneyBasinEndComListing.htm, Department of Environment and Climate Change and Water

NSW Scientific Committee (2008b). Little Lorikeet *Glossopsitta pusilla* - proposed vulnerable species listing, http://www.environment.nsw.gov.au/determinations/littlelorikeetpd.htm,

NSW Scientific Committee (2009a). Flame Robin *Petroica phoenicea* - Final Determination of proposed vulnerable species listing, http://www.environment.nsw.gov.au/determinations/flamerobinpd.htm, Department of Environment, Climate Change and Water

NSW Scientific Committee (2009b). Little Eagle *Hieraaetus morphnoides* - proposed vulnerable species listing, http://www.environment.nsw.gov.au/determinations/littleeaglepd.htm, NSW Scientific Committee

NSW Scientific Committee (2009c). Scarlet Robin *Petroica boodang* - proposed vulnerable species listing, http://www.environment.nsw.gov.au/determinations/scarletrobinpd.htm,

NSW Scientific Committee (2009d). White-fronted Chat *Epthianura albifrons* - proposed vulnerable species listing, http://www.environment.nsw.gov.au/determinations/whitefrontedchatpd.htm, Department of Environment and Climate Change and Water

NSW Scientific Committee (2009e). White-fronted Chat *Epthianura albifrons* population in the Sydney Metropolitan Catchment management Authority area - proposed endangered population listing, http://www.environment.nsw.gov.au/determinations/witefrontedchatpopulationpd.htm, Department of Environment and Climate Change and Water

NSW Scientific Committee (2010a). Pied Oystercatcher *Haematopus longirostris* - endangered species listing, http://www.environment.nsw.gov.au/determinations/piedoystercatcherFD.htm, Department of Environment, Climate Change and Water

NSW Scientific Committee (2010b). Spotted Harrier *Circus assimilis* - Final Determination of vulnerable species listing, http://www.environment.nsw.gov.au/determinations/spottedharrierFD.htm, Department of Environment, Climate Change and Water

NSW Scientific Committee (2010c). Varied Sittella *Daphoenositta chrysoptera* - Final Determination of proposed vulnerable species listing, http://www.environment.nsw.gov.au/determinations/variedsittellaFD.htm, Department of Environment, Climate Change and Water

OBPRT (1998) 'Orange-bellied Parrot Recovery Plan 1998-2002.' Orange-bellied Parrot Recovery Team. Parks and Wildlife Service, Hobart.

Ollerenshaw PJ (1979) '*Australian National Botanic Gardens: Growing Native Plants* - Boronia deanei.'

Penman TD, Lemckert FL, and Mahony MJ (2008) Spatial ecology of the giant burrowing frog (*Heleioporus australiacus*): implications for conservation prescriptions. *Australian Journal of Zoology* 56**,** 179-186.

Pennay M (2008) A maternity roost of the Large-eared Pied Bat *Chalinolobus dwyeri* (Ryan) (Microchiroptera: Vespertilionidae) in central New South Wales Australia. *Australian Zoologist* 34**,** 564-569.

Pizzey G and Knight F (1997) 'The Field Guide to the Birds of Australia.' Angus and Robertson, Sydney.

Pizzey G and Knight F (2003) 'The Field Guide to the Birds of Australia (Seventh Edition).' Harper Collins, Sydney.

QDMR (1997) 'Roads in the wet tropics - Planning, design, construction, maintenance and operation best practice manual.' Queensland Department of Main Roads, Technology and Environment Division, Brisbane.

QDMR (1998) 'Wet tropics world heritage area road maintenance code of practice.' Queensland Department of Main Roads, Cairns.

QDMR (2000) 'Fauna sensitive road design. Volume 1 - Past and existing practices.' Queensland Department of Main Roads, Technology and Environment Division, Brisbane.

Quin DG (1995) Population ecology of the Squirrel Glider (*Petaurus norfolcensis*) and the Sugar Glider (*P. breviceps*) (Marsupialia: Petauridae) at Limeburners Creek, on the central North Coast of New South Wales. *Wildlife Research* 22**,** 471-505.

Recsei J (1996) Eastern Owl Frog, *Heleioporus australiacus*. Pp. 55-64 In 'Threatened Frogs of New South Wales: Habitats, Status and Conservation.' (Ed. H Ehmann). Frog and Tadpole Study Group of NSW, Sydney South.

Reed PC and Lunney D (1990) Habitat loss: the key problem for the long-term survival of Koalas in New South Wales. In 'Koala Summit: Managing Koalas in New South Wales' (Eds D Lunney, CA Urquhart, and PC Reed). NSW NPWS, Hurstville.

Richards GC (2008) Yellow-bellied Sheath-tailed Bat *Saccolaimus flaviventris*. Pp. 472-473 In 'Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Richards GC *et al.* (2008) Large-footed Myotis: *Myotis macropus*. Pp. 544-545 In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). Reed New Holland, Sydney.

Robinson NH (1985) Bats of the Illawarra Region. *Australian Zoologist* 22.

Robinson L (1994) 'Field Guide to the Native Plants of Sydney.' Kangaroo Press, Sydney.

RTA (2001) 'Compensatory Habitat Policy and Guidelines. Providing Compensatory Habitat as Amelioration for Impacts on habitat Resulting from Road Development. Draft 7.' Roads and Traffic Authority, Sydney.

RTA (2009a) 'Princes Highway (HW1) Upgrade from Warra Warra Road to Forest Road, south of Nowra. Review of Environmental Factors'. Roads and Traffic Authority, Sydney.

RTA (2009b) 'Princes Highway upgrade between Kinghorne Street and Warra Warra Road, South Nowra. Review of Environmental Factors'. Roads and Traffic Authority, Sydney.

RTA (2009c) 'Use of fauna passage structures on RTA roads'. Roads and Traffic Authority, Sydney.

RTA (2011) 'Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects'. NSW Roads and Traffic Authority, Sydney.

Scotts D, Drielsma M, and Kingma L (2000) 'Key habitats and corridors for fauna: A landscape framework for bioregional conservation planning in North-east New South Wales. II. Methods, decision rules, assumptions and mapped outputs.' NPWS, Coffs Harbour.

Seebeck J.H. (1995) Long-nosed Potoroo. Pp. 131-133 in Menkhorst, P. (ed.). The Mammals of Victoria - Distribution, Ecology and Conservation. Oxford University Press, Australia.

Shields J and Crome F (1992) 'Parrots and Pigeons of Australia.' Angus and Robertson, Sydney.

Shoalhaven City Council (2004). Shoalhaven City Council - SOE Maps, Vegetation, http://gis.shoalhaven.nsw.gov.au/soemaps/viewer.htm, Shoalhaven City Council.

Shoalhaven City Council (2005) 'Draft Remnant Vegetation Management Strategy for the Shoalhaven.'

Simpson K and Day N (1996) 'Field guide to the birds of Australia.' Viking. Penguin Books Australia Ltd., Ringwood.

Slater P *et al.* (2003) 'The Slater Field Guide to Australian Birds.' New Holland Publishers, Australia.

Soanes K and Van der Ree R (2008) 'Highway impacts on arboreal mammals and the use and effectiveness of novel mitigation techniques.'.

Strahan R (1995) 'The Mammals of Australia.' Reed Books, Chatswood.

Swift Parrot Recovery Team (2001). Swift Parrot (*Lathamus discolor*) Recovery Plan 2001-2005, http://www.environment.gov.au/biodiversity/threatened/publications/recovery/swift-parrot/pubs/swift-parrot.pdf, Swift Parrot Recovery Team, Accessed 2009.

Thackway and I. Cresswell. (1995). Biogeographic regionalisation for Australia: A framework for establishing the national system of reserves, Version 4.0. Nature Conservation Agency, Canberra.

Threatened Species Listing Advice (2008) '*Commonwealth Listing Advice on* Thelymitra sp. Kangaloon (D.L. Jones 18108). Department of the Environment, Water, Heritage and the Arts.'

Threatened Species Scientific Committee (2010). Commonwealth listing advice on *Pseudomys novaehollandiae* (New Holland Mouse), http://www.environment.gov.au/biodiversity/threatened/species/pubs/96-listing-advice.pdf, Department of Environment, Water, Heritage and the Arts

Thumm K and Mahoney M (2002) Evidence for continuous iteroparity in a temperate-zone frog, the Red-crowned Toadlet, *Pseudophryne australis* (Anura: Myobatrachidae). *Australian Journal of Zoology* 50**,** 151-167.

Thumm K and Mahony M (1997) Red-crowned Toadlet *Pseudophryne australis*. Pp. 125-135 In 'Threatened Frogs of New South Wales: Habitats, Status and Conservation' (Ed. H Ehmann). Frog and Tadpole Study Group of NSW, Sydney South.

Tidemann CR (1995) Grey-headed Flying-fox. Pp. 439-440 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

Tozer *et. al.* (2010) 'Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. Cunninghamia 11(3): 359-406.'.

Turner V and Ward SJ (1995) Eastern Pygmy-possum. Pp. 217-218 In 'The Mammals of Australia' (Ed. R Strahan). Reed New Holland, Sydney.

Van der Ree R and Suckling GC (2008) Squirrel Glider *Petaurus norfolcensis*.In 'The Mammals of Australia' (Eds S Van Dyck and R Strahan). New Holland Publishers (Australia) Pty Ltd, Sydney.

Van dyck S and Strahan R (2008) 'The Mammals of Australia Third Edition.' Reed New Holland, Sydney.

Veage L and Jones DN (2007) 'Breaking the Barrier: Assessing the Value of Fauna-friendly Crossing Structures at Compton Road.' Griffith University, Report for Brisbane City Council, Centre of Innovative Conservation Strategies Brisbane, QLD.

Ward SJ (1990) Life history of the eastern pygmy possum, *Cercartetus nanus* (Burramyidae, Marsupialia) in south-eastern Australia. *Australian Journal of Zoology* 38**,** 287-304.

Ward SJ and Turner V (2008) Eastern Pygmy-possum *Cercartetus nanus*. Pp. 219-221 In 'The Mammals of Australia' (Eds S van dyck and R Strahan). Reed New Holland, Sydney.

Webb JK (1996) Ecology and Conservation of the Threatened Broad-headed Snake *Hoplocephalus bungaroides*.PhD Dissertation,' University of Sydney.

Webb JK and Shine R (1998) Ecological characteristic of an endangered snake species *Hoplocephalus bungeroides* (Sepentes: Elapidae). *Animal Conservation* 1**,** 185-193.

Wellington R and Wells R (1985) 'Fauna survey of the Morisset Forestry District, Central Coast NSW. Reptiles and Amphibians.' State Forests of NSW, Pennant Hills.

White AW and Pyke GH (1996) Distribution and conservation status of the Green and Golden Bell Frog *Litoria aurea* in New South Wales. *Australian Zoologist* 30**,** 177-189.

Wilson A and Lindenmayer DB (1995) 'Wildlife Corridors and the Conservation of Biodiversity: A Review.' National Corridors of Green Program, Green Australia Ltd., Canberra.

Terms and acronyms used in this EA

Term	Definition
ACT	Australian Capital Territory
CAMBA	China-Australia Migratory Bird Agreement
CEMP	Construction Environmental Management Plan
DEC	NSW Department of Environment and Conservation (became DECCW and now OEH)
DECCW	NSW Department of Environment, Climate Change and Water (formerly DEC and now OEH)
DEWHA	Commonwealth Department of Environment, Water, Heritage and the Arts (now DSEWPaC)
DPC	NSW Department of Premier and Cabinet
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA)
EEC	Endangered ecological community
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EP&A Regulation	*Environmental Planning and Assessment Regulation 2000* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).
Fauna	Animal life occurring in a particular region
Flora	Plant life occurring in a particular region
GPS	Global positioning system
ILGW	Illawarra lowlands grassy woodland in the Sydney basin bioregion
ISR	Illawarra subtropical rainforest in the Sydney basin bioregion
Infrastructure SEPP	State Environmental Planning Policy (Infrastructure) 2007
Intergrade	The way in which two distinct species are connected via areas where ecological communities are found that have characteristics of both.
JAMBA	Japan Australia Migratory Bird Agreement
Lerp	Structure of crystallised honeydew produced by the larvae of psyllid insects as a protective cover.
LGA	Local government area
MNES	Matters of national environmental significance. Refers to the seven matters
Noxious Weeds Act	*Noxious Weeds Act 1993* (NSW)
NPWS	NSW National Park and Wildlife Service
NSW	New South Wales
OBPRT	Orange–bellied Parrot Recovery Team
OEH	NSW Office of Environment and Heritage (formerly DECCW)
RFEF	River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and south east corner bioregions

Term	Definition
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RMS	NSW Roads and Maritime Services (formally RTA)
RTA	NSW Roads and Traffic Authority (now RMS)
SEPP	State Environmental Planning Policy. A type of planning instrument made under Part 3 of the EP&A Act.
SEPP 14	State Environmental Planning Policy No.14 – Coastal Wetlands
SEPP 44	State Environmental Planning Policy No.44 – Koala Habitat Protection
Stag	Dead tree (often provide habitat for fauna)
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
VMP	Vegetation management plan

Appendix A

Flora results recorded within the Foxground and Berry bypass study area

Flora results

Flora species recorded in Foxground and Berry bypass study area (quadrat locations shown on **Figure 2.2** and in Appendix J):

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Abrophyllum ornans	Native Hydrangea																						+
Abutilon oxycarpum	Flannel Weed																						+
Acacia binervata	Two-veined Hickory														1		3					+	+
Acacia decurrens	Black Wattle																						+
Acacia falcata	Acacia																						+
Acacia irrorata ssp. irrorata	Green Wattle										1												+
Acacia longifolia	Coast/Sallow Wattle																						+
Acacia maidenii	Maiden's Wattle			3	4	2		1										1					+
Acacia mearnsii	Black Wattle																						+
Acacia melanoxylon	Blackwood																						+
Acacia myrtifolia	Red-stemmed Wattle																						+
Acacia parramattensis	Parramatta Wattle																						+
Acacia spp.	Acacia																						+
Acacia suaveolens	Sweet Wattle																						+
Acacia terminalis	Sunshine Wattle																						+
Acacia terminalis ssp. angustifolia	Acacia																						+
Acacia ulicifolia	Prickly Moses																						+
Acetosella vulgaris	Sheep Sorrel	*																					+
Acmena smithii	Lilly Pilly		2																3				+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Acronychia oblongifolia	Common Acronychia						5																+
Adiantum aethiopicum	Common Maidenhair											3	3				2						+
Adiantum formosum	Giant Maidenhair		3	3		2																	+
Adiantum hispidulum var. hispidulum	Rough Maidenhair										1								2	3			+
Agapanthus praecox	Agapanthus	*																					+
Ageratina adenophora	Crofton Weed	*			2						1									1			+
Ageratina riparia	Mistflower	*	1	1	3				4	2	5								2	3			+
Aira spp.	Aira	*																					+
Alectryon subcinereus	Wild Quince		1			1																	+
Allocasuarina littoralis	Black Sheoak																						+
Alocasia brisbanensis	Cunjevoi																						+
Alphitonia excelsa	Red Ash			1				4				1											+
Alpinia caerulea	Native Ginger																						+
Amyema gaudichaudii	Amyema																						+
Amyema spp.	Amyema																						+
Amylotheca dictyophleba	Amylotheca																						+
Anagallis arvensis	Scarlet/Blue Pimpernel	*																				+	+
Andropogon virginicus	Whisky Grass	*																					+
Aneilema acuminatum	Aneilema		1						1										2				+
Angophora floribunda	Rough-barked Apple													2									+
Anisopogon avenaceus	Oat Speargrass																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Anredera cordifolia	Madeira Vine	*																					+
Aphanopetalum resinosum	Gum Vine																						+
Apium prostratum ssp. prostratum	Sea Celery	*																					+
Araucaria spp.	Araucaria																						+
Araucaria heterophylla	Norfolk Island Pine																					+	
Araujia hortorum	Araujia	*				2		2	2	1	1												+
Aristida ramosa var. ramosa	Aristida																						+
Aristida vagans	Threeawn Speargrass																						+
Arthropodium milleflorum	Vanilla Lily																						+
Arthropteris tenella	Arthropteris						5																+
Asparagus densiflorus	Sprengeri Fern	*																					+
Asperula conferta	Common Woodruff																						+
Asplenium australasicum	Asplenium																						+
Asplenium flabellifolium	Necklace Fern																						+
Atriplex cinerea	Grey Saltbush																						+
Atriplex prostrata	Hastate Orache	*																					+
Atriplex spp.	Atriplex																						+
Austrodanthonia spp.	Austrodanthonia																2						+
Austrodanthonia tenuior	Purplish Wallaby-grass																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Austrostipa pubescens	Austrostipa																						+
Austrostipa ramosissima	Stout Bamboo Grass																						+
Austrostipa spp.	Austrostipa							1															+
Austrostipa verticillata	Austrostipa																						+
Avena fatua	Wild Oats	*																					+
Axonopus affinis	Narrow-leaved Carpet Grass	*								2	3										2		+
Backhousia myrtifolia	Grey Myrtle																						+
Baloghia inophylla	Brush Bloodwood																						+
Banksia spinulosa var. collina	Banksia																						+
Banksia spinulosa var. spinulosa	Hairpin Banksia																						+
Baumea spp.	Baumea																			1			+
Bidens pilosa	Cobbler's Pegs	*			1			1	1														+
Billardiera scandens var. scandens	Common Apple-berry													1	2		1						+
Blechnum cartilagineum	Gristle Fern											2	3		1			2					+
Blechnum patersonii ssp. patersonii	Strap Water-fern																		2				+
Blechnum spp.	Blechnum																						+
Bossiaea heterophylla	Variable Bossiaea																						+
Botrychium australe	Parsley Fern																						+
Brachychiton acerifolius	Illawarra Flame Tree						2		1														+
Brassica rapa	White Turnip	*																					+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Brassica spp.	Brassica																						+
Breynia oblongifolia	Coffee Bush			1				2						2		1	1	1					+
Briza maxima	Quaking Grass	*															1						+
Bromus catharticus	Prairie Grass	*									1										2	+	+
Brunoniella pumilio	Dwarf Blue Trumpet																						+
Bursaria spinosa ssp. spinosa	Sweet Bursaria																						+
Callistemon rigidus	Stiff Bottlebrush																						+
Callistemon salignus	Willow Bottlebrush																						+
Callistemon viminalis	Weeping Bottlebrush																					+	
Calochlaena dubia	Common Ground Fern																	3	2	2			+
Calystegia sepium	Large Bindweed																1						+
Calystegia silvatica	Greater Bindweed	*																					+
Canna indica	Tous-les-mois Arrowroot	*																				+	
Carex appressa	Tall Sedge											3				2							+
Carex fascicularis	Tassel Sedge															3	2						+
Carex longebrachiata	Bergalia Tussock		2	2	3					2	2		3		1			4					+
Carex spp.	Carex																						+
Carronia multisepalea	Carronia																						+
Cassine australis var. australis	Red Olive-berry		4			2		5															+
Cassinia spp.	Cassinia																						+
Cassytha glabella forma glabella	Slender Dodder-laurel																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Casuarina cunninghamiana ssp. cunninghamiana	River Oak								4	3	4										5	+	+
Casuarina glauca	Swamp Oak																						+
Cayratia clematidea	Slender Grape																						+
Celastrus australis	Staff VIne																						+
Celastrus spp.	Celastrus																						+
Celastrus subspicata	Celastrus																						+
Centaurium tenuiflorum	Slender Centaury	*																					+
Centella asiatica	Pennywort											2	1		1								+
Cephalaralia cephalobotrys	Climbing Panax																						+
Cestrum elegans	Elegant Poison-berry	*																					+
Cheilanthes sieberi ssp. sieberi	Narrow Rock-fern																						+
Chlorophytum comosum	Spider Plant	*																					+
Christella dentata	Binung																		2				+
Chrysocephalum apiculatum	Common Everlasting																						+
Cinnamomum camphora	Camphor Laurel	*							2	1											2	+	+
Cirsium vulgare	Spear Thistle	*			1					2	1											+	+
Cissus antarctica	Water Vine																						+
Cissus hypoglauca	Giant Water Vine																						+
Citrus limonia	Rough Lemon	*																					+
Claoxylon australe	Brittlewood																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Clematis aristata	Mountain Clematis																						+
Clerodendrum tomentosum	Hairy Clerodendrum		1			2	1	2											2	1			+
Colocasia esculenta	Taro	*								1	2									1			+
Commelina cyanea	Commelina												2				1					+	+
Commersonia fraseri	Brush Kurrajong																						+
Convolvulus erubescens	Convolvulus																						+
Conyza albida	Tall Fleabane	*																					+
Conyza spp.	Conyza	*			1																	+	+
Coreopsis lanceolata	Coreopsis	*																					+
Correa reflexa var. reflexa	Native Fuschia																						+
Corymbia gummifera	Red Bloodwood																						+
Corymbia maculata	Spotted Gum																					+	+
Cotula coronopifolia	Water Buttons	*																					+
Croton acronychioides	Thick-leaved Croton																						+
Croton verreauxii	Native Cascarilla					3													2				+
Cryptocarya glaucescens	Jackwood																						+
Cryptocarya microneura	Murrogun						3												2				+
Cryptocarya spp.	Cryptocarya							1															+
Cryptostylis erecta	Tartan Tongue Orchid																2						+
Cryptostylis spp.	Cryptostylis											1	1										+
Cryptostylis subulata	Large Tongue Orchid																1						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Cyathea australis	Rough Treefern		1																1				+
Cyathochaeta diandra	Sheath Sedge																						+
Cymbidium suave	Snake Orchid																						+
Cymbopogon refractus	Barbed Wire Grass																						+
Cynodon dactylon	Common Couch									2											1		+
Cyperus brevifolius	Mullumbimby Couch										2												+
Cyperus eragrostis	Umbrella Sedge	*								2	2									1	2	+	+
Cyperus imbecillis	Cyperus																						+
Cyperus spp.	Cyperus							1												1			+
Daphnandra sp. 'Illawarra' (Schodde)	Daphnandra					5																	+
Daviesia ulicifolia ssp. aridicola	Daviesia																						+
Daviesia ulicifolia ssp. stenophylla	Daviesia																						+
Daviesia ulicifolia ssp. ulicifolia	Gorse Bitter-pea																						+
Deeringia amaranthoides	Deeringia																						+
Delairea odorata	Cape Ivy	*			3	3		2												1			+
Dendrobium speciosum	Rock Lily																						+
Dendrocnide excelsa	Giant Stinging Tree																						+
Desmodium rhytidophyllum	Desmodium														3								+
Desmodium varians	Slender Tick-trefoil																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Dianella caerulea var. caerulea	Paroo Lily																						+
Dianella caerulea var. producta	Blue Flax-lily												1	3			2					+	+
Dianella longifolia var. longifolia	Pale Flax-lily																						+
Dichelachne micrantha	Shorthair Plumegrass																						+
Dichondra repens	Kidney Weed			2	2			2					2		2	2	3	3				+	+
Dicksonia antarctica	Soft Treefern															1							+
Dillwynia retorta (J.C.Wendl.) Druce species complex	Dillwynia																						+
Dillwynia spp.	Dillwynia																						+
Dioscorea transversa	Native Yam																						+
Diospyros australis	Black Plum																						+
Diploglottis australis	Native Tamarind							1															+
Dipodium punctatum	Hyacinth Orchid																						+
Dodonaea triquetra	Large-leaf Hop-bush																						+
Doodia aspera	Prickly Rasp Fern		2		2		3					1	3			4		3	4	3			+
Doryphora sassafras	Sassafras						2												6				+
Duboisia myoporoides	Corkwood													3									+
Echinopogon ovatus	Forest Hedgehog Grass																2						+
Echium plantagineum	Patterson's Curse	*																					+
Ehretia acuminata var. acuminata	Koda																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Ehrharta erecta	Panic Veldtgrass	*			1			2	2		3										5		+
Ehrharta longiflora	Annual Veldtgrass	*																					+
Einadia hastata	Berry Saltbush																						+
Elaeocarpus kirtonii	Silver Quandong																						+
Elaeocarpus reticulatus	Blueberry Ash												1										+
Eleusine indica	Crowsfoot Grass	*																			2		+
Endiandra sieberi	Hard Corkwood																						+
Entolasia marginata	Bordered Panic						1					3	3	4	2	2	2	3	3				+
Entolasia stricta	Wiry Panic																						+
Epacris microphylla var. microphylla	Coast Coral Heath																						+
Epacris pulchella	Epacris																						+
Eragrostis brownii	Brown's Lovegrass																						+
Eragrostis spp.	Eragrostis																						+
Eriobotrya japonica	Loquat	*																					+
Erythrina crista-galli	Cockspur Coral Tree	*																				+	
Erythrina X sykesii	Coral tree	*																				+	+
Eucalyptus amplifolia ssp. amplifolia	Cabbage Gum																						+
Eucalyptus botryoides	Bangalay												3				1	2	4				+
Eucalyptus eugenioides	Thin-leaved Stringybark																						+
Eucalyptus globoidea	White Stringybark																						+
Eucalyptus microcorys	Tallowwood																					+	+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Eucalyptus paniculata ssp. paniculata	Grey Ironbark																						+
Eucalyptus pilularis	Blackbutt													5	5	4	5						+
Eucalyptus piperita	Sydney Peppermint																						+
Eucalyptus quadrangulata	White-topped Box																						+
Eucalyptus racemosa	Narrow-leaved Scribbly Gum																						+
Eucalyptus robusta	Swamp Mahogany																					+	+
Eucalyptus saligna	Sydney Blue Gum		4																				+
Eucalyptus scias ssp. scias	Large-fruited Red Mahogany																						+
Eucalyptus sclerophylla	Hard-leaved Scribbly Gum																						+
Eucalyptus spp.	-																						+
Eucalyptus tereticornis	Forest Red Gum																						+
Euphorbia oblongata	Egg-leaf Spurge	*																				+	
Euphorbia peplus	Petty Spurge	*																					+
Eupomatia laurina	Bolwarra		1																4				+
Eustrephus latifolius	Wombat Berry		2	1	1	2	1	2								2	1			2			+
Exocarpos cupressiformis	Native Cherry																						+
Ficus coronata	Creek Sandpaper Fig								1										4				+
Ficus macrophylla ssp. macrophylla	Moreton Bay Fig																						+
Ficus obliqua var.	Ficus																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
obliqua																							
Ficus rubiginosa	Ficus																						+
Ficus spp.	Ficus																						+
Ficus watkinsiana	Strangling Fig																						+
Foeniculum vulgare	Fennel	*									1												+
Fumaria spp.	Fumaria	*																				+	+
Gahnia aspera	Gahnia																						+
Gahnia clarkei	Tall Saw-sedge																1						+
Gahnia melanocarpa	Black-fruit Saw-sedge											5	4	3				1					+
Galium aparine	Goosegrass	*																			1		+
Galium ciliare	Hairy Bedstraw																						+
Galium propinquum	Maori Bedstraw																						+
Galium spp.	Galium																						+
Geitonoplesium cymosum	Scrambling Lily					2		2					1	3				2					+
Geranium homeanum	Northern Cranesbill										2				1							+	+
Geranium spp.	Geranium																						+
Glochidion ferdinandi var. ferdinandi	Cheese Tree				2						1		4	3	1	5	4	1					+
Glycine clandestina	Twining Glycine				1												2						+
Glycine tabacina	Variable Glycine														3								+
Gnaphalium spp.	Gnaphalium																						+
Gompholobium grandiflorum	Large Wedge Pea																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Gompholobium minus	Dwarf Wedge Pea																						+
Gompholobium pinnatum	Pinnate Wedge Pea																						+
Gonocarpus tetragynus	Common Raspwort																						+
Gonocarpus teucrioides	Germander Raspwort																1						+
Goodenia hederacea ssp. hederacea	Ivy Goodenia																						+
Goodenia heterophylla ssp. eglandulosa	Goodenia																						+
Goodenia spp.	Goodenia																						+
Grevillea linearifolia	Small-flower Grevillea																						+
Grevillea robusta	Silky Oak																					+	+
Guioa semiglauca	Guioa					4																	+
Gymnostachys anceps	Settler's Flax					2	3	2					1					1	2				+
Hakea dactyloides	Finger Hakea																						+
Hakea salicifolia ssp. salicifolia	Hakea																						+
Hakea sericea	Bushy Needlewood																						+
Hardenbergia violacea	False Sarsaparilla														2								+
Hedycarya angustifolia	Native Mulberry																						+
Hedychium gardnerianum	Ginger Lily	*																					+
Helichrysum elatum	Tall Everlasting																						+
Hibbertia aspera ssp. aspera	Hibbertia																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Hibbertia dentata	Twining Guinea Flower													3				2					+
Hibbertia diffusa	Wedge Guinea-flower																						+
Hibbertia scandens	Climbing Guinea Flower													2	2		3						+
Holcus lanatus	Yorkshire Fog	*																				+	+
Hovea linearis	Hovea																						+
Hydrocotyle laxiflora	Stinking Pennywort																						+
Hydrocotyle peduncularis	Pennywort																						+
Hydrocotyle spp.	Hydrocotyle				2											2		2					+
Hymenanthera dentata	Tree Violet					2																	+
Hymenophyllum cupressiforme	Common Filmy Fern																						+
Hypericum gramineum	Small St John's Wort																						+
Hypochaeris radicata	Catsear	*									2												+
Hypolepis muelleri	Harsh Ground Fern											3	4			4							+
Imperata cylindrica var. major	Blady Grass														5	1	4						+
Indigofera australis	Austral Indigo																						+
Isolepis prolifera	Proliferous Club-sedge	*																					+
Jacaranda mimosifolia	Jacaranda	*																				+	+
Juncus kraussii ssp. australiensis	Sea Rush																						+
Juncus spp.	Juncus																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Juncus tenuis	Slender Rush	*																					+
Juncus usitatus	Billabong Rush								2	4	1										2		+
Kennedia rubicunda	Red Kennedy Pea														2		1						+
Kunzea ambigua	Tick Bush																						+
Lagenifera stipitata	Blue Bottle-daisy																						+
Lambertia formosa	Mountain Devil																						+
Lantana camara	Lantana	*	2	1	3	4		3	2	2	2	1	3	4	3	2	3	4	3	2		+	+
Lastreopsis acuminata	Shiny Shield Fern																						+
Lastreopsis decomposita	Trim Shield Fern																						+
Lastreopsis microsora ssp. microsora	Creeping Shield-fern																						+
Lastreopsis spp.	Lastreopsis																						+
Laxmannia gracilis	Slender Wire-lily																						+
Legnephora moorei	Round-leaf Vine		1																				+
Lepidosperma laterale	Variable Sword-sedge													5			1						+
Leptinella longipes	Coast Cotula																						+
Leptomeria acida	Sour Currant Bush																						+
Leptospermum continentale	Prickly Teatree																						+
Leptospermum polygalifolium ssp. polygalifolium	Tantoon													2									+
Leptospermum spp.	Leptospermum																						+
Leptospermum	Paperbark Tea-tree																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
trinervium																							
Leucopogon juniperinus	Long-flower Beard-heath																						+
Leucopogon lanceolatus var. lanceolatus	Lance Beard-heath													2									+
Libertia paniculata	Branching Grass-flag																		1				+
Ligustrum lucidum	Large-leaved Privet	*	1						1											6	1	+	+
Ligustrum sinense	Small-leaved Privet	*						1	3	3	4				1	2	1	2	1	1	2	+	+
Lindsaea linearis	Screw Fern																						+
Litsea reticulata	Bolly Gum																						+
Livistona australis	Cabbage Palm		1				1							1				1	3	1			+
Lolium perenne	Perennial Ryegrass	*																					+
Lomandra filiformis ssp. filiformis	Wattle Mat-rush																						+
Lomandra glauca	Pale Mat-rush																						+
Lomandra longifolia	Spiny-headed Mat-rush									2	3		1		3	1	2				1	+	+
Lomandra multiflora ssp. multiflora	Many-flowered Mat-rush																						+
Lomandra obliqua	Lomandra																						+
Lomatia ilicifolia	Holly Lomatia																						+
Lonicera japonica	Japanese Honeysuckle	*																					+
Ludwigia peploides ssp montevidensis	Water Primrose																					+	
Lycium ferocissimum	African Boxthorn	*																					+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Maclura cochinchinensis	Cockspur Thorn					2		2							1								+
Macrozamia spp.	Macrozamia																						+
Malus spp.	Malus	*																					+
Marsdenia flavescens	Hairy Milk Vine						1																+
Marsdenia rostrata	Common Milk Vine		2	1	2			2	1			2	1		2	2	1	2	2	1			+
Maytenus silvestris	Narrow-leaved Orangebark																						+
Melaleuca decora	-																					+	
Melaleuca linariifolia	Budjur											5	2										+
Melaleuca quinquenervia	Broad-leaved Paperbark																					+	
Melaleuca styphelioides	Prickly-leaved Tea Tree																						+
Melia azedarach	White Cedar							2															+
Melicope micrococca	Hairy-leaved Doughwood							1															+
Micrantheum ericoides	Micrantheum																						+
Microlaena stipoides var. stipoides	Weeping Grass				1						4				3		2			2	3		+
Microsorum scandens	Fragrant Fern																						+
Mirbelia rubiifolia	Heathy Mirbelia																						+
Morinda jasminoides	Jasmine Morinda			1		1		1				4	4					3	3	2			+
Modiola caroliniana	Red-flowered Mallow	*																				+	
Myriophyllum sp		*																				+	
Myoporum acuminatum	Myoporum																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Nephrolepis cordifolia	Fishbone Fern																						+
Notelaea longifolia	Large Mock-olive																						+
Notelaea spp.	Notelaea																						+
Notelaea venosa	Veined Mock-olive						1	2				3	3	2						1			+
Ochna serrulata	Mickey Mouse Plant	*																					+
Olea europaea	Common Olive	*																					+
Olea europaea ssp. cuspidata	Olea	*													1								+
Olearia viscidula	Wallaby Weed																						+
Omalanthus populifolius	Omalanthus																						+
Opercularia diphylla	Stinkweed																						+
Oplismenus aemulus	Basket Grass		1								3									1			+
Oplismenus imbecillis	Oplismenus		2	1	3	2		2				3	2	3	2	2	2	3	2				+
Oxalis perennans	Grassland Wood-sorrel																						+
Oxalis spp.	Oxalis									1	1												+
Ozothamnus diosmifolius	White Dogwood																						+
Palmeria scandens	Anchor Vine		1																				+
Pandorea pandorana ssp. pandorana	Wonga Vine		3	2	3	2		1			1		2			1	1	3	2	1			+
Panicum simile	Two-colour Panic																						+
Panicum spp.	Panicum																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Pararchidendron pruinosum var. pruinosum	Snow Wood					4	2																+
Parsonsia straminea	Common Silkpod			2		2			1	1		2	2	3	2			3					+
Paspalum dilatatum	Paspalum	*								2	3										1	+	+
Paspalum urvillei	Vasey Grass	*																					+
Passiflora edulis	Common Passionfruit	*																					+
Passiflora herbertiana ssp. herbertiana	Native Passionfruit																						+
Passiflora subpeltata	White Passionflower	*																					+
Patersonia glabrata	Leafy Purple-flag																						+
Patersonia sericea	Silky Purple-flag																						+
Pellaea falcata	Sickle Fern		2	2	2			1															+
Pennantia cunninghamii	Brown Beech																						+
Pennisetum clandestinum	Kikuyu Grass	*							2						1							+	+
Persicaria decipiens	Slender Knotweed																					+	+
Persicaria praetermissa	Spotted Knotweed									3	1									1			+
Persicaria spp.	Persicaria									3												+	+
Persicaria strigosa	-																					+	
Persoonia levis	Broad-leaved Geebung																						+
Persoonia linearis	Narrow-leaved Geebung													2									+
Persoonia mollis ssp. leptophylla	Persoonia																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Petrophile pulchella	Petrophile																						+
Petrophile sessilis	Petrophile																						+
Phragmites australis	Common Reed																						+
Phytolacca octandra	Inkweed	*			1																		+
Pimelea linifolia ssp. linifolia	Slender Rice-flower																						+
Pinus radiata	Radiata Pine	*																					+
Pinus spp.	Pine	*																					+
Piper novae-hollandiae	Giant Pepper Vine						2																+
Pittosporum multiflorum	Orange Thorn		1	2	1		3	2															+
Pittosporum revolutum	Rough Fruit Pittosporum											1		2	1			1					+
Pittosporum undulatum	Sweet Pittosporum		4	6	6	4		1							4					2			+
Planchonella australis	Black Apple																						+
Plantago lanceolata	Lamb's Tongues	*									1												+
Platylobium formosum ssp. formosum	Handsome Flat-pea													3									+
Platysace linearifolia	Platysace																						+
Plectranthus parviflorus	Cockspur Flower																						+
Poa labillardierei var. labillardierei	Tussock																	2					+
Poa spp.	Poa																						+
Podocarpus elatus	Plum Pine						1																+
Polyosma cunninghamii	Featherwood																						+
Polyscias elegans	Celery Wood																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Polyscias murrayi	Pencil Cedar																						+
Pomaderris ferruginea	Rusty Pomaderris													2									+
Pomax umbellata	Pomax																						+
Pratia purpurascens	Whiteroot																2						+
Protasparagus aethiopicus	Sprengeri Fern	*																					+
Protasparagus plumosus	Climbing Asparagus Fern	*																					+
Prunella vulgaris	Self-heal	*																					+
Prunus spp.	Prunus																						+
Pseuderanthemum variabile	Pastel Flower		2	3		3		3				2	1			2		3	2				+
Psychotria loniceroides	Hairy Psychotria																						+
Pteridium esculentum	Bracken													3			2						+
Pteris umbrosa	Jungle Brake				1																		+
Pultenaea retusa	Blunt Bush-pea																						+
Pyrrosia rupestris	Rock Felt Fern															1							+
Ranunculus inundatus	River Buttercup									2													+
Ranunculus plebeius	Forest/Hairy Buttercup																						+
Ranunculus repens	Creeping Buttercup	*																					+
Ranunculus sceleratus	Celery Buttercup	*																					+
Ranunculus spp.	Ranunculus																						+
Rapanea howittiana	Brush Muttonwood																		1				+
Rapanea variabilis	Muttonwood				1								1										+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Rhodamnia rubescens	Scrub Turpentine							1															+
Ricinus communis	Castor Oil Plant	*																					+
Ripogonum album	White Supplejack																						+
Rorippa microphylla	One-rowed Watercress	*								2													+
Rorippa nasturtium-aquaticum	Watercress	*																				+	+
Rorippa spp.	Rorippa																				1		+
Rubus fruiticosus	Blackberry complex	*								1													+
Rubus moluccanus var. trilobus	Molucca Bramble																						+
Rubus parvifolius	Native Raspberry							1								1	2						+
Rubus rosifolius var. rosifolius	Rose-leaf Bramble																						+
Rubus spp.	Rubus																						+
Rumex brownii	Swamp Dock																						+
Rumex crispus	Curled Dock	*							1	2	2									1	2	+	+
Sagittaria graminea	Sagittaria	*																					+
Salix babylonica	Weeping Willow	*																				+	+
Salix spp.	Willow	*									2												+
Sambucus australasica	Native Elderberry																						+
Samolus repens	Creeping Brookweed																						+
Santalum obtusifolium	Sandalwood																						+
Sarcocornia quinqueflora ssp.	Beaded Glasswort																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
quinqueflora																							
Sarcomelicope simplicifolia ssp. simplicifolia	Big Yellow Wood							4															+
Sarcopetalum harveyanum	Pearl Vine																		1				+
Schelhammera undulata	Lilac Lily											1		2		2		2	1				+
Schinus areira	Pepper Tree	*																				+	
Scolopia braunii	Flintwood						1																+
Sedum spp.	Sedum																						+
Selliera radicans	Shiny Swamp-mat																						+
Senecio madagascariensis	Fireweed	*								3							1				1	+	+
Senecio spp.	Senecio																						+
Senna pendula var. glabrata	Cassia	*																					+
Setaria gracilis	Slender Pigeon Grass	*																		1	1		+
Setaria italica	Foxtail Millet	*																				+	
Sherardia arvensis	Field Madder	*																					+
Sida rhombifolia	Paddy's Lucerne	*							2	2	3									1	2		+
Sigesbeckia orientalis ssp. orientalis	Indian Weed																			1	1	+	+
Smilax australis	Sarsaparilla		2					1											1				+
Smilax glyciphylla	Sweet Sarsparilla													1									+
Solanum aviculare	Kangaroo Apple																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Solanum jasminoides	Potato Climber	*																					+
Solanum mauritianum	Wild Tobacco Bush	*						1	3		3									1		+	+
Solanum nigrum	Black-berry Nightshade	*						1											1		2		+
Solanum pseudocapsicum	Madeira Winter Cherry	*			2			2													1		+
Solanum pungetium	Eastern Nightshade																						+
Solanum spp.	Solanum																						+
Solanum vescum	Gunyang																						+
Sonchus oleraceus	Common Sowthistle	*								1													+
Spiranthes sinensis ssp. australis	Ladies Tresses																						+
Spirodela spp.	Spirodela									2											1		+
Sporobolus indicus	Parramatta Grass	*									1												+
Sporobolus indicus var. capensis	Parramatta Grass	*																					+
Sporobolus spp.	Sporobolus																						+
Stellaria flaccida	Forest Starwort																						+
Stenocarpus salignus	Scrub Beefwood																						+
Stenotaphrum secundatum	Buffalo Grass	*																					+
Stephania japonica var. discolor	Snake Vine			2		2	1	1				1	1						1				+
Streblus brunonianus	Whalebone Tree		2	2	2	4	3	4											2	1			+
Stylidium productum	Stylidium																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Suaeda australis	Austral Seablite																						+
Symplocos thwaitesii	Buff Hazelwood																						+
Syncarpia glomulifera ssp. glomulifera	Turpentine											5	4					5				+	+
Synoum glandulosum ssp. glandulosum	Bastard Rosewood		1																				+
Syzygium australe	Brush Cherry																			1		+	+
Syzygium spp.	Syzygium																						+
Tagetes minuta	Stinking Roger	*																					+
Taraxacum officinale	Dandelion	*																					+
Tecoma capensis	Cape Honeysuckle	*																					+
Tetragonia tetragonioides	New Zealand Spinach																						+
Thelionema caespitosum	Tufted Lily																						+
Themeda australis	Kangaroo Grass																						+
Thunbergia alata	Black-eyed Susan	*																					+
Thysanotus tuberosus ssp. tuberosus	Common Fringe-lily																						+
Todea barbara	King Fern																						+
Toona ciliata	Red Cedar		1																				+
Tradescantia albiflora	-	*						2															+
Tradescantia fluminensis	-	*							5	3	3								4	2	5	+	+
Trema tomentosa var. viridis	Native Peach																						+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Trifolium repens	White Clover	*									2											+	+
Triglochin striatum	Streaked Arrowgrass																						+
Tristaniopsis laurina	Kanuka																					+	+
Trophis scandens ssp. scandens	Trophis																						+
Tylophora barbata	Bearded Tylophora		2	1			2								2	2	2	2	1				+
Typha orientalis	Broadleaf Cumbungi																					+	
Typha spp.	Typha																						+
Urtica incisa	Stinging Nettle					1														1	2	+	+
Verbascum virgatum	Twiggy Mullein	*																					+
Verbena bonariensis	Purpletop	*									1											+	+
Verbena rigida	Veined Verbena	*																					+
Vernonia cinerea var. cinerea	Vernonia																						+
Veronica plebeia	Trailing Speedwell																						+
Viola hederacea	Ivy-leaved Violet			1												2							+
Viola spp.	Viola																						+
Wahlenbergia gracilis	Sprawling or Australian Bluebell																						+
Wahlenbergia spp.	Wahlenbergia																						+
Watsonia bulbillifera	Watsonia	*																					+
Wilkiea huegeliana	Veiny Wilkiea					2							2							1			+
Xanthorrhoea spp.	Grass Tree																						+
Zantedeschia aethiopica	Arum Lily	*																					+

Scientific name	Common name	Exotic	Quadrat number and cover abundance																			T	A
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
Zieria granulata	Zieria																						+
Zieria smithii	Sandfly Zieria													1									+

* *Denotes exotic species*
T *Recorded during Town Creek surveys*
A *Denotes opportunistic records of all flora species*

Cover abundance scores:

Score	Species cover in Quadrat	Other attributes
1	<5%	3 or less individual of a species
2	<5%	More than 3 individuals of a species
3	<5%	Species common throughout plot
4	5% - 25%	-
5	25% - 50%	-
6	50% - 75%	-
7	75% - 100%	-

Appendix B

Fauna results recorded within the Foxground and Berry bypass study area

Fauna results

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Amphibians					
Hylidae	*Litoria dentata*	Bleating Tree Frog			W
Hylidae	*Litoria fallax*	Eastern Dwarf Tree Frog			O/W
Hylidae	*Litoria jervisiensis*	Jervis Bay Tree Frog			W
Hylidae	*Litoria lesueuri*	Lesueur's Frog			O
Hylidae	*Litoria nudidigita*	Leaf Green Tree Frog (Southern Call Race)			W
Hylidae	*Litoria peronii*	Peron's Tree Frog			O/W
Hylidae	*Litoria verreauxii*	Verreaux's Frog			O/W
Myobatrachidae	*Crinia signifera*	Common Eastern Froglet			W
Myobatrachidae	*Limnodynastes peronii*	Striped Marsh Frog			O/W
Birds					
Alaudidae	*Alauda arvensis*	Skylark		U	W
Anatidae	*Anas platyrhynchos*	Mallard		U	O
Columbidae	*Streptopelia chinensis*	Spotted Turtle-Dove		U	W
Fringillidae	*Carduelis carduelis*	European Goldfinch		U	O
Muscicapidae	*Turdus merula*	Common Blackbird		U	O
Passeridae	*Passer domesticus*	House Sparrow		U	O
Pycnonotidae	*Pycnonotus jocosus*	Red-whiskered Bulbul		U	O/W
Sturnidae	*Acridotheres tristis*	Common Myna		U	O/W
Sturnidae	*Sturnus vulgaris*	Common Starling		U	O
Accipitridae	*Accipiter cirrhocephalus*	Collared Sparrowhawk			O
Accipitridae	*Accipiter fasciatus*	Brown Goshawk			O
Accipitridae	*Aquila audax*	Wedge-tailed Eagle			O

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Accipitridae	*Circus approximans*	Swamp Harrier			O
Accipitridae	*Elanus axillaris*	Black-shouldered Kite			O
Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-eagle	M		O
Anatidae	*Anas castanea*	Chestnut Teal			O
Anatidae	*Anas gracilis*	Grey Teal			O
Anatidae	*Anas superciliosa*	Pacific Black Duck			O/W
Anatidae	*Aythya australis*	Hardhead			O
Anatidae	*Chenonetta jubata*	Australian Wood Duck			O
Apodidae	*Apus pacificus*	Fork-tailed Swift	M		O
Ardeidae	*Ardea ibis*	Cattle Egret	M		O
Ardeidae	*Ardea pacifica*	White-necked Heron			O
Ardeidae	*Egretta novaehollandiae*	White-faced Heron			O/W
Artamidae	*Artamus cyanopterus*	Dusky Woodswallow			O
Artamidae	*Cracticus nigrogularis*	Pied Butcherbird			O
Artamidae	*Cracticus torquatus*	Grey Butcherbird			W
Artamidae	*Grallina cyanoleuca*	Magpie-lark			O/W
Artamidae	*Gymnorhina tibicen*	Australian Magpie			O/W
Artamidae	*Strepera graculina*	Pied Currawong			W
Cacatuidae	*Cacatua galerita*	Sulphur-crested Cockatoo			O/W
Cacatuidae	*Cacatua roseicapilla*	Galah			O/W
Cacatuidae	*Cacatua sanguinea*	Little Corella			O/W
Cacatuidae	*Cacatua tenuirostris*	Long-billed Corella			O/W
Cacatuidae	*Callocephalon fimbriatum*	Gang-gang Cockatoo		V	W
Cacatuidae	*Calyptorhynchus funereus*	Yellow-tailed Black-Cockatoo			O/W
Campephagidae	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike			O/W

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Campephagidae	*Coracina tenuirostris*	Cicadabird			W
Charadriidae	*Vanellus miles*	Masked Lapwing			O
Cinclosomatidae	*Psophodes olivaceus*	Eastern Whipbird			O/W
Climacteridae	*Cormobates leucophaeus*	White-throated Treecreeper			O/W
Columbidae	*Columba leucomela*	White-headed Pigeon			O/W
Columbidae	*Geopelia humeralis*	Bar-shouldered Dove			O/W
Columbidae	*Leucosarcia melanoleuca*	Wonga Pigeon			W
Columbidae	*Lopholaimus antarcticus*	Topknot Pigeon			O
Columbidae	*Macropygia amboinensis*	Brown Cuckoo-Dove			O/W
Columbidae	*Ocyphaps lophotes*	Crested Pigeon			O/W
Columbidae	*Phaps chalcoptera*	Common Bronzewing			O/W
Coraciidae	*Eurystomus orientalis*	Dollarbird			O/W
Corvidae	*Corvus coronoides*	Australian Raven			O/W
Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo			W
Cuculidae	*Cacomantis variolosus*	Brush Cuckoo			W
Cuculidae	*Chrysococcyx lucidus*	Shining Bronze-Cuckoo			W
Cuculidae	*Cuculus pallidus*	Pallid Cuckoo			O
Cuculidae	*Eudynamys scolopacea*	Common Koel			W
Cuculidae	*Scythrops novaehollandiae*	Channel-billed Cuckoo			O/W
Dicaeidae	*Dicaeum hirundinaceum*	Mistletoebird			O/W
Dicruridae	*Monarcha melanopsis*	Black-faced Monarch	M		O/W
Dicruridae	*Myiagra inquieta*	Restless Flycatcher			W
Dicruridae	*Rhipidura albiscapa*	Grey Fantail			O/W
Dicruridae	*Rhipidura leucophrys*	Willie Wagtail			O/W
Dicruridae	*Rhipidura rufifrons*	Rufous Fantail	M		O/W

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Falconidae	*Falco cenchroides*	Nankeen Kestrel			O
Falconidae	*Falco peregrinus*	Peregrine Falcon			O
Halcyonidae	*Dacelo novaeguineae*	Laughing Kookaburra			O/W
Halcyonidae	*Todiramphus sanctus*	Sacred Kingfisher			O/W
Hirundinidae	*Hirundo neoxena*	Welcome Swallow			O
Hirundinidae	*Hirundo nigricans*	Tree Martin			O
Maluridae	*Malurus cyaneus*	Superb Fairy-wren			O/W
Maluridae	*Malurus lamberti*	Variegated Fairy-wren			O/W
Maluridae	*Stipiturus malachurus*	Southern Emu-wren			O
Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill			O/W
Meliphagidae	*Anthochaera carunculata*	Red Wattlebird			W
Meliphagidae	*Anthochaera chrysoptera*	Little Wattlebird			W
Meliphagidae	*Lichenostomus chrysops*	Yellow-faced Honeyeater			O/W
Meliphagidae	*Manorina melanocephala*	Noisy Miner			O/W
Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater			O/W
Meliphagidae	*Melithreptus lunatus*	White-naped Honeyeater			W
Meliphagidae	*Myzomela sanguinolenta*	Scarlet Honeyeater			W
Meliphagidae	*Philemon citreogularis*	Little Friarbird			W
Meliphagidae	*Philemon corniculatus*	Noisy Friarbird			W
Meliphagidae	*Phylidonyris novaehollandiae*	New Holland Honeyeater			W
Motacillidae	*Anthus novaeseelandiae*	Richard's Pipit			O
Muscicapidae	*Acrocephalus stentoreus*	Australian Reed-Warbler	M		O
Muscicapidae	*Zoothera lunulata*	Bassian Thrush			W
Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole			O/W
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush			W

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Pachycephalidae	*Falcunculus frontatus*	Crested Shrike-tit			O
Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler			O/W
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler			O/W
Pardalotidae	*Acanthiza chrysorrhoa*	Yellow-rumped Thornbill			O/W
Pardalotidae	*Acanthiza lineata*	Striated Thornbill			O/W
Pardalotidae	*Acanthiza nana*	Yellow Thornbill			O/W
Pardalotidae	*Acanthiza pusilla*	Brown Thornbill			O/W
Pardalotidae	*Acanthiza reguloides*	Buff-rumped Thornbill			O
Pardalotidae	*Gerygone mouki*	Brown Gerygone			O/W
Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote			W
Pardalotidae	*Sericornis frontalis*	White-browed Scrubwren			O/W
Passeridae	*Neochmia temporalis*	Red-browed Finch			O/W
Passeridae	*Stagonopleura bella*	Beautiful Firetail			O/W
Pelecanidae	*Pelecanus conspicillatus*	Australian Pelican			O
Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin			O/W
Petroicidae	*Microeca fascinans*	Jacky Winter			O
Petroicidae	*Petroica rosea*	Rose Robin			O/W
Phalacrocoracidae	*Phalacrocorax melanoleucos*	Little Pied Cormorant			O
Phalacrocoracidae	*Phalacrocorax varius*	Pied Cormorant			O
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant			O
Podargidae	*Podargus strigoides*	Tawny Frogmouth			O
Podicipedidae	*Tachybaptus novaehollandiae*	Australasian Grebe			O
Psittacidae	*Alisterus scapularis*	Australian King-Parrot			O/W
Psittacidae	*Glossopsitta concinna*	Musk Lorikeet			W
Psittacidae	*Platycercus elegans*	Crimson Rosella			O/W

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Psittacidae	*Platycercus eximius*	Eastern Rosella			O/W
Psittacidae	*Trichoglossus haematodus*	Rainbow Lorikeet			O/W
Ptilonorhynchidae	*Ailuroedus crassirostris*	Green Catbird			W
Ptilonorhynchidae	*Ptilonorhynchus violaceus*	Satin Bowerbird			O/W
Rallidae	*Gallinula tenebrosa*	Dusky Moorhen			O
Rallidae	*Fulica atra*	Eurasian Coot			O
Rallidae	*Gallirallus philippensis*	Buff-banded Rail			O
Rallidae	*Porphyrio porphyrio*	Purple Swamphen			O
Strigidae	*Ninox strenua*	Powerful Owl		V	W
Threskiornithidae	*Platalea regia*	Royal Spoonbill			O
Threskiornithidae	*Threskiornis molucca*	Australian White Ibis			O
Threskiornithidae	*Threskiornis spinicollis*	Straw-necked Ibis			O
Zosteropidae	*Zosterops lateralis*	Silvereye			O/W
Mammals					
Canidae	*Vulpes vulpes*	Fox		U	P
Cervidae	*Cervus timorensis*	Rusa Deer		U	O
Leporidae	*Lepus capensis*	Brown Hare		U	O
Leporidae	*Oryctolagus cuniculus*	Rabbit		U	O
Muridae	*Rattus rattus*	Black Rat		U	T
Dasyuridae	*Antechinus stuartii*	Brown Antechinus			T
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail Bat		V	AD/AP/AM
Macropodidae	*Macropus giganteus*	Eastern Grey Kangaroo			O
Macropodidae	*Wallabia bicolor*	Swamp Wallaby			O/P
Molossidae	*Mormopterus norfolkensis*	Eastern Freetail Bat		V	AD
Molossidae	*Mormopterus sp. (little penis)*	Mormopterus sp. (little penis)			AD

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Molossidae	*Tadarida australis*	White-striped Freetail Bat			AD/W
Muridae	*Rattus fuscipes*	Bush Rat			T
Petauridae	*Petaurus breviceps*	Sugar Glider			O/W/N
Petauridae	*Pseudocheirus peregrinus*	Common Ringtail Possum			O/W/P
Phalangeridae	*Trichosurus vulpecula*	Common Brushtail Possum			O/R
Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying-fox	V	V	O
Rhinolophidae	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat			AD
Tachyglossidae	*Tachyglossus aculeatus*	Short-beaked Echidna			O
Vespertilionidae	*Miniopterus schreibersii oceanensis*	Eastern Bentwing-bat		V	AD/AP/AM
Vespertilionidae	*Chalinolobus gouldii*	Gould's Wattled Bat			AD/T
Vespertilionidae	*Chalinolobus morio*	Chocolate Wattled Bat			AD/AP
Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle		V	AP/AM
Vespertilionidae	*Myotis macropus*	Southern Myotis		V	AD/AP
Vespertilionidae	*Nyctophilus geoffroyi*	Lesser Long-eared Bat			T
Vespertilionidae	*Nyctophilus gouldi*	Gould's Long-eared Bat			T
Vespertilionidae	*Nyctophilus sp.*	Long-eared bat sp.			AD/AP
Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat		V	T/AP/AM
Vespertilionidae	*Scotorepens orion*	Eastern Broad-nosed Bat			T/AD/AP
Vespertilionidae	*Vespadelus darlingtoni*	Large Forest Bat			AD/AP
Vespertilionidae	*Vespadelus pumilus*	Eastern Forest Bat			AD/AP/AM
Vespertilionidae	*Vespadelus regulus*	Southern Forest Bat			AP
Vespertilionidae	*Vespadelus vulturnus*	Little Forest Bat			T/AD
Vombatidae	*Vombatus ursinus*	Common Wombat			P
Reptiles					
Agamidae	*Physignathus lesueurii*	Eastern Water Dragon			O

Family name	Latin name	Common name	EPBC Act	TSC Act	Obs. type
Boidae	*Morelia spilota spilota*	Diamond Python			O
Chelidae	*Chelodina longicollis*	Eastern Long-necked Tortoise			R
Elapidae	*Pseudechis porphyriacus*	Red-bellied Black Snake			O
Scincidae	*Ctenotus robustus*	Striped Skink			O
Scincidae	*Eulamprus quoyii*	Eastern Water Skink			O
Scincidae	*Lampropholis delicata*	Grass Skink			O
Scincidae	*Lampropholis guichenoti*	Garden Skink			O
Scincidae	*Tiliqua scincoides*	Eastern Blue-tongued Lizard			O

Act listing: *V = Vulnerable, M = Migratory, U = Unprotected/introduced*
Observation type: *W = heard, O = seen, T = trapped, P = scat, N = glider notches/scratches, R = roadkill, AD = anabat recording (definite), AP = Anabat recording (probable), AM = Anabat recording (possible)*

Appendix C

Threatened flora potentially occurring in the local area

Terrestrial flora listed on the TSC Act and/or the EPBC Act that may occur in the local area

Key: 1) Listed on the EPBC Act as Endangered (E), Critically Endangered (Z) or Vulnerable (V)
2) Listed on the TSC Act as Endangered (E1), Vulnerable (V) or Preliminary Determination (PD)
*) Subject species considered further in Chapter 6

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Acacia baueri ssp. *aspera*	-	V	Occurs in the Hawkesbury/Nepean, Southern Rivers, and Sydney Metropolitan Catchment Authority Regions. More specifically it occurs on the Kings Tableland in the central Blue Mountains and with sporadic occurrences on the Woronora Plateau in the Royal National Park, Mt. Keira district and at Wedderburn. May also occur on the escarpment/Woronora Plateau in the Flat Rock Junction and Stanwell Tops area of the Illawarra (DEC 2005a). Occurs in low, damp heathlands, often on exposed rocky outcrops over a wide range of climatic and topographical conditions (DEC 2005a). For instance, at Kings Tableland *A. baueri* subsp. *aspera* occurs on Narrabeen Group Sandstones. The soil landscape is Mount Sinai comprising narrow, rocky crests with steep-sided slopes and rocky benches(NPWS 2000). At Woronora Plateau *A. baueri* subsp. *aspera* occurs in dry to damp heath associated with more open areas within Sandstone Woodland (Keith 1994) dominated by *Eucalyptus sieberi*, *E. rossii* and *Allocasuarina distyla - Banksia ericifolia* scrub-heath. The geology is Hawkesbury Sandstone and soil landscapes include Maddens Plains, Bundeena and Lucas Heights (NPWS 2000). Appears to prefer open conditions; rarely observed where there is any shrub or tree canopy development; and many of the observations of this species have been made following fire, suggesting the species prefers early successional habitats. Peak flowering occurs December to March. Pods have been observed to remain on the plants for several months, maturing October to December (DEC 2005a).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Arthropteris palisotii Lesser Creeping Fern	-	E1	May be extinct in NSW. Found in rainforest where it usually grows on tree trunks (Harden and Murray 2000).	Yes. Illawarra Wet Gully Forest and Warm Temperate Layered Forest provide marginal habitat for the species.	Low. There are no records of the species in the locality. There are only two records of the species in NSW. Habitat is marginal and the nearest record of the species is 140 kilometres north of the study area recorded in 1996.
Boronia deanei Deane's Boronia	V	V	Occurs in Hawkesbury/Nepean and Southern Rivers catchments. There are scattered populations of Deane's Boronia between the far south-east of NSW and the Blue Mountains (DEC 2005d). The species grows on the margins of high altitude swamps (Ollerenshaw 1979), in wet heath and in drier open forest on low nutrient, poorly drained peaty soils on sandstone or granite (Benson and McDougall 2001). The distribution of this species overlaps with the following *EPBC Act*-listed threatened ecological communities: White Box-Yellow Box-Blakely's Red Gum grassy woodland and derived native grassland, natural temperate grassland of the Southern Tablelands of NSW and ACT, and temperate highland peat swamps on sandstone (DEC 2005d).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Caladenia tessellata Tessellated Spider Orchid	V	E1	*Caladenia tessellata* is found in the Sydney Metropolitan, Southern Rivers, Hawkesbury/Nepean, and Hunter/Central Rivers Catchment Management Regions. Currently known from three disjunct areas: Braidwood on southern tablelands, Ulladulla on the south coast and three populations in Wyong area on the Central Coast (DEC 2005d). It is generally found in grassy, dry sclerophyll forests/woodland, particularly those associated with clay loam, or sandy soils. However, there is one population at Braidwood in lowland on stony soil (DEC 2005d). This species only grows in very dense shrubbery in coastal areas (Bishop 1996). Flowers appear between September and November, but generally late September or early October in extant southern populations (DEC 2005d).	Yes. Currambene-Batemans Lowlands Forest provides marginal habitat for the species.	Low. There are no records of the species in the locality. The potential habitat is marginal and is small in area. The nearest record of the species is a single observation made in 1931 30 kilometres south of the study area. The majority of remaining records are from the Sydney Metropolitan and Central Coast areas.
Callistemon linearifolius	-	V	Occurs chiefly from Georges River to the Hawkesbury River where it grows in dry sclerophyll forest (Harden 2002), open forest, scrubland (Fairley and Moore 2000) or woodland on sandstone. Found in damp places, usually in gullies (Robinson 1994). Flowers in Spring.	No	Low
Chamaesyce psammogeton Sand Spurge	-	E1	Found sparsely along the coast from south of Jervis Bay to Queensland, in the following catchment regions – Hunter/Central Rivers, Hawkesbury/Nepean, Northern Rivers, Southern Rivers and Sydney Metropolitan. Populations have been recorded in Wamberal Lagoon Nature Reserve, Myall Lakes National Park and Bundjalung National Park. Grows on fore-dunes and exposed headlands, often with *Spinifex sericeus.* Flowering occurs in summer, with plant growth occurring in spring and summer (DEC 2005g).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
*Cryptostylis hunteriana** Leafless Tongue Orchid	V	V	This species typically grows in swamp-heath on sandy soils chiefly in coastal districts (Harden 1993) but has also been recorded on steep bare hillsides (Bishop 1996). This species does not appear to have well defined habitat preferences and is known from a range of communities, including swamp-heath and woodland. The larger populations typically occur in woodland dominated by *Eucalyptus sclerophylla, E. sieberi, Corymbia gummifera* and *Allocasuarina littoralis;* appears to prefer open areas in the understorey of this community and is often found in association with *Cryptostylis subulata* (DEC 2005h).	Yes. Potential habitat considered to be associated with Currambene-Batemans lowlands forest.	Low. The potential habitat is marginal and is small in area. The nearest record of the species is 15 kilometres southwest of the study area recorded in 2005.
*Cynanchum elegans** White-flowered Wax Plant	E	E1	Restricted to eastern NSW where it is distributed from Brunswick Heads on the north coast to Gerroa in the Illawarra region. The species has been recorded as far west as Merriwa in the Upper Hunter River Valley. Catchment management regions include Hawkesbury/Nepean, Hunter/Central Rivers, Northern Rivers, Southern Rivers and Sydney Metropolitan (DEC 2005‰). *Cynanchum elegans* usually occurs on the edge of dry rainforest vegetation. Other associated vegetation types include littoral rainforest; *Leptospermum laevigatum, Banksia integrifolia* subsp. *integrifolia; Eucalyptus tereticornis* open forest and woodland; *Eucalyptus maculata* open forest and woodland; and *Melaleuca armillaris* scrub to open scrub (DEC 2005‰). Flowering occurs between August and May, with a peak in November. Flower abundance on individual plants varies from sparse to prolific (DEC 2005‰).	Yes. Potential habitat considered to be associated with subtropical complex rainforest and warm temperate layered forest.	High. Records in the eastern area of the locality.
Daphnandra sp. "Illawarra'* Illawarra Socketwood	E	E1	Occupies the rocky hillsides and gullies of the Illawarra lowlands, occasionally extending onto the upper escarpment slopes. Associated vegetation includes rainforest and moist eucalypt forest (DEC 2005j).	Yes. Potential habitat considered to be associated with subtropical complex rainforest and warm temperate layered forest.	High. Multiple records in the eastern area of the locality.

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Distichlis distichophylla Australian Saltgrass	-	E1	This grass is common in Victoria and Tasmania, and extends to South Australia and Western Australia. In Victoria it is found inland as well, but in its limited NSW range it grows only in coastal situations, except for one existing population at Lake Cargelligo. Scattered records are from the areas of Jervis Bay, Bermagui, Wonboyn, Narooma, Bodalla and Nadgee Nature Reserve (at Womboyn). A coloniser of damp saline soils; found at the edges of salt marshes and on low dunes. Flowers and sets seed in late spring and summer (DEC 2005f).	No	Low
Eucalyptus langleyi Albatross Mallee	V	V	The main occurrence of the Albatross Mallee is to the south-west of Nowra as far as Yarramunmun Creek. It is also found to a limited extent north of the Shoalhaven River in the vicinity of Bomaderry Creek. Found in mallee shrubland on poorly-drained, shallow, sandy soils on sandstone. The species regenerates from rootstock after fire (DEC 2005o).	No	Low
Eucalyptus sturgissiana Ettrema Mallee	-	V	The Ettrema Mallee is mostly restricted to the Northern Budawang Range in Morton National Park, with a few occurrences on the nearby coastal plain. Usually grows as an emergent in low shrub-heath. Grows on sandy, swampy soils (DEC 2005h).	No	Low
*Genoplesium baueri** Bauer's Midge Orchid	-	V	This terrestrial orchid species grows in open sclerophyll forest or moss gardens on sandstone. Typically the habitat is a drier heathy forest (Harden 1993; Bishop 1996). The species has been recorded from locations between Nowra and Pittwater and may occur as far north as Port Stephens. About half the records were made before 1960 with most of the older records being from Sydney suburbs including Asquith, Cowan, Gladesville, Longueville and Wahroonga. No collections have been made from those sites in recent years. Flowers December to March (DEC 2005i).	No	Low
Genoplesium superbum	-	E1	*Genoplesium superbum* is restricted to the southern tablelands of NSW where it has been recorded from two locations near Nerriga, c. 20 km apart. Some plants fall within the boundary of Morton National Park. Occurs predominantly in wet heathland on shallow soils above a sandstone cap but has also been found in open woodland interspersed with heath (DEC 2005j).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Haloragis exalata ssp *exalata* Square Raspwort	-	V	Square Raspwort occurs in four widely scattered localities in eastern NSW. These disjunct populations occur on the central coast, south coast and north-western slopes of NSW. This species prefers protected and shaded damp habitat in riparian communities. Flowering has been recorded throughout November to January (DEC 2005l).	Yes. Riverbank forest provides habitat for the species.	Low. Habitat for the species in the study area is highly degraded and subject to continuing impacts such as weed invasion and grazing. There are no records of the species in the locality and nearest record of the species is 140 kilometres north of the study area recorded in 1996.
*Irenepharsus trypherus** Delicate Cress	E	E1	Occurs on coast and escarpment between Wollongong and the Shoalhaven River (Harden 1990). Typically inhabits steep rocky slopes near cliff lines and ridge tops. The species is less typically found growing out of rock crevices or on narrow benches along cliff lines. The vast majority of sites are recorded from the upper slopes of the ridge systems that extend south and east of the Illawarra escarpment, although the species has also been recorded from the deep sandstone gorges of the Shoalhaven River. Associated vegetation includes moist sclerophyll forest, Ironwood *Backhousia myrtifolia* thicket, and rainforest (DEC 2005u).	Yes. Potential habitat considered to be associated with subtropical complex rainforest, Illawarra gully wet forest and warm temperate layered forest.	Low. Although there are no records of the species in the locality there are multiple records of the species approximately 15 kilometres to the west in the vicinity of Kangaroo Valley.

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Lastreopsis hispida Bristly Shield Fern	-	E1	In NSW, occurs in the Blue Mountains. Also occurs in Southern Victoria and Tasmania. Grows in wet forests, frequently under *Nothofagus antarcticus* and often rotting on logs (DEC 2005x).	Yes. Illawarra Wet Gully Forest and Warm Temperate Layered Forest provide marginal habitat for the species.	Low. Habitat is marginal and there are only five records of the species in NSW. The single record in the southeast area of the locality dates from 1884. The remaining records are from the Blue Mountains between 1914 and 1979.
Melaleuca biconvexa Biconvex Paperbark	V	V	*Melaleuca biconvexa* is only found in NSW, with scattered and dispersed populations found in the Jervis Bay area in the south and the Gosford-Wyong area in the north. Catchment regions include: Hunter/Central Rivers, Hawkesbury/Nepean, Southern Rivers, and Northern River catchments (DEC 2005{). *Melaleuca biconvexa* generally grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Flowering occurs over just three to four weeks in September and October (DEC 2005{).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Pimelea spicata Spiked Rice-flower	E	E1	Once widespread on the Cumberland Plain, *Pimelea spicata* occurs in two disjunct areas, the Cumberland Plain and the Illawarra. Catchment areas are Hawkesbury/Nepean, Southern Rivers, and Sydney Metropolitan catchment (NPWS 2000). In the Illawarra region, *P. spicata* is found in open woodland and also in coastal grassland communities with emergent shrubs. Dominant species within the woodland habitat include *Eucalyptus tereticornis, E. eugenioides, Themeda australis,* and *Lomandra longifolia*. In the Coastal Illawarra it occurs commonly in Coast Banksia open woodland with a well developed shrub and grass understorey (NPWS 2004). *Pimelea spicata* flowers sporadically throughout the year, with flowering likely to depend upon climatic conditions, particularly rainfall. Flowering times recorded for *P. spicata* vary. Benson and McDougall (2001) noted peak flowering period as March/April (NPWS 2000).	No	High. One record at Black Head at the eastern extent of the locality.
Pomaderris adnata Sublime Point Pomaderris	-	E1	Ridgetop vegetation often with *Eucalyptus sieberi* and *Corymbia gummifera* (NSW Scientific Committee 2001). Occurs near the edge of the plateau behind the Illawarra escarpment. Known only from one site at Sublime Point, north of Wollongong (DEC 2005p).	No	Low
*Pterostylis gibbosa** Illawarra Greenhood	E	E1	Known from a small number of populations in the Hunter region, the Illawarra region and the Shoalhaven region. It is apparently extinct in Western Sydney which is the area where it was first collected (1803) (DEC 2005€). All known populations grow in open forest or woodland, on flat or gently sloping land with poor drainage. In the Illawarra region, the species grows in woodland dominated by *Eucalyptus tereticornis, E. longifolia and Melaleuca decora*. Near Nowra, the species grows in an open forest of *Corymbia maculata, E. tereticornis* and *E. paniculata*. In the Hunter region, the species grows in open woodland dominated by *E. crebra, Forest Red Gum* and *Callitris endlicherii* (DEC 2005€). The Illawarra Greenhood is a deciduous orchid that is only visible above the ground between late summer and spring, and only when soil moisture levels can sustain its growth. The leaf rosette grows from an underground tuber in late summer, followed by the flower stem in winter (DEC 2005€).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Pterostylis pulchella Waterfall Greenhood	V	V	The Waterfall Greenhood is found only at Fitzroy Falls, Belmore Falls, upper Bundanoon Creek (Meryla) and Minnamurra Falls (DEC 2005‹). Usually favours creek banks and mossy rocks very close to running water (Bishop 1996). Flowers appear from February to May (DEC 2005‹).	No	Low
Pultenaea aristata Prickly Bush-pea	V	V	Restricted to the Woronora Plateau, a small area between Helensburgh, south of Sydney, and Mt Keira above Wollongong. The species occurs in either dry sclerophyll woodland or wet heath on sandstone. Flowering has been recorded in winter and spring (DEC 2005s).	No	Low
Rulingia prostrata Dwarf Kerrawang	E	E1	*Rulingia prostata* occurs on the Southern Tablelands, and on the North Coast, in the Hawkesbury/Nepean, Hunter/Central Rivers, Murrumbidgee and Southern Rivers Catchments. Occurs on sandy, sometimes peaty soils in a wide variety of habitats: *Eucalyptus pauciflora* Woodland at Rose Lagoon; *E. agglomerata* Open Forest at Tallong; and in *E. mannifera* Low Open Woodland at Penrose; *Eucalyptus haemostoma*/*E. robusta* Ecotonal Forest at Tomago (DEC 2005v). Associated native species may include *Imperata cylindrica*, *Empodisma minus* and *Leptospermum continentale*. Appears to respond positively to some forms of disturbance (DEC 2005v).	No	Low
Senna acclinis Rainforest Cassia	-	E1	Found in coastal districts and adjacent tablelands of NSW from the Illawarra in NSW to Queensland. Grows in or on the edges of subtropical and dry rainforest (DEC 2005w).	Yes. Illawarra Wet Gully Forest and Warm Temperate Layered Forest provide marginal habitat for the species.	Low. There are no records of the species in the locality and the nearest record of the species is 40 kilometres north of the study area recorded in 1998.

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Solanum celatum	-	E1	Restricted to an area from Wollongong to just south of Nowra, and west to Bungonia. Majority of records are prior to 1960 and the majority of populations are likely to have been lost to clearing. Grows in rainforest clearings, or in wet sclerophyll forests. Flowers August to October and produces fruit December to January (DEC 2005x).	Yes. Illawarra Wet Gully Forest and Warm Temperate Layered Forest provide marginal habitat for the species.	Low. There are no records of the species in the locality and the habitat is marginal. The majority of records in the region are on the higher slopes of the Cambewarra and Illawarra Ranges.
Syzygium paniculatum Magenta Lilly Pilly	V	V	Subtropical and littoral rainforest on sandy soils or stabilised dunes near the sea (Harden 1991). Found only in NSW, in a narrow, linear coastal strip from Bulahdelah to Conjola State Forest. On the south coast the Magenta Lilly Pilly occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral (coastal) rainforest. On the central coast Magenta Lilly Pilly occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities (DEC 2005{). The species occurs in the Hunter/Central Rivers, Hawkesbury/Nepean, Sydney Metropolitan, and Southern Rivers Catchment Authority Regions	Yes. Illawarra Wet Gully Forest and Warm Temperate Layered Forest provide marginal habitat for the species.	Low. There are no records of the species in the locality. The nearest record of the species is from 2004, 17 kilometres to the south in an urban area.
Thelymitra sp. Kangaloon Kangaloon Sun-orchid	Z	PD E1	*Thelymitra* sp. Kangaloon is a terrestrial orchid endemic to NSW, and is known from three locations near Robertson in the Southern Highlands. The swamp habitat in which the species occurs has an extent of occurrence of 300 square kilometres and an area of occupancy of 10 square kilometres. The three swamps are Butlers Swamp, Stockyard Swamp and Wildes Meadow Swamp, and are all located above what is known as the Kangaloon aquifer. It flowers in late October and early November. The species grows amongst tall sedges and rushes in seasonally swampy sedgeland on grey silty clay loam at 600 metres to 700 metres above sea level (Threatened Species Listing Advice 2008).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Thesium australe Austral Toad-flax	V	V	Found in very small to large populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. *Thesium australe* is a root parasite that takes water and some nutrient from other plants, especially Kangaroo Grass (DEC 2005ˆ). It is often found in damp sites in association with *Themeda australis*, but also found on other grass species at inland sites (G. Leonard pers. obs.). Occurs on clay soils in grassy woodlands or coastal headlands (James *et al.* 1999).	Yes. Potential habitat considered to be associated with Currambene-Batemans lowlands forest.	Low. The potential habitat is small in area. The nearest record of the species is 67 kilometres south of the study area recorded in 1911.
Triplarina nowraensis Nowra Heath-myrtle	E	E1	There are five known populations of *Triplarina nowraensis.* Three of these form a cluster to the immediate west of Nowra. A fourth, much smaller population is found 18 kilometres south-west of Nowra in the Boolijong Creek Valley. The fifth population is located north of the Shoalhaven River on the plateau above Bundanon. *Triplarina nowraensis* occurs on poorly drained, gently sloping sandstone shelves or along creek lines underlain by Nowra Sandstone. The sites are often either treeless or have a very open tree canopy due to the impeded drainage (DEC 2005Œ).	No	Low
Wilsonia backhousei Narrow-leafed Wilsonia	-	V	In NSW *Wilsonia backhousei* is found in the Southern Rivers and Sydney Metropolitan Catchment Area, specifically on the coast between Mimosa Rocks National Park and Wamberal north of Sydney (Nelson's Lake, Potato Point, Sussex Inlet, Wowly Gully, Parramatta River at Ermington, Clovelly, Voyager Point, Wollongong and Royal National Park) (DEC 2005}). This is a species of the margins of salt marshes and lakes, both coastal and inland, chiefly in the Sydney district, also common at Jervis Bay (Harden 1992). Flowering occurs in spring and summer (DEC 2005}).	No	Low
Wilsonia rotundifolia Round-leafed Wilsonia	-	E1	Occurs in the Sydney Metropolitan, Hawkesbury/Nepean, Murray and Southern Rivers Catchment Authority Regions. Is known from several sites in the Jervis Bay area, Royal National Park, near Deniliquin and in Lake George and Lake Bathurst (DEC 2005d~). Grows in mud in coastal salt marsh and inland saline lakes. It occurs in mid marsh, mixed with *Sporobolus virginicus* and *Sarcocornia quinqueflora*. Flowers mainly appear in spring and summer (DEC 2005d~).	No	Low

Latin name/common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in the study area?	Likelihood of occurrence in the locality?
Zieria baeuerleni Bomaderry Zieria	E	E1	The species occurs in only one location north-west of Nowra. The population occurs in a total of 43 colonies in six discrete clusters. These clusters are confined within a 0.5 kilometre x 1.0 kilometre area of the bushland, and are found on both sides of Bomaderry Creek. Bomaderry *Zieria baeuerleni* occurs on skeletal sandy loam overlaying sandstone, on a rocky plateau amongst sandstone boulders in either shrubby open forest, shrubby woodland or closed scrub (DEC 2005).	No	Low
*Zieria granulata** Hill Zieria	E	E1	Occurs in the Kiama district where it grows on dry rocky ridges in sclerophyll forest to rainforest margins (Harden 2002). The species primarily occupies the coastal lowlands between Oak Flats and Toolijooa, in the local government areas of Shellharbour and Kiama. The typical habitat is dry ridge tops and rocky outcrops on shallow volcanic soils. Less frequently found on the moist slopes of the Illawarra escarpment and in low-lying areas on Quaternary sediments. Associated vegetation includes *Melaleuca armillaris* scrub, *Eucalyptus tereticornis* woodland and rainforest margins, although the species has been recorded from a number of other vegetation types (DEC 2005').	Yes. Potential habitat considered to be associated with subtropical complex rainforest and warm temperate layered forest, associated with rocky outcrops.	High. Multiple records in the eastern area of the locality.
Zieria tuberculata Warty Zieria	V	V	Warty Zieria grows in the Mt Dromedary and Tilba Tilba area. The population in the Cambewarra Mountain area near Nowra is now referable to a separate taxon. The Warty Zieria grows in heath amongst rocky outcrops on rain forest edges and in tall forest and shrubland. The flowers appear from late winter to spring (DEC 2005). Now known only from Little Dromedary Mt and the lower eastern slopes of Mt Dromedary in the Central Tilba area on the South Coast of NSW, the species has a geographic range of 6 kilometres. In 1931, it was collected from Good Dog Mountain in the Cambewarra Range, north of Nowra but more recent searches have failed to find the species there. Although this site is now heavily revegetated, the species may have been eliminated from the area as a result of earlier clearing and grazing (DEWHA 2008b). The total known population of about 900 plants grows at eight sites. Four populations are on private property. Three of the smaller populations totalling about 60 plants occur within Gulaga NP and the Little Dromedary Mt population is on crown land (DEWHA 2008b).	No	Low

Appendix D

Threatened and migratory fauna potentially occurring in the local area

Terrestrial fauna listed on the TSC Act and/or the EPBC Act that may occur in the local area

Key: 1) Listed on the EPBC Act as Endangered (E), Critically Endangered (Z), Vulnerable (V) or covered under migratory provisions (M) of the Act
2) Listed on the TSC Act as Endangered (E1), Critically Endangered (CI) or Vulnerable (V)
*) Subject species considered further in Chapter 6
#) Migratory species considered further in Chapter 6

Note: Species which were recorded in the study area during current surveys are presented in bold font.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Amphibians					
*Litoria aurea** Green and Golden Bell Frog	V	E1	Most existing locations for the species occur as small, coastal, or near coastal populations, with records occurring between south of Grafton and northern Victoria (NSW Government 2009). The species is found in marshes, dams and stream sides, particularly those containing bullrushes or spikerushes. Preferred habitat contains water bodies that are unshaded, are free of predatory fish, have a grassy area nearby and have diurnal sheltering sites nearby such as vegetation or rocks (NPWS 1999e; White and Pyke 1996), although the species has also been recorded from highly disturbed areas including disused industrial sites, brick pits, landfill areas and cleared land. Breeding usually occurs in summer. Tadpoles, which take about 10-12 weeks to develop (DECC 2008), feed on algae and other vegetative matter. Adults eat insects as well as other frogs, including juveniles of their own species (DEC2005k).	Yes, but limited.	High. Previously recorded south of the study area within Foys and Coomonderry swamps.
Litoria littlejohni Littlejohn's Tree Frog	V	V	The species is distributed along the eastern slopes of the Great Dividing Range from Watagan State Forest near Wyong, south to Buchan in north-eastern Victoria. It is not known from coastal habitats (DEH 2005). Occurs in wet and dry sclerophyll forests and heath communities associated with sandstone outcrops between 280 metres and 1000 metres (Barker *et al.* 1995). Littlejohn's Tree Frog prefers permanent and semi-permanent rocky flowing streams, but individuals have also been collected from semi-permanent dams with some emergent vegetation (Barker *et al.* 1995). Forages both in the tree canopy and on the ground, and has been observed sheltering under rocks on high exposed ridges during summer. The species breeds in autumn but will also breed after heavy rainfall in spring and summer (NSW Scientific Committee 2000). The species has been recorded calling in all seasons with variously reported peak calling periods (DEH 2005). Eggs are laid in loose gelatinous masses attached to submerged twigs; eggs and tadpoles are most often recorded in slow-flowing pools that receive extended exposure to sunlight (DSEWPC 2010).	No	Low. Previously recorded north and north-west of the locality. Not a coastal species.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Heleioporus australiacus Giant Burrowing Frog	V	V	Prefers hanging swamps on sandstone shelves adjacent to perennial non-flooding creeks (Daly 1996; Recsei 1996). Can also occur within shale outcrops within sandstone formations. Known from wet and dry forests and montane woodland in the southern part range (Daly 1006). Individuals can be found around sandy creek banks or foraging along ridge-tops during or directly after heavy rain. Males often call from burrows located in sandy banks next to water (Barker *et al.* 1995). Spends the majority of its time in non-breeding habitat 20-250 metres from breeding sites (Penman *et al.* 2008).	No	Low. Previously recorded 10 kilometres west and south-west of the study area.
Mixophyes balbus Stuttering Frog	V	E1	This species is usually associated with mountain streams, wet mountain forests and rainforests (Barker *et al.* 1995). It rarely moves very far from the banks of permanent forest streams, although it will forage on nearby forest floors. Eggs are deposited in leaf litter on the banks of streams and are washed into the water during heavy rains (Barker *et al.* 1995).	No	Low. Not previously recorded within 10 kilometres of the study area.
Pseudophryne australis Red-crowned Toadlet	-	V	Occurs on wetter ridge tops and upper slopes of sandstone formations on which the predominant vegetation is dry open forests and heaths. This species typically breeds within small ephemeral creeks characterised by a series of shallow pools that feed into larger semi-perennial streams (Thumm and Mahony 1997). Breeds all year round (Thumm and Mahony 1997).	No	Low. Not previously recorded within 10 kilometres of the study area.
Birds					
*Circus assimilis** Spotted Harrier	-	V	The Spotted Harrier is found throughout Australia but rarely in densely forested and wooded habitat of the escarpment and coast (NSW Scientific Committee 2010b). Preferred habitat consists of open and wooded country with grassland nearby for hunting. Habitat types include open grasslands, acacia and mallee remnants, spinifex, open shrublands, saltbush, very open woodlands, crops and similar low vegetation (NSW Scientific Committee 2010b). The Spotted Harrier is more common in drier inland areas, nomadic part migratory and dispersive, with movements linked to the abundance of prey species. Nesting occurs in open or remnant woodland and unlike other harriers, the Spotted Harrier nests in trees (Marchant and Higgins 1993).	Yes	High. Previously recorded just south of the study area within Berry and north of the study area.
***Haliaeetus leucogaster*[#] White-bellied Sea-eagle**	**M**	**-**	**A migratory species that is generally sedentary in Australia, although immature individuals and some adults are dispersive** (Marchant and Higgins 1993)**. Found in terrestrial and coastal wetlands; favouring deep freshwater swamps, lakes and reservoirs; shallow coastal lagoons and saltmarshes. It hunts over open terrestrial habitats. Feeds on birds, reptiles, fish, mammals, crustaceans and carrion. Roosts and makes nest in trees** (Marchant and Higgins 1993)**.**	**Yes**	**High. Recorded during field surveys at the western end of the study area. Also previously recorded north, south, east and west of the study area.**

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Hieraaetus morphnoides** Little Eagle	-	V	The Little Eagle is most abundant in lightly timbered areas with open areas nearby providing an abundance of prey species (NSW Scientific Committee 2009b). It has often been recorded foraging in grasslands, crops, treeless dune fields, and recently logged areas. The Little Eagle nests in tall living trees within farmland, woodland and forests (Marchant and Higgins 1993).	Yes	High. Previously recorded east of the study area at Crooked River. Also previously recorded north and south-west of the study area.
*Lophoictinia isura** Square-tailed Kite	-	V	Typically inhabits coastal forested and wooded lands of tropical and temperate Australia (Marchant and Higgins 1993). In NSW it is often associated with ridge and gully forests dominated by *Eucalyptus longifolia, Corymbia maculata, E. elata*, or *E. smithii* (NPWS 1999i). Individuals appear to occupy large hunting ranges of more than 100 square kilometres. They require large living trees for breeding, particularly near water with surrounding woodland/forest close by for foraging habitat. Nest sites are generally located along or near watercourses, in a tree fork or on large horizontal limbs (Marchant and Higgins 1993).	Yes	High. Previously recorded south of the study area at Coomonderry Swamp and 10 kilometres to the south-west.
*Pandion haliaetus** Osprey	M	V	Found in coastal waters, inlets, estuaries and offshore islands. Occasionally found 100 kilometres inland along larger rivers (Pizzey and Knight 1997). It is water-dependent, hunting for fish in clear, open water. The Osprey occurs in terrestrial wetlands, coastal lands and offshore islands. It is a predominantly coastal species, generally using marine cliffs as nesting and roosting sites. Nests can also be made high up in dead trees or in dead crowns of live trees, usually within one kilometre of the sea (Marchant and Higgins 1993).	Yes	Moderate. Previously recorded once, south of the study area at Seven Mile Beach National Park.
*Oxyura australis** Blue-billed Duck	-	V	Almost wholly aquatic, preferring deep water in large, permanent wetlands with an abundant aquatic flora (Marchant and Higgins 1990).	Yes, but limited.	Low. Habitat is marginal and the closest records occur 10 kilometres southeast of the study area recorded over 25 years ago in 1985.
*Stictonetta naevosa** Freckled Duck	-	V	The Freckled Duck breeds in permanent fresh swamps that are heavily vegetated. Found in fresh or salty permanent open lakes, especially during drought. Often seen in groups on fallen trees and sand spits (Simpson and Day 1996).	Yes, but limited.	Low. Habitat is marginal and the closest record occurs 11 kilometres southwest of the study area recorded 30 years ago in 1981.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
***Apus pacificus*[#]** **Fork-tailed Swift**	**M**	**-**	**Almost exclusively aerial. The Fork-tailed Swift breeds in Asia but migrates to Australia from September to April (Higgins 1999). Individuals or flocks can be observed hawking for insects at varying heights from only a few metres from the ground and up to 300 metres high (Boehm 1944).**	**Yes**	**High. Recorded during field surveys (site 7). Likely to fly high over the study area.**
Hirundapus caudacutus[#] White-throated Needletail	M	-	An aerial species found in feeding concentrations over cities, hilltops and timbered ranges. Breeds in Asia (Pizzey and Knight 1997).	Yes	High. Likely to fly high over the study area.
Ardea alba[#] Great Egret	M	-	Terrestrial wetlands, estuarine and littoral habitats and moist grasslands. Inland, prefer permanent waterbodies on floodplains; shallows of deep permanent lakes (either open or vegetated), semi-permanent swamps with tall emergent vegetation and herb dominated seasonal swamps with abundant aquatic flora. Also regularly use saline habitats including mangrove forests, estuarine mudflats, saltmarshes, bare saltpans, shallows of salt lakes, salt fields and offshore reefs. Breeding requires wetlands with fringing trees in which to build nests including mangrove forest, freshwater lakes or swamps and rivers (Marchant and Higgins 1990).	Yes	High. Previously recorded within Broughton Creek (site 32) as well as south of the study area.
***Ardea ibis*[#]** **Cattle Egret**	**M**	**-**	**Occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands** (Marchant and Higgins 1990)**.**	**Yes**	**High. Recorded during field surveys. Also previously recorded north, south, east and west of the study area.**
*Botaurus poiciloptilus** Australasian Bittern	E	E1	The Australasian Bittern is distributed across south-eastern Australia. Often found in terrestrial and estuarine wetlands, generally where there is permanent water with tall, dense vegetation including Typha spp. and Eleoacharis spp. (DECC 2005; NPWS 1999a). Typically this bird forages at night on frogs, fish and invertebrates, and remains inconspicuous during the day. The breeding season extends from October to January with nests being built amongst dense vegetation on a flattened platform of reeds (DECC 2005).	Yes	High. Previously recorded north-east, south-east and south of the study area (including within Coomonderry Swamp).
Egretta sacra Eastern Reef Egret	M	-	Widely distributed throughout a range of maritime littoral and estuarine habitats on mainland, islands and atolls. Prefers rocky shorelines. Roosts within close proximity to water, on dead or living trees, sand spits, banks, and artificial structures, such as wharfs (Marchant and Higgins 1990).	No	High. Previously recorded south-east of the study area at Crooked River and Black Head.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Ixobrychus flavicollis** Black Bittern	-	V	The Black Bittern is found along the coastal plains within NSW, although individuals have rarely being recorded south of Sydney or inland. It inhabits terrestrial and estuarine wetlands such as flooded grasslands, forests, woodlands, rainforests and mangroves with permanent water and dense waterside vegetation (DEC 2005c). The Black Bittern typically roosts on the ground or in trees during the day and forages at night on frogs, reptiles, fish and invertebrates (DEC 2005c). The breeding season extends from December to March. Nests are constructed of reeds and sticks in branches overhanging the water.	Yes	High. Previously recorded on the edge of the study area adjacent to Town Creek (south of Berry) and south-east of the study area at Black Head.
*Burhinus grallarius** Bush Stone-curlew	-	E1	Lightly timbered open forest and woodland, or partly cleared farmland with remnants of woodland, with a ground cover of short sparse grass and few or no shrubs where fallen branches and leaf litter are present (Marchant and Higgins 1993).	Yes	Moderate. Previously recorded once, about 9 kilometres south of the study area.
Esacus neglectus Beach Stone-curlew	-	C1	Occurs on open, undisturbed beaches, islands, reefs and estuarine intertidal sand and mudflats (Marchant and Higgins 1993).	No	Moderate. Previously recorded once, about 10 kilometres south of the study area.
Callocephalon fimbriatum* **Gang-gang Cockatoo**	**-**	**V**	**In summer, occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests** (Higgins 1999)**. Also occur in subalpine Snow Gum woodland and occasionally in temperate or regenerating forest (Forshaw and Cooper 1981). In winter, occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas (Shields and Crome 1992). It requires tree hollows in which to breed (Gibbons and Lindenmayer 1997).**	**Yes**	**High. Recorded during field surveys (site 8). Also previously recorded north, south, east and west of the study area.**
*Calyptorhynchus lathami** Glossy Black-cockatoo	-	V	Inhabits forest with low nutrients, characteristically with key Allocasuarina species. Tends to prefer drier forest types (NPWS 1999c). Often confined to remnant patches in hills and gullies. Breed in hollows stumps or limbs, either living or dead (Higgins 1999).	Yes	High. Recorded during field surveys within the Berry to Bomaderry upgrade study area. Also previously recorded north, south, east and west of the current study area.
Charadrius bicinctus[#] Double-banded Plover	M	-	Tidal mudflats, beaches, exposed reefs, salt marshes, freshwater wetlands, inland salt lakes, short grass on golf courses, airfields (Morcombe 2003).	Yes	High. Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Charadrius leschenaultia** Greater Sand Plover	M	V	Entirely coastal in NSW, foraging on intertidal sand and mudflats in estuaries and roosting during high tide on sandy beaches or rocky shores. Individuals have been recorded on inshore reefs, rock platforms, small rocky islands and sand cays on coral reefs, within Australia. Occasional sightings have also occurred on near-coast saltlakes, brackish swamps, shallow freshwater wetlands and grassed paddocks (NPWS 1999d).	Yes	Moderate. Previously recorded once, south-east of the study area at Seven Mile Beach National Park.
Charadrius mongolus Lesser Sand Plover	M	V	In Australia, the species is known to favour coastal environs including beaches, mudflats and mangroves. Within NSW, individuals have been observed on intertidal sand and mudflats in estuaries or roosting on sandy beaches or rocky shores at high tide (NPWS 1999f).	No	Moderate. Previously recorded south of the study area at Coomonderry Swamp.
Charadrius ruficapillus Red-capped Plover	M	-	Large numbers occur on inland salt lakes, salty edges of waterways, brackish pools and claypans. Commonly found within sheltered estuaries and salt marsh lagoons (Morcombe 2003).	No	Low. Not previously recorded within 10 kilometres of the study area.
Charadrius veredus# Oriental Plover	M	-	Generally inland; open grasslands in arid and semi-arid zones; less often in estuarine or littoral environments. Prefers flat inland plains, sparsely vegetated with short grass, and with much hard bare ground, including claypans, playing fields, lawns and cattle camps. At onset of wet season, may move to lightly wooded grasslands (Marchant and Higgins 1993).	Yes	Low. Not previously recorded within 10 kilometres of the study area.
Pluvialis fulva# Pacific Golden Plover	M	-	Migratory species that visits estuaries mudflats, saltmarshes and ocean shores as well as paddocks, grasslands and swamps near the coast (Pizzey and Knight 1997).	Yes	High. Previously recorded south of the study area at Coomonderry Swamp.
Pluvialis squatarola Grey Plover	M	-	Almost entirely coastal, but occasionally recorded on inland wetlands. Mainly on marine shores, inlets, estuaries and lagoons where there are nearby large tidal mudflats or sandflats for feeding and sandy beaches for roosting (Marchant and Higgins 1993).	No	Low. Previously recorded once, south of the study area at Shoalhaven Heads.
Thinornis rubricollis Hooded Plover	-	C1	Prefers sandy ocean beaches, especially those that are broad and flat (Marchant and Higgins 1993).	No	Low. Previously recorded once about 10 kilometres south of the study area at Shoalhaven River mouth.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Ephippiorhynchus asiaticus** Black-necked Stork	-	E1	Found in swamps, mangroves and mudflats. Can also occur in dry floodplains and irrigated lands and occasionally forages in open grassy woodland. Nests in live or dead trees usually near water (Pizzey and Knight 1997).	Yes	Low. Previously recorded south-east of the study area at Crooked River and south of the study area at Coomonderry Swamp (records over 30 years old).
*Ptilinopus magnificus** Wompoo Fruit-dove	-	V	Mainly occurs in large undisturbed patches of tall tropical or subtropical rainforest. Occasionally occurs in patches of monsoon forest, closed gallery forest, wet sclerophyll forest, tall open forest, open woodland or vine thickets near rainforest (Higgins and Davies 1996).	Yes, but limited.	Low. Not previously recorded within 10 kilometres of the study area.
*Ptilinopus regina** Rose-crowned Fruit-dove	-	V	Occurs in tall tropical and subtropical, evergreen or semi-deciduous rainforest, especially with dense growth of vines. Prefers large patches of rainforest, but sometimes occurs in remnant patches surrounded by suboptimal habitat including farmlands (Higgins and Davies 1996).	Yes, but limited.	Low. Not previously recorded within 10 kilometres of the study area.
*Ptilinopus superbus** Superb Fruit-Dove	-	V	The Superb Fruit Dove's NSW distribution ranges from northern NSW to as far south as Moruya (DEC 2005y). It is found in rainforests, closed forests (including mesophyll vine forests) and sometimes in eucalypt and acacia woodlands where there are fruit-bearing trees (Higgins and Davies 1996). It forages in the canopy of fruiting trees such as figs and palms. Nests are constructed high in the canopy throughout September to January (DEC 2005y).	Yes, but limited.	Low. Previously recorded once, north-east of the study area, outside the locality.
Cuculus saturatus[#] Oriental Cuckoo	M	-	Canopy or shrub layer of monsoon rainforest, vine thickets, wet sclerophyll forest, or open casuarina, Acacia or Eucalyptus woodland (Higgins 1999).	Yes	Low. Previously recorded nine kilometres north of the study area.
Monarcha melanopsis[#] **Black-faced Monarch**	**M**	**-**	**A migratory species found during the breeding season in damp gullies in temperate rainforests. Disperses after breeding into more open woodland** (Pizzey and Knight 1997)**.**	**Yes**	**High. Recorded during field surveys (sites 3, 15, 17, 18, 20, 23 and 28). Also previously recorded north, north-east, south and west of the study area.**
Monarcha trivirgatus[#] Spectacled Monarch	M	-	Found in darker parts of mountain and lowland rainforest, adjacent to thickly wooded gullies (Pizzey and Knight 1997).	Yes	Low. Previously recorded eight kilometres and 10 kilometres north of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Myiagra cyanoleuca[#] Satin Flycatcher	M	-	Migratory species that occurs in coastal forests, woodlands and scrubs during migration. Breeds in heavily vegetated gullies (Pizzey and Knight 1997).	Yes	High. Previously recorded south-east of the study area at Seven Mile Beach National Park and once, 9.5 kilometres to the north.
Rhipidura rufifrons[#] **Rufous Fantail**	**M**	**-**	**Migratory species that prefers dense, moist undergrowth of tropical rainforests and scrubs. During migration it can stray into gardens and more open areas** (Pizzey and Knight 1997)**.**	**Yes**	**High. Recorded during field surveys (sites 3, 15 and 20). Also previously recorded north, south, east and west of the study area.**
Haematopus fuliginosus Sooty Oystercatcher	-	V	The Sooty Oystercatcher is found on undisturbed tidal rocks on ocean shores and islands. Occasionally it is observed on sandspits and mudflats (Pizzey and Knight 1997). It forages on exposed rock or coral at low tide for limpets and mussels. The Sooty Oystercatcher breeds in spring and summer almost exclusively offshore or on isolated promontories (DECCW 2005b).	No	High. Previously recorded east and south-east of the study area along the coast.
*Haematopus longirostris** Pied Oystercatcher	-	E1	An intertidal forager found on undisturbed sandy beaches and spits, tidal mudflats and estuaries. Its food supply (beach macroinvertebrates) have been negatively affected by human impacts (NSW Scientific Committee 2010a). The Pied Oystercatcher is restricted to the littoral zone of beaches and estuaries, nesting on the ground above the tideline. A pair will re-nest in the same spot each year, rarely shifting their territory (NSW Scientific Committee 2010a). Occasionally the Pied Oystercatcher is found in paddocks near the coast (Pizzey and Knight 1997).	Yes	High. Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.
Irediparra gallinacea Comb-crested Jacana	-	V	Occurs in freshwater wetlands, lagoons, Billabongs, swamps, lakes, rivers and reservoirs, generally with abundant floating aquatic vegetation (Marchant and Higgins 1993).	Yes	Low. Not previously recorded within 10 kilometres of the study area.
Anous stolidus Common Noddy	M	-	Pelagic bird, found well offshore except when it is breeding. During these times it is observed in coastal waters close to island breeding colonies (Morcombe 2003).	No	Moderate. Previously recorded south-east of the study area at Black Head.
Sterna albifrons Little Tern	M	E1	The Little Tern favours sheltered coasts, harbours, bays, lakes, inlets, estuaries, coastal lagoons and ocean beaches especially with sand-spits and sand islets (Higgins and Davies 1996; Morcombe 2003). It forages over shallow waters close inshore or over sandbars and reefs (Morcombe 2003).	No	Moderate. Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Sterna caspia[#] Caspian Tern	M	-	Usually coastal, with a preference for sheltered estuaries, inlets, bays, harbours, lagoons with muddy or sandy shores. Keeps close inshore, not out beyond reef line. Also extends well inland on fresh or salt lakes, temporary floodwaters, large rivers, reservoirs, sewage ponds (Morcombe 2003).	Yes	High. Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.
Sterna hirundo Common Tern	M	-	Marine, typically well offshore, but also in coastal waters, sheltered bays, estuaries, and on ocean beaches (Morcombe 2003).	No	High. Previously recorded south-east of the study area at Seven Mile Beach National Park and Black Head, as well as 10 kilometres south of the study area.
*Anthochaera Phrygia** Regent Honeyeater	E	C1	A semi-nomadic species occurring in temperate eucalypt woodlands and open forests. Most records are from box-ironbark eucalypt forest associations and wet lowland coastal forests (NPWS 1999g; Pizzey and Knight 1997). Key eucalypt species include Mugga Ironbark, Yellow Box, Blakely's Red Gum, White Box and Swamp Mahogany. Also utilises: *E. microcarpa*, *E. punctata*, *E. polyanthemos*, *E. mollucana*, *Corymbia robusta*, *E. crebra*, *E. caleyi*, *C. maculata*, *E. mckieana*, *E. macrorhyncha*, *E. laevopinea* and *Angophora floribunda.* Nectar and fruit from the mistletoes *A. miquelii, A. pendula, A. cambagei* are also eaten during the breeding season (DEC 2005t). Regent Honeyeaters usually nest in horizontal branches or forks in tall mature eucalypts and sheoaks. Also nest in mistletoe haustoria. An open cup-shaped nest is constructed of bark, grass, twigs and wool by the female (DEC 2005t).	Yes, but limited.	Moderate.,Previously recorded south of the study area at Seven Mile Beach National Park.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Epthianura albifrons** White-fronted Chat	-	V	The White-fronted Chat occupies foothills and lowlands below 1000 metres above sea level. In NSW it occurs mostly in the southern half of the state, occurring in damp open habitats along the coast, and near waterways in the western part of the state (Higgins *et al* 2001). The White-fronted Chat is found in damp open habitats, particularly wetlands containing saltmarsh areas that are bordered by open grasslands or lightly timbered lands. Along the coastline, they are found in estuarine and marshy grounds with vegetation less than 1 metre tall. The species is also observed in open grasslands and sometimes in low shrubs bordering wetland areas. Inland, the species is often observed in open grassy plains, saltlakes and saltpans that are along the margins of rivers and waterways (Higgins *et al* 2001). In Victoria White-fronted Chats have been observed breeding from late July through to early March. Nests are built in low vegetation and in the Sydney region nests have also been observed in low isolated mangroves (NSW Scientific Committee 2009d). An Endangered Population occurs in the Sydney Metropolitan CMA area, at Newington Nature Reserve near Homebush and at Towra Point Nature Reserve (NSW Scientific Committee 2009e).	Yes, but limited.	Low. Previously recorded south of the study area at Shoalhaven Heads.
Merops ornatus[#] Rainbow Bee-eater	M	-	Usually occurs in open or lightly timbered areas, often near water. Nest in embankments, including banks of creeks and rivers, in sand dunes, in quarries and in roadside cuttings. Breeding occurs from November to January. It has complex migratory movements in Australia. NSW populations migrate north for winter (Higgins 1999).	Yes	Moderate. Previously recorded once, south of the study area at Seven Mile Beach National Park and once, 10 kilometres to the north.
Acrocephalus australis[#] **Australian Reed-Warbler**	**M**	**-**	**This species lives singly or in pairs usually in wetlands with reeds. It feeds on insects (Blakers *et al.* 1984).**	**Yes**	**High. Recorded during field surveys (site 3). Also previously recorded 2 kilometres south-east of Berry at Seven Mile Beach National Park.**

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Daphoenositta chrysoptera** Varied Sittella	-	V	The Varied Sittella is a sedentary species which inhabits a wide variety of dry eucalypt forests and woodlands, usually with either shrubby understorey or grassy ground cover or both, in all climatic zones of Australia. Usually inhabit areas with rough-barked trees, such as stringybarks or ironbarks, but also in mallee and acacia woodlands, paperbarks or mature Eucalypts (Higgins and Peter 2002; NSW Scientific Committee 20010c). The Varied Sittella feeds on arthropods gleaned from bark, small branches and twigs. It builds a cup-shaped nest of plant fibres and cobweb in an upright tree fork high in the living tree canopy, and often re-uses the same fork or tree in successive years (NSW Scientific Committee 2010c).	Yes	High. Previously recorded north and south of the study area.
*Pachycephala olivacea** Olive Whistler	-	V	Found in a range of habitats including alpine thickets, wetter rainforest/woodlands, riparian vegetation and heaths (Pizzey and Knight 1997).	Yes	Moderate. Previously recorded north and south of the study area.
*Dasyornis brachypterus** Eastern Bristlebird	E	E1	Found in coastal woodlands, dense scrub and heathlands, particularly where it borders taller woodlands (Pizzey and Knight 1997).	Yes, but limited	Moderate. Recently recorded less than one kilometre north of the study area in Broughton. Also previously recorded north of the study area at Barren Grounds Nature Reserve.
*Stagonopleura guttata** Diamond Firetail	-	V	Found in a range of habitat types including open eucalypt forest, mallee and acacia scrubs (Pizzey and Knight 1997). Often occur in vegetation along watercourses (Higgins *et al* 2006).	Yes	Low. Not previously recorded within 10 kilometres of the study area. The closest record for this species occurs 18 kilometres west of the study area recorded in 2001.
*Petroica boodang** Scarlet Robin	-	V	During the breeding season the Scarlet Robin is found in eucalypt forests and temperate woodlands, often on ridges and slopes. During autumn and winter it moves to more open and cleared areas. It has dispersive or locally migratory seasonal movements. The Scarlet Robin forages amongst logs and woody debris for insects which make up the majority of its diet (NSW Scientific Committee 2009c). The nest is an open cup of plant fibres and cobwebs, sited in the fork of a tree (often a dead branch in a live tree, or in a dead tree or shrub) which is usually more than two metres above the ground (NSW Scientific Committee 2009c). It is conspicuous in open and suburban habitats (Moorcombe 2003).	Yes	High. Previously recorded north and south of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Petroica phoenicea** Flame Robin	-	V	Flame Robins are found in a broad coastal band from southern Queensland to just west of the South Australian border (Australian Museum 2009). The species is also found in Tasmania. The preferred habitat in summer includes moist eucalyptus forests and open woodlands, whilst in winter prefers open woodlands and farmlands (NSW Scientific Committee 2009a). It is considered migratory. The Flame Robin breeds from about August to January (Morcombe 2003).	Yes	Moderate. Previously recorded north of the study area.
Petroica rodinogaster Pink Robin	-	V	The Pink Robin is found in dense, dank forests and treefern gullies (Pizzey and Knight 1997). During the winter months the Pink Robin disperses north (as far up as the central coast of NSW) and west (as far as the ACT area) into more open forests, woodlands and scrublands (DECCW 2005a).	No	Low. Not previously recorded within 10 kilometres of the study area.
*Glossopsitta pusilla** Little Lorikeet	-	V	Distributed in forests and woodlands from the coast to the western slopes of the Great Dividing Range in NSW, extending westwards to the vicinity of Albury, Parkes, Dubbo and Narrabri. Mostly occur in dry, open eucalypt forests and woodlands. They feed primarily on nectar and pollen in the tree canopy. Nest hollows are located at heights of between 2 metres and 15 metres, mostly in living, smooth-barked eucalypts. Most breeding records come from the western slopes (NSW Scientific Committee 2008b).	Yes	High. Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp as well as 10 kilometres to the north of the study area.
*Lathamus discolor** Swift Parrot	E	E1	The Swift Parrot occurs in woodlands and forests of NSW from May to August, where it feeds on eucalypt nectar, pollen and associated insects(Forshaw and Cooper 1981). The Swift Parrot is dependent on flowering resources across a wide range of habitats in its wintering grounds in NSW (Shields and Crome 1992). Favoured feed trees include winter flowering species such as Swamp Mahogany *Eucalyptus robusta*, Spotted Gum *Corymbia maculata*, Red Bloodwood *C. gummifera*, Mugga Ironbark *E. sideroxylon*, and White Box *E. albens*. Commonly used lerp infested trees include Grey Box *E. microcarpa*, Grey Box *E. moluccana* and Blackbutt *E. pilularis* (DEC 2005z). This species is migratory, breeding in Tasmania and also nomadic, moving about in response to changing food availability (Pizzey and Knight 1997).	Yes	Moderate. Previously recorded north and south of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Neophema chrysogaster** Orange-bellied Parrot	ZM	C1	A single breeding population of fewer than 200 individuals occurs in a narrow coastal strip of south-west Tasmania. Adult birds depart Tasmania for the mainland in February. The first adults begin leaving the mainland for Tasmania in September with the last birds having departed by November. It is a coastal species inhabiting saltmarshes, sedgeplains, coastal dunes, pastures, shrublands and moorlands, generally within 10 kilometres of the coast (OBPRT 1998). Critical winter habitat for the species includes natural saltmarshes dominated by *Sarcocornia quinqueflora* (Beaded Glasswort) and *Sclerostegia arbuscula* (Shrubby Glasswort), as well as the associated grassy or weedy pastures (DECC 2007). Historical records indicate that the Orange-bellied Parrot was formerly more abundant and widespread in NSW than it is now, however the species' distribution continues to extend into south-eastern NSW where suitable habitat is still available (DECC 2007).	Yes	Low. Previously recorded once 9.5 kilometres south of the study area.
*Neophema pulchella** Turquoise Parrot	-	V	Occurs in open woodlands and eucalypt forests with a ground cover of grasses and understorey of low shrubs (Morros 1980). Generally found in the foothills of the Great Divide, including steep rocky ridges and gullies (Higgins 1999). Nest in hollow-bearing trees, either dead or alive; also in hollows in tree stumps. Prefer to breed in open grassy forests and woodlands, and gullies that are moist (Higgins 1999).	Yes	Moderate. Previously recorded north of the study area at Barren Grounds Nature Reserve.
*Pezoporus wallicus wallicus** Eastern Ground Parrot	-	V	Mainly found in heathland, sedgeland or buttongrass plains providing medium to dense cover (Higgins 1999).	Yes, but limited.	Moderate. Recently recorded less than one kilometre north of the study area in Broughton. Also previously recorded north of the study area at Barren Grounds Nature Reserve and once to the south at Seven Mile Beach National Park.
*Rostratula australis** Australian Painted Snipe	VM	E1	Usually found in shallow inland wetlands including farm dams, lakes, rice crops, swamps and waterlogged grassland. They prefer freshwater wetlands, ephemeral or permanent, although they have been recorded in brackish waters (Marchant and Higgins 1993).	Yes	Low. Not previously recorded within 10 kilometres of the study area. The closest record of this species occurs 20 kilometres north of the study area recorded over 40 years ago in 1970.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Actitis hypoleucos Common Sandpiper	M	-	Inhabits a wide range of coastal and inland wetlands, often with muddy or rocky margins. Also known to occur at estuaries, billabongs, dams, pools and lakes, often associated with mangroves (Higgins and Davies 1996).	No	Low. Previously recorded once, 5 kilometres east of the study area at Werri Beach.
Arenaria interpres Ruddy Turnstone	M	-	Inhabits tidal reefs, sandy beaches mudflats and exposed or shallow seaweed beds (Pizzey and Knight 1997).	No	Moderate. Previously recorded south-east of the study area at Black Head and Seven Mile Beach National Park.
Calidris acuminata Sharp-tailed Sandpiper	M	-	Inland waters, coastal (Simpson and Day 1996).	No	Low. Previously recorded once, south of the study area at Seven Mile Beach National Park.
Calidris alba Sanderling	M	V	Occurs on the coast mostly on open sand beaches exposed to open sea-swells (Higgins and Davies 1996).	No	Moderate. Previously recorded south-east and south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.
Calidris canutus Red Knot	M	-	Typically located within intertidal mudflats, sandflats and sandy beaches of sheltered coasts. Occasionally found on sandy open beaches or shallow pools, or in saline wetlands close to the coast (Higgins and Davies 1996).	No	Low. Previously recorded 10 kilometres south of the study area.
Calidris ferruginea Curlew Sandpiper	M	-	Inhabits sheltered intertidal mudflats. Also non-tidal swamps, lagoons and lakes near the coast. Infrequently recorded inland (Higgins and Davies 1996).	No	Moderate. Previously recorded south of the study area at Coomonderry Swamp and Shoalhaven Heads.
Calidris melanotos[#] Pectoral Sandpiper	M	-	Scarce, but regular visitor, usually recorded in summer from November to March (Slater *et al.* 2003). Widespread but scattered records in Australia. Usually found in fresh to saline wetlands, floodplains, swamps, estuaries and lagoons, sometimes with emergent or fringing vegetation such as grass (Higgins and Davies 1996).	Yes, but limited.	Low. Not previously recorded within 10 kilometres of the study area.
Calidris ruficollis[#] Red-necked Stint	M	-	Inhabits mainly coastal environments; saltmarshes, tidal mudflats, saline and freshwater wetlands, sandy or shelly beaches and sewage ponds (Higgins and Davies 1996).	Yes, but limited.	Moderate. Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Calidris subminuta Long-toed Stint	M	-	Inhabit coastal and inland shallow wetlands, sewage ponds and tidal mudflats (Pizzey and Knight 2003).	Yes, but limited.	Low. Not previously recorded within 10 kilometres of the study area.
Calidris tenuirostris Great Knot	M	V	Mainly found on intertidal mudflats, sandflats and sandy beaches (Higgins and Davies 1996).	No	Low. Previously recorded south of the study area at Coomonderry Swamp and Shoalhaven Heads.
Gallinago hardwickii[#] Latham's Snipe	M	-	Typically found on wet soft ground or shallow water with good cover of tussocks. Often found in wet paddocks, seepage areas below dams (Pizzey and Knight 1997).	Yes	High. Recorded during field surveys at site 2 of Gerringong upgrade. Also previously recorded south-east of current study area at Seven Mile Beach National Park as well as eight kilometres and nine kilometres to the north.
Heteroscelis brevipes Grey-tailed Tattler	M	-	Found in estuaries, mangroves and tidal mudflats. Also in shallow river margins, both coastal and inland (Pizzey and Knight 1997).	No	Low. Not previously recorded within 10 kilometres of the study area.
Limicola falcinellus Broad-billed Sandpiper	M	V	Occurs in sheltered parts of coasts, such as estuaries, harbours, embayments and lagoons, which have shell or sandbanks nearby (Higgins and Davies 1996).	No	Low. Previously recorded about 10 kilometres south of the study area within Comerong Lagoon.
Limosa lapponica Bar-tailed Godwit	M	-	Coastal species, usually inhabiting intertidal sandflats, spits and banks. Less frequently found in mudflats, estuaries, coastal lagoons and harbours (Higgins and Davies 1996).	No	Moderate. Previously recorded south-east and south of the study area at Seven Mile Beach National Park and Coomonderry Swamp.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Limosa limosa Black-tailed Godwit	M	V	Mainly coastal, usually in sheltered bays, estuaries and lagoons with large intertidal mudflats or sandflats (Higgins and Davies 1996).	No	Moderate. Previously recorded south of the study area in Coomonderry Swamp and south-east of the study area in the Shoalhaven River.
Numenius madagascariensis Eastern Curlew	M	-	Occurs in sheltered coasts, especially estuaries, embayments, harbours, inlets and coastal lagoons with large intertidal mudflats or sandflats often with beds of seagrass (Higgins and Davies 1996).	No	Moderate. Previously recorded east of the study area at Werri Beach as well as south and south-east of the study area.
Numenius minutus Little Curlew	M	-	Short, dry grasslands and sedgelands, including dry floodplains and blacksoil plains, which have scattered, shallow freshwater pools. Mostly feed in dry grassland or sedgeland, either natural or artificial. Foraging sites usually occur within five kilometres of daytime roosting sites (Higgins and Davies 1996).	Yes, but limited.	Low. Not previously recorded within 10 kilometres of the study area.
Numenius phaeopus Whimbrel	M	-	Occurs in intertidal mudflats of sheltered coasts (Higgins and Davies 1996). Also in estuaries, mangroves, coral clays and exposed reefs. Roosts in trees and mangroves (Pizzey and Knight 1997).	No	Low. Previously recorded once, south-east of the study area near Crooked River.
Philomachus pugnax Ruff	M	-	Rare migrant from northern Eurasia (Slater et al. 2003), regularly visits fresh, brackish or saline wetlands with exposed mudflats at edges, usually terrestrial but sometimes found in sheltered coast habitats (Higgins and Davies 1996).	No	Low. Not previously recorded within 10 kilometres of the study area.
Tringa glareola[#] Wood Sandpiper	M	-	Freshwater swamps, lakes, flooded pasture; less frequently on brackish waters, occasionally in mangroves (Morcombe 2003).	Yes	Low. Not previously recorded within 10 kilometres of the study area.
Tringa nebularia[#] Common Greenshank	M	-	Widely distributed throughout a range of inland wetlands and sheltered coastal habitats. Occurs in habitats with varying salinity (Higgins and Davies 1996).	Yes	Low. Previously recorded about 10 kilometres south of the study area within Comerong Lagoon.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Tringa stagnatilis[#] Marsh Sandpiper	M	-	Inhabits permanent or ephemeral wetlands, including swamps, billabongs, lagoons, saltmarshes and estuaries. Forages at the edge of wetlands in shallow water (Higgins and Davies 1996).	Yes	Low. Previously recorded once about 10 kilometres south of the study area within Comerong Lagoon.
Xenus cinereus Terek Sandpiper	M	V	Mainly found on saline intertidal mudflats in sheltered estuaries, embayments, harbours and lagoons (Higgins and Davies 1996).	No	Low. Previously recorded about 10 kilometres south of the study area within Comerong Lagoon.
*Ninox connivens** Barking Owl	-	V	Generally found in open forests, woodlands, swamp woodlands and dense scrub. Can also be found in the foothills and timber along watercourses in otherwise open country (Pizzey and Knight 1997). Territories are typically 2000 hectares in NSW habitats (DEC 2005b).	Yes	Moderate. Previously recorded east of the study area at Werri Beach as well as north and north-west of the study area.
Ninox strenua* **Powerful Owl**	**-**	**V**	**The Powerful Owl occupies wet and dry eucalypt forests and rainforests. It may inhabit both un-logged and lightly logged forests as well as undisturbed forests where it usually roosts on the limbs of dense trees in gully areas (Debus and Chafer 1994b; Debus and Shafer 1994a). Large mature trees with hollows at least 0.5 metres deep are required for nesting (Garnett 1992). Tree hollows are particularly important for the Powerful Owl because a large proportion of the diet is made up of hollow-dependent arboreal marsupials** (Gibbons and Lindenmayer 1997)**. Nest trees for this species are usually emergent with a diameter at breast height of at least 100 centimetres** (Gibbons and Lindenmayer 1997)**. It has a large home range of between 450 and 1450 hectares (DEC 2005q).**	**Yes**	**High. Recorded during field surveys (site 15). Also recorded north, east and south of the study area.**
Plegadis falcinellus[#] Glossy Ibis	M	-	Terrestrial wetlands, and occasionally wet grasslands and sheltered marine habitats. Forage in shallow water over soft substrate or on grassy or muddy verges of wetlands, preferring those providing variety of water depths; avoid dry ground (Marchant and Higgins 1990).	Yes	Low. Previously recorded once eight kilometres south of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Tyto novaehollandiae Masked Owl	-	V	The Masked Owl may be found across a diverse range of wooded habitat that provide tall or dense mature trees with hollows suitable for nesting and roosting (Higgins 1999). It has mostly been recorded in open forests and woodlands adjacent to cleared lands. They nest in hollows, in trunks and in near vertical spouts or large trees, usually living but sometimes dead (Higgins 1999). The nest hollows are usually located within dense forests or woodlands (Gibbons and Lindenmayer 1997). Masked Owls prey upon hollow-dependent arboreal marsupials, but terrestrial mammals make up the largest proportion of the diet (Gibbons and Lindenmayer 1997; Higgins 1999). It has a large home range of between 500 to 1000 hectares(DEC 2005n).	Yes	Moderate. Previously recorded once, south of the study area at Seven Mile Beach National Park.
*Tyto tenebricosa** Sooty Owl	-	V	The Sooty Owl is often found in tall old-growth forests, including temperate and subtropical rainforests. In NSW it is mostly found on escarpments with a mean altitude less than 500 metres. The Sooty Owl nests and roosts in hollows of tall emergent trees, mainly eucalypts (Higgins 1999) often located in gullies (Gibbons and Lindenmayer 1997). Nests have been located in trees 125 to 161 centimetres in diameter (Gibbons and Lindenmayer 1997).	Yes	High. Previously recorded north of the study area including at Barren Grounds Nature Reserve.
Mammals					
*Cercartetus nanus** Eastern Pygmy-possum	-	V	Patchily distributed from the coast to the Great Dividing Range, and as far as Pillaga, Dubbo, Parkes and Wagga Wagga on the western slopes. Inhabits rainforest through to sclerophyll forest and tree heath. Banksias and myrtaceous shrubs and trees are a favoured food source. Soft fruits are eaten when flowers are unavailable and it also feeds on insects (DEC 1005g; Turner 2008). Will often nest in tree hollows, but can also construct its own nest (Turner and Ward 1995). Because of its small size it is able to utilise a range of hollow sizes including very small hollows (Gibbons and Lindenmayer 1997). Individuals will use a number of different hollows and an individual has been recorded using up to 9 nest sites within a 0.5 hectare area over a 5 month period (Ward 1990). It is mainly solitary, and each individual uses several nests. Home ranges of males are generally less than 0.75 hectares, and those of females are smaller (Ward andn Turner 2008).	Yes	Low. Previously recorded outside the locality between six kilometres and 10 kilometres north of the study area. Previous records occur up on the escarpment and within better connected habitat.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Dasyurus maculatus maculatus** Spotted-tailed Quoll (south eastern mainland)	E	V	Occurs along the east coast of Australia and the Great Dividing Range (Belcher *et al.* 2008). Uses a range of habitats including sclerophyll forests and woodlands, coastal heathlands and rainforests (Dickman and Read 1992). Occasional sightings have been made in open country, grazing lands, rocky outcrops and other treeless areas (NPWS 1999k). Habitat requirements include suitable den sites, including hollow logs, rock crevices and caves, an abundance of food and an area of intact vegetation in which to forage (Edgar and Belcher 1995). Seventy per cent of the diet is medium-sized mammals, and also feeds on invertebrates, reptiles and birds. Individuals require large areas of relatively intact vegetation through which to forage (NPWS 1999h). The home range of a female is between 180 – 1000 hectares, while males have larger home ranges of between 2000 – 5000 hectares. Breeding occurs from May to August (Belcher *et al.* 2008).	Yes	High. Previously recorded just north of the study area at Broughton (east of site 15) and 0.5 kilometres south-east of the Toolijooa Road and Princes Highway intersection. Records further north and south exist also.
*Sminthopsis leucopus** White-footed Dunnart	-	V	The White-footed Dunnart is found in a range of different habitats across its distribution, including coastal dune vegetation, coastal forest, tussock grassland and sedgeland, heathland, woodland and forest. They shelter in bark nests in hollows under standing or fallen timber, burrows in the ground, piles of logging debris, large grass clumps such as provided by Grass Trees Xanthorrhoea sp. and Macrozamias and rock crevices (DEC 2005|).	Yes, but limited.	Low. Not previously recorded within 10 kilometres of the study area.
Saccolaimus flaviventris* **Yellow-bellied Sheathtail Bat**	**-**	**V**	**Found throughout NSW (Richards 2008). They have been reported from southern Australia between January and June (Churchill 1998). Reported from a wide range of habitats throughout eastern and northern Australia, including wet and dry sclerophyll forest, open woodland, acacia shrubland, mallee, grasslands and desert (Churchill 1998). They roost in tree hollows in colonies of up to 30 (but more usually two to six) and have also been observed roosting in faunal burrows, abandoned Sugar Glider nests, cracks in dry clay, hanging from buildings and under slabs of rock. It is high-flying, making it difficult to detect. It forages above the canopy of eucalypt forests, but comes lower to the ground in mallee or open country (Churchill 2008; Richards 2008).**	**Yes**	**High. Recorded during field surveys (sites 3, 17, 28 and close to 8). Also previously recorded south and south-west of the study area.**
Petrogale penicillata Brush-tailed Rock-wallaby	V	E1	Occurs along the Great Dividing Range south to the Shoalhaven, and also occurs in the Warrumbungles and Mt Kaputar. Habitats range from rainforest to open woodland. It is found in areas with numerous ledges, caves and crevices, particularly where these have a northerly aspect. Individuals defend a specific rock shelter, emerging in the evening to forage on grasses and forbs, as well as browse in drier months. Home sizes range from 2-30 hectares (Eldridge and Close 1995).	No	Low. Not previously recorded within 10 kilometres of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Mormopterus norfolkensis* **Eastern Freetail Bat**	**-**	**V**	**Distribution extends east of the Great Dividing Range from southern Queensland to south of Sydney (Churchill 1998). Most records are from dry eucalypt forests and woodland. Individuals tend to forage in natural and artificial openings in forests, although it has also been caught foraging low over a rocky river within rainforest and wet sclerophyll forest habitats. The species generally roosts in hollow spouts of large mature eucalypts (including paddock trees), although individuals have been recorded roosting in the roof of a hut, in wall cavities, and under metal caps of telegraph poles. Foraging generally occurs within a few kilometres of roosting sites (Churchill 2008; Hoye *et al.* 2008).**	**Yes**	**High. Recorded during field surveys (sites 3, 17, 28, 32 and close to 8). Also previously recorded south-west of the study area, within the locality.**
Pseudomys fumeus Smoky Mouse	E	E1	Appears to prefer heathy ridgetops and slopes within sclerophyll forests, heathland and open forest from the coast to sub-alpine regions of up to 1800 metres (Lee 1995).	No	Low. Not previously recorded within 10 kilometres of the study area.
Pseudomys novaehollandiae New Holland Mouse	V	-	The New Holland Mouse currently has a disjunct, fragmented distribution across Tasmania, Victoria, New South Wales and Queensland. Across the species' range the New Holland Mouse is known to inhabit open heathlands, open woodlands with a heathland understorey, and vegetated sand dunes. The home range of the New Holland Mouse can range from 0.44 hectares to 1.4 hectares. The New Holland Mouse is a social animal, living predominantly in burrows shared with other individuals. The species is nocturnal and omnivorous, feeding on seeds, insects, leaves, flowers and fungi, and is therefore likely to play an important role in seed dispersal and fungal spore dispersal. It is likely that the species spends considerable time foraging above-ground for food, predisposing it to predation by native predators and introduced species. Breeding typically occurs between August and January, but can extend into autumn (Threatened Species Scientific Committee 2010).	No	Low. Not previously recorded within 10 kilometres of the study area.
Isoodon obesulus obesulus Southern Brown Bandicoot	E	E1	This species prefers sandy soils with scrubby vegetation and/or areas with low ground cover that are burnt from time to time (Braithwaite 1995). A mosaic of post fire vegetation is important for this species (Maxwell *et al.* 1996).	No	Low. Not previously recorded within 10 kilometres of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
*Petaurus australis** Yellow-bellied Glider	-	V	Restricted to tall native forests in regions of high rainfall along the coast of NSW. Preferred habitats are productive, tall open sclerophyll forests where mature trees provide shelter and nesting hollows. Critical elements of habitat include sap-site trees, winter flowering eucalypts, mature trees suitable for den sites and a mosaic of different forest types (NPWS 1999j). Live in family groups of 2-6 individuals which commonly share a number of tree hollows. Family groups are territorial with exclusive home ranges of 30-60 hectares. Very large expanses of forest (more than 15,000 hectares) are required to conserve viable populations (Goldingay 2008).	Yes	Moderate. Previously recorded north and north-west of the study area, within the locality.
Petaurus norfolcensis Squirrel Glider	-	V	Sparsely distributed along the east coast and immediate inland areas as far west as Coonabarabran in the northern part of the state (DEC 1999) and as far west as Tocumwal along the southern border of the state (NSW Government 2009). Generally occurs in dry sclerophyll forests and woodlands but is absent from dense coastal ranges in the southern part of its range. Requires abundant hollow-bearing trees and a mix of eucalypts, banksias and acacias (Van de Ree and Suckling 2008). Within a suitable vegetation community at least one species should flower heavily in winter and one species of eucalypt should be smooth barked (Mnekhorst *et al.* 1988). They live in family groups of 2-10 individuals and maintain home ranges of 0.65 and 10.5 hectares, varying according to habitat quality and food resource availability (Quin 1995; Goldingay and Jackson 2004). Family groups occupy multiple hollows over time (Van de Ree and Suckling 2008).	No	Low. Not previously recorded within 10 kilometres of the study area. Closest records occur 18 kilometres south and 26 kilometres north of the study area.
*Phascolarctos cinereus** Koala	N	V	In NSW the Koala mainly occurs on the central and north coasts with some populations in the western region (DEC 2005m). Koalas feed almost exclusively on eucalypt foliage, and their preferences vary regionally (Martin *et al.* 2008). Primary feed trees include Eucalyptus robusta, E. tereticornis, E. punctata, E. haemostoma and E. signata (DoP 1995). They are solitary with varying home ranges. In high quality habitat home ranges may be one hectare - two hectares and overlap, while in semi-arid country they are usually discrete and around 100 hectares (Martin *et al.* 2008).	Yes, but limited.	Moderate. Previously recorded north and south of the study area.
*Potorous tridactylus** Long-nosed Potoroo	V	V	Occurs from Queensland to Victoria, normally within 50 kilometres of the coast (Claridge *et al.* 2007). Inhabits coastal heath and wet and dry sclerophyll forests. Generally found in areas with rainfall greater than 760 mm. Requires relatively thick ground cover where the soil is light and sandy. Known to eat fungi, arthropods, fleshy fruit, seeds and plant tissue. It is solitary and sedentary, buts tends to aggregate in small groups. It has two breeding seasons, one in late winter-early spring and the other in late summer (Johnston 2008). This species appears to benefit from a lack of recent disturbance (Claridge *et al.* 2007).	Yes, but limited.	Moderate. Previously recorded north and south of the study area.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Pteropus poliocephalus* **Grey-headed Flying-fox**	**V**	**V**	**Occurs along the NSW coast, extending further inland in the north. This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and banksia woodlands. Roosts in large colonies (camps), commonly in dense riparian vegetation. Bats commute daily to foraging areas, usually within 15 kilometres of the day roost (Tideman 1995) although some individuals may travel up to 70 kilometres (Augee and Ford 1999).**	**Yes**	**High. Recorded during field surveys (site 15). Also previously recorded north-east, south and west of the study area. Known camp site within Coomonderry Swamp.**
*Chalinolobus dwyeri** Large-eared Pied Bat	V	V	Occurs from the Queensland border to Ulladulla, with largest numbers from the sandstone escarpment country in the Sydney Basin and Hunter Valley (Van dyck and Strahan 2008). Primarily found in dry sclerophyll forests and woodlands, but also found in rainforest fringes and subalpine woodlands (Churchill 2008; Hoye and Schulz 2008). Forages on small, flying insects below the forest canopy. Roosts in caves in colonies of between three and 80 individuals, Fairy Martin nests and mines, and beneath rock overhangs, but usually less than 10 individuals. Likely that it hibernates during the cooler months (Churchill 2008). The only known existing maternity roost is in a sandstone cave near Coonabarabran (Pennay 2008).	Yes	Moderate. Recorded once during 2007 surveys west of the current study area. One other record 10 kilometres north of the study area.
Falsistrellus tasmaniensis* **Eastern False Pipistrelle**	**-**	**V**	**Distribution extending east of the Great Dividing Range throughout the coastal regions of NSW, from the Queensland border to the Victorian border. Prefers wet high-altitude sclerophyll and coastal mallee habitat, preferring wet forests with a dense understorey but being found in open forests at lower altitudes** (Churchill 2008). **Apparently hibernates in winter. Roosts in tree hollows and sometimes in buildings in colonies of between 3 and 80 individuals. Often change roosts every night. Forages for beetles, bugs and moths below or near the canopy in forests with an open structure, or along trails (Law *et al.* 2008). Has a large foraging range, up to 136 hectares (Churchill 2008; Law *et al.* 2008). Records show movements of up to 12 kilometres between roosting and foraging sites (Menkhorst and Lumsden 1995).**	**Yes**	**High. Recorded during field surveys (site 15). Also previously recorded north-east, south-east and south of the study area.**
Kerivoula papuensis Golden-tipped Bat	-	V	Occurs in a narrow band down the coast from Cape York to Eden, in moist, closed forest that receives high rainfall (Law and Chidel 2004). Important habitat features include forest ecotones, streams and an abundance of vines (Van dyckand Strahan 2008). Primarily feeds on web-building spiders. Most nightly movements occur within 2 kilometres of the roost. Roosts in the nests of Yellow-throated Scrubwren and Brown Gerygone, as well as in tree hollows, foliage and roofs of houses (Van dyckand Strahan 2008.	No	Low. Not previously recorded within 10 kilometres of the study area. No records on entire Kiama 1:100 000 map sheet.

Latin name/ common name	EPBC Act[1]	TSC Act[2]	Habitat	Potential habitat in study area?	Likelihood of occurrence in the locality?
Miniopterus schreibersii oceanensis* **Eastern Bentwing-bat**	**-**	**V**	**Occurs from Victoria to Queensland, on both sides of the Great Dividing Range. Forms large maternity roosts (up to 100,000 individuals) in caves and mines in spring and summer. Individuals may fly several hundred kilometres to their wintering sites, where they roost in caves, culverts, buildings, and bridges. They occur in a broad range of habitats including rainforest, wet and dry sclerophyll forest, paperbark forest and open grasslands. Has a fast, direct flight and forages for flying insects (particularly moths) above the tree canopy and along waterways (Churchill 2008; Hoye and Hall 2008).**	**Yes**	**High. Recorded during field surveys (sites 3, 17, 28, 32 and close to 8). Also previously recorded north, south-east and south-west of the study area.**
Myotis macropus* **Southern Myotis**	**-**	**V**	**Scattered, mainly coastal distribution extending to South Australia along the Murray River. Roosts in caves, mines or tunnels, under bridges, in buildings, tree hollows, and even in dense foliage. Colonies occur close to water bodies, ranging from rainforest streams to large lakes and reservoirs. They catch aquatic insects and small fish with their large hind claws, and also catch flying insects (Richards *et al.* 2008).**	**Yes**	**High. Recorded during field surveys (sites 3, 15, 17, 28, 32 and close to 8). Also previously recorded west and south-west of the study area.**
Scoteanax rueppellii* **Greater Broad-nosed Bat**	**-**	**V**	**Occurs along the Great Dividing Range, generally at an altitude of 500 metres but also up to 1200 metres, and in coastal areas. Occurs in woodland and rainforest, but prefers open habitats or natural or human-made openings in wetter forests. Often hunts along creeks or river corridors. Flies slowly and directly at a height of 30 metres or so to catch beetles and other large, flying insects. Also known to eat other bats and spiders. Roosts in hollow tree trunks and branches (Churchill 2008; Richards *et al.* 2008).**	**Yes**	**High. Recorded during field surveys (sites 3, 15, 18, 32 and close to 8). Also previously recorded north, south and south-west of the study area.**
Reptiles					
Hoplocephalus bungaroides Broad-headed Snake	V	E1	Mainly occurs in association with communities occurring on Triassic sandstone within the Sydney Basin. Typically found among exposed sandstone outcrops with vegetation types ranging from woodland to heath. Within these habitats they generally use rock crevices and exfoliating rock during the cooler months and tree hollows during summer (Webb 1996; Webb and Shine 1998).	No	Low. One record occurs within 10 kilometres of the study area, outside the locality.
Varanus rosenbergi Rosenberg's Goanna	-	V	This species is a Hawkesbury/Narrabeen sandstone outcrop specialist (Wellington and Wells 1085). Occurs in coastal heaths, humid woodlands and both wet and dry sclerophyll forests (Cogger 1992). Termite mounds are a critical habitat component (DEC 2005u).	No	Low. Not previously recorded within 10 kilometres of the study area.

Appendix E

Biodiversity offset strategy

Foxground and Berry bypass

Biodiversity offset strategy

1 Introduction

RMS is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the upgrade of 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.
The project and the key features of the project are shown in **Figure AE-1**.

The preparation of this Biodiversity Offset Strategy has involved:

- Review by the NSW Office of Environment and Heritage (OEH) and subsequent amendments according to comments received.
- Consultation with the Southern Rivers Catchment Management Authority (CMA) to determine broad scale priority corridors for riparian restoration works.
- Reference to the RMS 'Biodiversity Guidelines - Protecting and managing biodiversity on RTA projects' (RTA 2011).

1.1 Purpose of the strategy

This Biodiversity Offset Strategy has been prepared to address the NSW Department of Planning and Infrastructure (DP&I) Director-General's requirements (DGRs) issued for assessment of the project under Part 3A of the NSW EP&A Act for both terrestrial and aquatic ecology.

1.2 Director-General's requirements

The DGRs require:

> *'an assessment of all project components on flora and fauna and their habitat (both terrestrial and aquatic, as relevant) be prepared according to the Draft Guidelines for Threatened Species Assessment (Department of Environment and Conservation (DEC) & DP&I, 2005) for the Part 3A environmental assessment.'*

The DGRs identify broad focus areas for the terrestrial and aquatic flora and fauna impact assessments. Terrestrial and aquatic flora and fauna surveys consistent with the DEC and DP&I (2005) guidelines have been carried out. These surveys have informed the current project technical working papers and are the basis for the environmental assessment and terrestrial and aquatic ecological investigations.

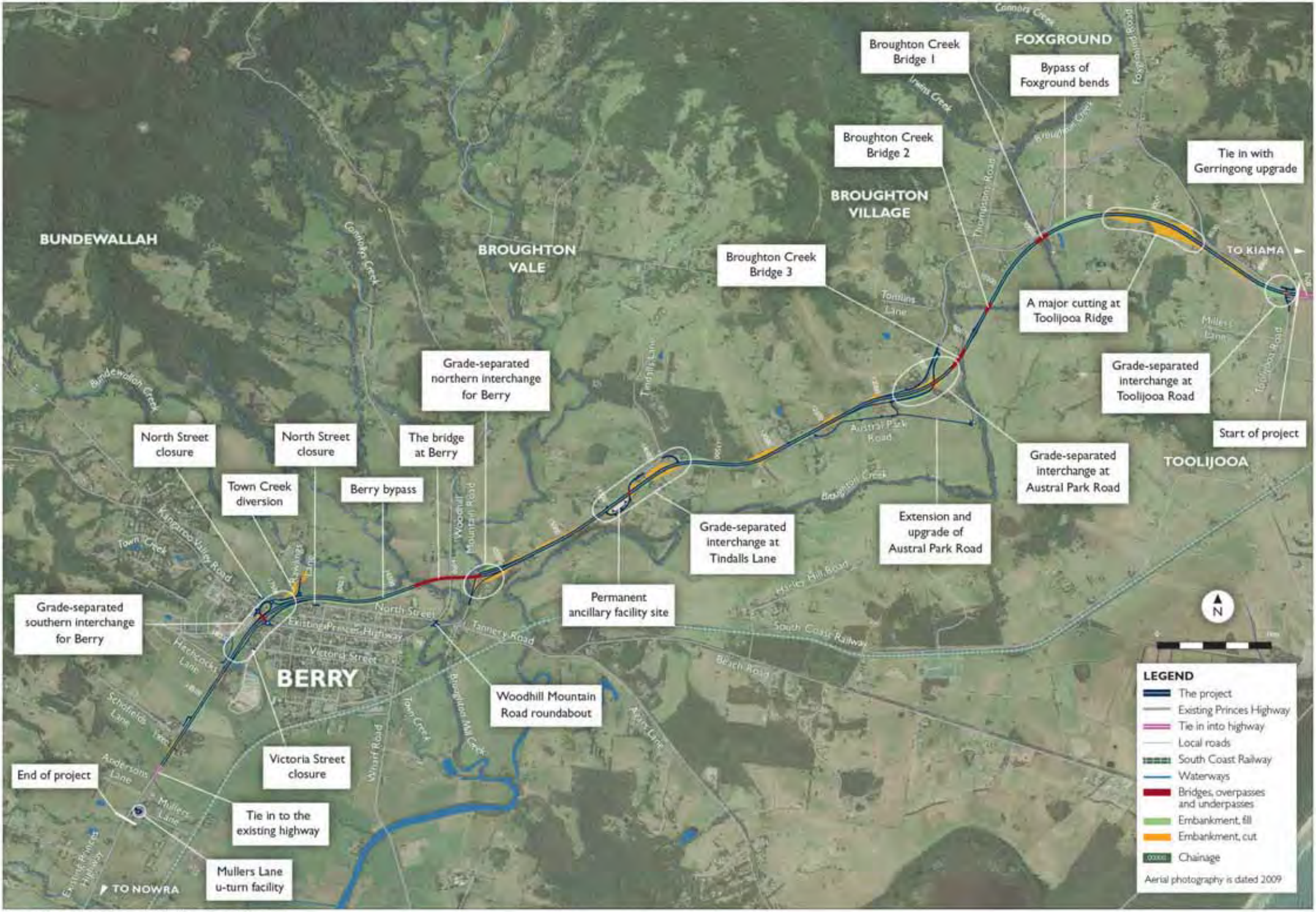

Figure AE-1 – The project and key features of the project

In addition to providing the main scope for terrestrial and aquatic flora and fauna surveys and assessments the DGRs specify that the environmental assessment must:

> *'demonstrate actions to be undertaken to avoid, mitigate or offset impacts associated with the project (all components) consistent with the principles of "improve or maintain". Sufficient details must be provided to demonstrate the availability of viable and achievable options to offset the impacts of the project, where offset measures are proposed to address residual impacts.'*

1.3 Aims

Terrestrial and aquatic ecological assessments determined that biodiversity offsets are required to meet the 'improve or maintain' principle specified in the DGRs as a result of residual impacts on biodiversity values from the project. The aim of this Biodiversity Offset Strategy is to provide the framework, baseline data and options for the development of a Biodiversity Offset Package that will achieve an 'improve or maintain' biodiversity outcome for the region as a result of the project.

1.4 Definitions

This Biodiversity Offset Strategy adopts the definitions of the main *Environmental Assessment – Terrestrial Flora and Fauna Assessment* (Biosis Research 2012) and *Aquatic Ecology and Water Quality Management Assessment* (CEL 2012). Definitions of the terrestrial ecology impact assessments and aquatic ecology impact assessments relevant to the Biodiversity Offset Strategy are summarised below.

1.4.1 Terrestrial

Project – all components of the proposed upgrade of the Princes Highway between about the junction of Toolijooa Road and the Princes Highway and about the junction of Schofields Lane and the Princes Highway on the NSW south coast (Foxground and Berry bypass project).

Subject site – the area to be directly impacted by the project (ie the development "footprint"). The subject site includes the roadway, temporary creek crossings and areas for ancillary facilities.

Study area – the subject site and any additional areas which are likely to be affected by the project, either directly or indirectly. In the case of the project, the study area includes the subject site and a 50 metre buffer to account for any indirect impacts.

Locality – for the purposes of this report, the "locality" is defined as the area within a five kilometre radius of the perimeter of the study area.

Direct impacts – the loss of terrestrial native vegetation and modification of potential terrestrial flora and fauna habitat that will occur for the construction and operation of the project. Project components that will result in direct impacts are the roadway, temporary creek crossings and areas for ancillary facilities. Direct impacts are likely to be limited to the subject site.

Indirect impacts - are calculated by buffering the area that would be directly impacted (subject site) by construction of the project by 50 metres to account for an average extent of edge effects (see Section 4.1 of main *Environmental Assessment – Terrestrial Flora and Fauna Assessment* (Biosis Research 2012) report for details of edge effects). Indirect impacts extend to at least the limits of the study area.

Residual impacts – these are impacts that remain following actions to avoid and mitigate direct and indirect impacts. The unavoidable loss of the endangered ecological community (EEC) River-flat eucalypt forest (RFEF) will be a residual impact of the project.

1.4.2 Aquatic

Riparian vegetation – the plants that occur on the land that adjoins, directly influences or is influenced by bodies of water, such as creeks, rivers, lakes and wetlands on river floodplains.

2 Methods

This Biodiversity Offset Strategy relies on the terrestrial flora and fauna and aquatic ecology field surveys and desktop assessments of the environmental assessment. Methods for the terrestrial flora and fauna assessments are detailed in Section 2 of the *Environmental Assessment – Terrestrial Flora and Fauna Assessment* (Biosis Research 2012). Methods for the aquatic ecology are described in Section 2.2 of the *Aquatic Ecology and Water Quality Management Assessment* (CEL 2012) which is provided at Appendix G of the environmental assessment. Terrestrial and aquatic field survey and desktop assessment methods most relevant to the Biodiversity Offset Strategy are summarised in Sections 2.1 to 2.2 below. Section 2.3 provides an overview of the desktop mapping methods used to identity locations that will be most suitable for further consideration in development of a detailed Biodiversity Offset package.

2.1 Terrestrial

2.1.1 Flora survey

Flora surveys for the terrestrial ecology assessment were conducted in accordance with the draft publication, 'Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities' (DEC 2004). The bulk of flora surveys were carried out over a total of 22 days concentrated in February 2007, November 2008 and 22 May 2009.

2.1.2 Vegetation condition assessment

An assessment of plant community condition was conducted at all survey sites. Vegetation condition was assessed according to the degree to which it resembled relatively natural, undisturbed vegetation and is categorised as follows:

Good: containing a high number of indigenous species; no weeds present or weed invasion restricted to edges and track margins; vegetation community containing original layers of vegetation; vegetation layers (ground, shrub, canopy etc) intact.

Moderate: containing a moderate number of indigenous species; moderate level of weed invasion; weeds occurring in isolated patches or scattered throughout; one or more of original layers of vegetation modified; vegetation layers (ground, shrub, canopy etc) largely intact.

Poor: containing a low number of indigenous species; high level of weed invasion; weeds occurring in dense patches or scattered throughout; one or more of the original layers of vegetation highly modified; one or more original vegetation layers (ground, shrub, canopy etc) modified or missing.

Unnatural landscape: highly modified landscape containing few or no indigenous species; exotic species dominant; original native vegetation layers removed; natural soil profile disturbed; unable to be regenerated to natural condition; high input intervention required to revegetate.

2.1.3 Plant communities

Field survey

Native vegetation ground-truthed in the study area has been classified according to the plant community descriptions in *Native Vegetation of Southeast NSW: A Revised Classification and Map for the Coast and Eastern Tablelands* by DEC (2005). Plot based surveys to sample discrete vegetation communities and ground-truth existing vegetation mapping involved one or more 20 metre x 20 metre (400 square metre) quadrats. Quadrat sampling used a modified Braun-Blanquet cover abundance scale to record floristics and structure. Random meanders targeting threatened flora species were carried out in suitable habitats. Additionally, an inventory of all observed flora species was recorded at each site.

Following field surveys, plant communities mapped by DEC (2005) in some locations have been amended. All amendments to the DEC mapping are identified within the text in Section 3.2.2 of the *Terrestrial Flora and Fauna Assessment* report by Biosis Research (2012). Plant communities conforming to listed EECs were sampled, identified according to their floristic composition and compared to the OEH profiles and relevant scientific committee determinations.

Desktop analysis of impacts to native vegetation and potential terrestrial flora and fauna habitats involved calculation of estimates using the project footprint and data of the *Native Vegetation of Southeast NSW: A Revised Classification and Map for the Coast and Eastern Tablelands* (SCIVI) by DEC (2005). Determination of potential locations for implementing the preferred offset action has also used the DEC (2005) mapping and this has been amended using aerial photo interpretation, topographic data and reference to areas where ground-truthing of vegetation communities has been carried out. Further discussion of the use of vegetation mapping in identifying suitable areas for the preferred offset action is provided in Section 2.3.

2.1.4 Limitations

This assessment has relied on the broad scale regional vegetation survey and mapping project. SCIVI Plant communities as mapped by DEC (2005) have been amended following ground-truthing during the field surveys. All amendments to the DEC (2005) mapping are identified within the text in Section 3.2.2 and illustrated in Figure 3.1 of the main terrestrial ecology assessment report. The limitations of the surveys and mapping by (DEC 2005) and Tozer *et al* (2010) apply to some extent to the desktop vegetation assessments of this Biodiversity Offset Strategy.

2.2 Aquatic

Field surveys of aquatic habitat, biota and water quality were undertaken by Cardno Ecology Lab from 15 to 17 April, with subsequent inspection of potential sites for temporary crossings on 28 June 2011. Water quality parameters recorded, species sampled or observed are likely to be representative of the range of conditions and species that could be recorded using the methodology employed, but should be considered a “snapshot” in nature rather than representing seasonal changes in aquatic assemblage that may occur. Surveys were undertaken following a period of locally significant rainfall which was not considered to have significantly affected the number or type of species recorded.

2.3 Potential offset area mapping

Desktop mapping was carried out to identify areas that would be suitable for restoration and rehabilitation of riparian vegetation. The analysis focused primarily on defining areas where rehabilitation, focusing on revegetation, will improve the current connectivity of areas of riparian EEC’s (adopting a like for like or similar for like approach) and then more broadly over the coastal floodplain and low hills habitat of the riparian EEC’s throughout the locality. The analysis has adopted an investigation area of five kilometres from the project and applied a standardised riparian zone of 50 metres either side of a perennial or permanent drainage line consistent with the RMS ‘Biodiversity Guidelines’ (RTA 2011) and Category 1 – Environmental Corridor according to the *Riparian Corridor Management Study* (RCMS) by DIPNR (2004). In the absence of detailed top of bank mapping the 50 metres has been calculated from the drainage feature centreline.

The mapping adopted a qualitative three category mapping scheme which considers in order of ranked priority the perennial nature of streams, existing vegetation connectivity and existing plant community mapping. Each key theme corresponds to a layer of GIS data with the composite overlay identifying areas potentially suitable for offsets. The scheme ranks the lowest number eg one (1) as the most suitable and the highest numeric value eg three (3) as least suitable. The Priority 1 and 2 classes are further divided into two subclasses (a and b). The key offset suitability criteria are briefly discussed in the following sections and summarised in Table AE.1 below.

Table AE.1 Offset suitability mapping scheme.

Priority		Map colour	Physical attribute	Plant community (current surveys)	Restoration strategy
1	a		50 m riparian zone on perennial drainage with **no native vegetation cover**	-	Revegetation to replicate RFEF
	b		50 m riparian zone on perennial drainage with native vegetation cover	Riparian forest Illawarra wet gully forest	Weed control and supplementary planting
2	a		50 m riparian zone on non - perennial drainage with **no native vegetation cover**	-	Revegetation to replicate RFEF
	b		50 m riparian zone on non - perennial drainage with native vegetation cover	Riparian forest Illawarra wet gully forest	Weed control and supplementary planting
3	3		50 m riparian zone on perennial drainage with native vegetation cover	Floodplain swamp forest	Weed control and supplementary planting

2.3.1 Stream flow characteristics

Perennial streams were given the highest weighting as these provide a composite habitat for both RFEF and aquatic biodiversity values. Although non-perennial streams support RFEF and aquatic habitats, these are assigned lower weighting as these habitats are generally more simplified than perennial waterways. Stream flow characteristic data was sourced from the NSW Land and Property Information Authority (LPIs) digital topographic database, hydro line vector dataset.

2.3.2 Existing vegetation connectivity

Areas where improved connectivity along the riparian zones could be achieved through vegetation restoration were determined by automatic and interactive mapping techniques. These techniques involved the following process:

- A single polygon was created within the five kilometre locality to represent areas without recorded vegetation by creating a ‘negative’ of the SCIVI vegetation polygons which have been modified by Biosis Research through a combination of field survey and aerial image interpretation.
- The negative polygon was then intersected with the 1:25,000 scale stream polyline layer acquired from the NSW LPI to create lines representing sections of creek not covered by vegetation.
- Stream centrelines without vegetation were then buffered to 50 metres to identify possible revegetation areas.

2.3.4 Vegetation mapping

As noted the SCIVI mapping by DEC (2005) has been used as the baseline vegetation mapping in this assessment focusing on communities associated with the coastal floodplain and low foothill areas of the locality. The SCIVI data has been amended using aerial photo interpretation, topographic data and with reference areas where ground-truthing of vegetation communities has been carried out. SCIVI mapping vegetation communities incorporated into the offset suitability analysis are:

- Riverbank forest (corresponding to RFEF in places).
- Floodplain swamp forest (corresponding to Swamp oak floodplain forest (SOFF) in places).
- Illawarra wet gully forest (intergrading with Riverbank forest on perennial and non perennial drainages in areas of increasing elevation)

2.3.5 Southern Rivers CMA mapping

The Southern Rivers CMA provided Biosis Research with vector GIS data representing previously defined preferred corridors for vegetation rehabilitation and previous or current revegetation project locations. Although these map themes have not been included as part of the weighted analysis, they provide a general guide for focusing further investigation of offset areas consistent with current biodiversity planning and improvement strategies and programmes for the locality and region.

2.3.6 Land tenure

Land tenure within the study area is shown on the offset suitability maps. Similar to the Southern Rivers CMA data land tenure has not been included as part of the weighted analysis, however it provides a further guide to preferentially siting offset areas, such as on RMS land or other publically owned property.

2.3.7 Use and limitations

The purpose of the Biodiversity Offset Strategy suitability model is to identify potential locations for rehabilitation works to take place and it is expected that any potential locations which are chosen for rehabilitation will be more thoroughly assessed for suitability prior to finalisation of works being designed and as part of an offset delivery package.

This model has relied on data from a number of sources that has been captured using different techniques at a range of different scales. The model has been applied consistently and automatically within the five kilometre locality around the study area. The resulting suitability layer is therefore indicative only and should not be taken as a 100 per cent accurate representation of the various themed layers at an individual site.

3 Biodiversity impacts of the project

3.1 Terrestrial

The terrestrial ecological field investigations and assessments of the impacts of the project are detailed in the main body of the *Environmental Assessment – Terrestrial Flora and Fauna Assessment* (Biosis Research 2012) and relevant appendices. In summary, following the detailed terrestrial flora and fauna surveys encompassing the study area and impact assessments of the project at a locality scale (Section 4 of the main report), it was determined that the project is unlikely to have a significant impact on flora and fauna species listed under the *Threatened Species Conservation Act 1995)* (TSC Act) and/or the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provided recommended mitigation measures are implemented (refer Chapter 5 of the terrestrial ecology assessment report).

RFEF which is listed as an EEC under the TSC Act was recorded in the study area during the field surveys for the terrestrial flora and fauna assessment. A detailed description of the community is provided in the main terrestrial ecology assessment report. In summary, RFEF in the study area was dominated by characteristic tree species with the lower strata supporting sparse native shrubs and small trees and dense infestations of woody weeds. The groundcover in most areas was dominated by exotic annual and perennial herbs and grasses. The majority of RFEF in the study area was subject to edge effects with impacts in addition to weed invasion including, grazing and stream bank erosion. The overall condition of RFEF in the study area was considered to be Poor.

Areas where RFEF would be impacted by either direct removal or migrating existing edge effects for the construction and operation of the project including the permanent roadway, temporary creek crossings and other in stream works are at:

- Bundewallah Creek on the northern section of the Town Creek diversion (Figure 3.1.4).
- Below the junction of Bundewallah Creek and Connollys Creek and downstream to Broughton Mill Creek (Figure 3.1.7).
- Broughton Creek to the east of Berry on the southern side of the Princes Highway (Figure 3.1.7).
- Broughton Creek to the southeast and east of the intersection of Tomlins Road and Princes Highway, at Broughton (Figure 3.1.12).
- Broughton Creek to the east of the intersection of Thompson Road and Princes Highway, at Broughton (Figure 3.1.13).

Desktop analysis using geographic information systems (GIS) has determined that the project will likely result in:

- Direct removal of 2.9 hectares of the TSC Act-listed EEC RFEF from the subject site (incorporating the permanent roadway, temporary creek crossings and Town Creek diversion).
- Potential indirect impacts to 7.1 hectares of the TSC Act-listed EEC RFEF in the study area.

The unavoidable loss of the EEC RFEF would be a residual impact of the project. Table AE.2 below identifies the amount of RFEF and riparian habitat that would be affected by project construction activities.

Table AE.2 RFEF and riparian habitat impacted by the project.

Plant community	Impacted area (hectares)				
	Direct				Indirect (edge effects)
	Roadway	Ancillary facilities	Temporary crossings	Town Creek diversion	
Riverbank forest (equivalent to RFEF)	2.6	-	0.2	0.1	7.1

3.2 Aquatic flora and riparian vegetation

The aquatic ecological field investigations and assessments of the impacts of the project are detailed in *Aquatic Ecology and Water Quality Management Assessment* (CEL 2012). In summary, subsequent to the detailed aquatic ecology surveys of the study area and impact assessments of the project, it has been determined that impacts to aquatic ecology would not be significant. No impacts were identified to instream (emergent or submergent) aquatic flora.

The aquatic ecological value of riparian vegetation is outlined in Section 3.3.3 of the *Aquatic Ecology and Water Quality Management Assessment* (CEL 2012). The project would result in an estimated loss of riparian vegetation (Riverbank forest) within the study area of 2.9 hectares (see Table AE.2 above). This vegetation type is considered to be consistent with RFEF and as such meets the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) requirements in terms of provision of offset for residual impacts on aquatic ecology.

4 Biodiversity mitigation measures

Detailed discussion of mitigation measures to address impacts to biodiversity spanning the project inception, planning, construction and operation phases is provided in Section 5 of the terrestrial ecology assessment report and Section 5 of the aquatic ecology assessment report. In summary the development of impact mitigation measures has followed RMS policy (RTA 2001) and been consistent with the following key principles:

1. Avoid impacts on habitat though the planning process.
2. Minimise impacts on habitat through the planning process.
3. Mitigate impacts on habitat, through the use of a range of amelioration measures (RTA 2001).

4.1 Terrestrial flora and fauna

4.1.1 Impact avoidance through planning

The project has progressed to its current form through the consideration of multiple route options and these have been investigated as result of consultation with regulatory authorities and the broader community. As part of this process to the current design, important ecological features identified in the local area have been avoided where possible including patches of the EECs Illawarra subtropical rainforest and RFEF.

The project has been designed, where feasible, to minimise impacts on flora and fauna habitat. In areas where significant vegetation such as RFEF EEC cannot be avoided, the land area of the subject site, incorporating the permanent road and associated infrastructure and construction access requirements, has been reduced to minimise impacts.

4.1.2 Impact minimisation during construction

A number of measures have been recommended to minimise impacts on biodiversity during construction. These measures are detailed in the main terrestrial ecology assessment report and include:

- Vegetation clearing is restricted to those areas where it is necessary.
- Defining limits of clearing using temporary exclusion fencing.
- Implementing the RMS 'Biodiversity Guidelines' (RTA, 2011).
- Staged habitat removal.
- Pre-clearing process.
- Siting all ancillary building and works in cleared or otherwise disturbed areas away from waterways (50 metres[3]) and other sensitive areas.

[3] *Refers to the working footprint of the facility. The property on which the site is located may encompass or may extend within the 50 metre buffer to the watercourse.*

- Preparation of a Vegetation Management Plan (VMP) prior to construction that includes vegetation management actions that specifically address the construction phase.
- Installation and maintenance of sediment and erosion controls.

4.1.3 Impact mitigation measures

Terrestrial biodiversity impact mitigation measures proposed in the environmental assessment focus on restoring and improving flora and fauna habitat connectivity and condition following construction of the roadway. The main impact mitigation measures are:

- Restoration and management of the known or potential habitat of threatened flora and fauna species temporarily impacted by project. The preparation of a VMP (VMP) would detail restoration methods, performance measures and a monitoring programme to ensure restoration works achieve objectives. Optimally the VMP would integrate with the landscape plan for the project and be prepared in consultation with local Landcare groups and the CMA committing to input local expertise and resources during implementation.
- Construction of rope bridges for arboreal species and fauna underpasses (including road bridges and fauna dedicated underpasses incorporating fauna furniture). Fauna fencing would be installed as part of the function of these structures. Proposed sites have been selected for these structures as detailed in Table 5.1 of the terrestrial ecology assessment report.

4.2 Aquatic ecology

4.2.1 Impact avoidance through planning

It is recommended that the project design aims to minimise stormwater and disturbed surface runoff entering adjacent waterways by diverting and/or containing it in sediment basins/vegetated swales. Earthworks are recommended to be designed to minimise the risk of mobilising acid sulfate soils (ASS).

Impacts on the natural surface and groundwater flow regime of the study area would be minimised through the redirection of groundwater seepage into aquatic habitats via longitudinal drainage systems. It is recommended that bridge structures be designed to have minimal impact on the natural flow regime and to provide immunity from 100 and 50 year annual recurrence interval (ARI) flood events respectively. It is recommended that no bridge piers or abutments should be positioned within the section of waterway channel (wetted width) that carries median flows. Therefore, bridges are the recommended structures for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. It is recommended that bridge piers be placed outside the main channel to avoid formation of turbulence and bed erosion, and abutments placed away from the bank. If placement of bridge piers within waterways is unavoidable, impacts would be minimised through the provision of scour protection during the detailed design phase of the project. Due to their size and classification as fish habitat, culverts are considered adequate crossings for the remaining waterways.

4.2.2 Impact minimisation during construction

Erosion and sediment controls, such as bunding, silt fences/curtains, sediment basins and vegetated swales are recommended to minimise potential impacts to aquatic ecology during the construction phase of the project.

It is recommended that run-off from disturbed areas, stockpile dust suppression/washdown facilities be diverted into sediment basins and erosion controls, and that clean water be diverted around disturbed areas. Areas of exposed earthworks are recommended to be re-vegetated and remediated as soon as possible although erosion controls and sediment traps would remain in place until vegetation cover has been established. It is recommended that project works and ancillary infrastructure not take place within 50 metres of Category 1 (Environmental Corridor) riparian habitat.

The outline of a surface water quality monitoring program consistent with Australian and New Zealand Environment Conservation Council (ANZECC) guidelines has been prepared (*Aquatic Ecology and Water Quality Management Assessment*) and its incorporation into the erosion and sediment control plan is recommended. The measures that are recommended to minimise erosion and sedimentation would also address potential contamination and pollution issues. It is additionally recommended that any hazardous substances should be properly handled, stored, transported and disposed of. Invasive species have been identified within the study area (eg alligator weed). It is therefore recommended that alligator weed or other invasive pests are identified and appropriately disposed of. It is recommended that large woody debris displaced during construction should be relocated within the same reach.

4.2.3 Impact mitigation measures

The main impact mitigation measure is the revegetation and restoration of riparian vegetation, particularly the EEC RFEF along the waterway at strategic locations. This mitigation measure overlaps with that proposed for loss of terrestrial biodiversity.

4.2.4 Residual impacts

Residual impacts on aquatic ecology and water quality that cannot be adequately mitigated and fail to 'improve or maintain' biodiversity include:

- Direct impacts to 2.9 hectares and potential indirect impacts to 7.1 hectares of riparian habitat within the project corridor, ancillary infrastructure and temporary crossing footprint.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Slight changes to hydrology due to placement of pier structures within the waterway of Bundewallah Creek.
- Potential reduced longitudinal connectivity at temporary crossings during low flows.
- Changes to flood hydrology at Town Creek, Bundewallah Creek and Broughton Creek from installation of transverse drainage structures.

4.3 Offsets

The unavoidable loss of the EEC RFEF would be a residual impact of the project. To meet the 'improve or maintain' outcomes required by the project DGRs, offsetting is required. The following sections discuss general principles for planning and implementing biodiversity offset actions; and, proposes two actions for further consideration to maintain or improve the long-term viability of the local occurrence of RFEF and the habitat it may provide for threatened and non-threatened biodiversity.

The DTIRIS have a policy of 2:1 environmental compensation for direct loss of aquatic or riparian habitat (Smith and Pollard 1999). Compensation for the unavoidable loss of riparian habitat, changes to the natural flow regime and lateral connectivity caused by the project would be addressed by the offsets outlined below.

5 Proposed biodiversity offset actions

5.1 General biodiversity offset principles

Biodiversity offsets are commonly required for major developments under Part 3A of the EP&A Act. Biodiversity offsets are secured under mechanisms such as the BioBanking Scheme, conservation agreements and planning agreements under the EP&A Act. Outcomes for biodiversity offsets for major developments under Part 3A of the EP&A Act must meet the 'improve or maintain' standard (OEH, 2011). A set of general principles have been prepared by OEH (2011) to provide a framework and guidance when formulating biodiversity offsets and these are provided in Appendix F of the main report. Table AE.3 below identifies how the project has considered and is consistent with the OEH (2011) general principles for biodiversity offsetting.

Table AE.3 Compliance of the project with the OEH (2011) principles for the use of biodiversity offsets NSW

Impacts must be avoided first by using prevention and mitigation measures. Measures to prevent and mitigate biodiversity impacts of the project have been guided by the following key principles: 1. "Avoid impacts on habitat though the planning process. 2. Minimise impacts on habitat through the planning process. 3. Mitigate impacts on habitat, through the use of a range of amelioration measures (RTA 2001)". Section 5 of the *Terrestrial Flora and Fauna Assessment* (Biosis 2012) details avoidance, prevention and mitigation measures that have been implemented and are proposed to minimise impacts on terrestrial biodiversity. These are summarised in Section 4 of this Biodiversity Offset Strategy.
All regulatory requirements must be met. This Biodiversity Offset Strategy and the subsequent Biodiversity Offset Package is designed to offset the residual biodiversity impacts from the project and is not designed to satisfy any other legislative approvals. This Biodiversity Offset Strategy has been refined in consultation with OEH and would be finalised on the basis of the NSW Minister for Planning's Conditions of Approval for the project.
Offsets must never reward ongoing poor performance. The efforts that have been made to avoid, minimise and mitigate impacts to biodiversity as a result of the project are consistent with the DGR's and RMS 'Biodiversity Guidelines' (RTA 2011). Riparian habitats that are proposed for offsetting are highly degraded due to a long history of agriculture. Offsetting will aim to improve the condition and management of riparian habitats in the locality.
Offsets will complement other government programs. The preferred Action 1 proposed in this Biodiversity Offset Strategy is to restore riparian habitats in strategic locations with an objective of improving native riparian vegetation connectivity and aquatic habitats at a locality scale. Delivery of a Biodiversity Offset Package that maintains or improves riparian habitats and RFEF may compliment the following: Biodiversity targets of the Southern Rivers Catchment Action Plan (Southern Rivers CMA, 2005). Priority actions of the South Coast Regional Conservation Plan (Department of Environment, Climate Change and Water (DECCW), 2010). Biodiversity actions and targets of the Illawarra Biodiversity Strategy (Wollongong City Council (WCC) et al, 2010). In addition to this, community stakeholders such as the local Landcare groups and other government departments may be involved in the implementation of the Biodiversity Offset Package.

Offsets must be underpinned by sound ecological principles.

This Biodiversity Offset Strategy has been formulated on the basis of detailed field surveys and desktop analysis focusing on threatened terrestrial biodiversity and aquatic ecology. Direct and indirect impacts of the project have been considered on a scale that extends from the roadway footprint to the locality. As a result of the biodiversity impact assessment, the Biodiversity Offset Strategy proposes enhancing existing riparian habitat as the preferred offset action. Should proposed Action 1 become the preferred offset action consultation would occur with local Landcare groups and the Southern Rivers CMA providing input of local expertise and resources. (see section 5.1). Preliminary assessments have been carried out to identify locations that would be most suitable for improving riparian vegetation connectivity using best practice desktop analysis. Additionally this Biodiversity Offset Strategy provides baseline data for use of the BioBanking Assessment Methodology (BBAM) to guide the preparation of a Biodiversity Offsets Package for the project should Action 2 become the preferred offset arrangement.

Offsets should aim to result in a net improvement in biodiversity over time.

This Biodiversity Offset Strategy informs the preparation of a Biodiversity Offset Package that would achieve an 'improve or maintain' biodiversity outcome for the region as a result of the project. This Biodiversity Offset Strategy proposes to use the desktop mapping presented in Figures C1 to C7 or the BBAM to guide an offset that would result in a net improvement to riparian habitats in the locality over time.

Offsets must be enduring - they must offset the impact of the development for the period that the impact occurs.

The biodiversity benefits delivered by the Biodiversity Offset Package would be permanent including further investigation mechanisms to ensure the benefits are maintained and managed.

Offsets should be agreed prior to the impact occurring.

The preparation of this Biodiversity Offset Strategy is acknowledgement that an offset for riparian habitats would be delivered in a Biodiversity Offset Package, consistent with Minister for Planning's Conditions of Approval for the project.

Offsets must be quantifiable - the impacts and benefits must be reliably estimated.

This Biodiversity Offset Strategy has been formulated on the basis of detailed field surveys and desktop analysis focusing on threatened terrestrial biodiversity and aquatic ecology. Quantification of direct and indirect impacts of the project has been considered on a scale that extends from the roadway footprint to the locality. Methods to quantify the type and extent of impacts have referenced current technical information and scientific studies and reports. Preliminary assessments have been carried out as the basis for further investigation of locations most suitable for improving riparian vegetation connectivity or BBAM to guide the preparation of a Biodiversity Offsets Package for the project.

Offsets must be targeted.

Preliminary assessments have been carried out to provide the basis for further investigation of locations most suitable for improving riparian vegetation connectivity or the BBAM to guide the preparation of a Biodiversity Offsets Package for the project. This Biodiversity Offset Strategy proposes offsetting on a like for like basis for both the RFEF vegetation community and aquatic habitats and where this is not feasible then other vegetation types of a similar conservation value incorporating aquatic habitats of a similar quality may be considered in consultation with OEH and DTIRIS.

Offsets must be located appropriately.

This Biodiversity Offset Strategy proposes that:

- The Action 1 offset should be located within a five (5) kilometre radius of the project.
- The Action 2 offset should be located within a 30 kilometre radius of the project.
- There is enhancement of native riparian vegetation connectivity at a locality scale.
- The offset location, land and Action should seek to optimise improvement of threatened terrestrial flora and fauna species or aquatic biodiversity habitat.

Offsets must be supplementary. This Biodiversity Offset Strategy proposes that RMS owned land within the study area be considered for the implementation of the preferred Action 1. This land is not under an existing private agreement for protection or managed by any government agency for the purposes of conservation or open space. Properties where native vegetation restoration works either are or have been carried out in association with the Southern Rivers CMA, are identified in the accompanying mapping Consultation would occur with local Landcare groups and the Southern Rivers CMA with this local expertise ensuring that a Biodiversity Offsets Package results in a supplementary outcome.
Offsets and their actions must be enforceable through development consent conditions, licence conditions, conservation agreements or a contract. Development of this Biodiversity Offset Strategy has involved consultation with OEH and the Southern Rivers CMA. Additionally the development of a Biodiversity Offset Package would be in consultation with OEH, the Sothern Rivers CMA and local Berry Landcare groups. Further investigation of an appropriate agreement or contract to implementation the preferred offset action is to occur. The implementation of a Biodiversity Offset Package that proposes performance measures and includes reporting requirements is likely to be a Condition of Approval for the project.

5.2 Proposed actions

The following offset actions are proposed in order to achieve an 'improve or maintain' biodiversity outcome for the region as a result of the project:

Action 1 Revegetation and rehabilitation of riparian vegetation in strategic locations.

Action 2 Use of an appropriate legal instrument to acquire and/or secure native vegetation to ensure that the land is managed for conservation.

Action 1 is the first priority to achieve the objectives of the Biodiversity Offset Strategy. Action 2 would only be considered if there are residual offset requirements after Action 1 offset measures have been exhausted. Table AE.4 provides a summary of specific agency DGRs relating to terrestrial and aquatic biodiversity issues that would be addressed by Action 1. Further details on the proposed delivery of Actions 1 and 2 are provided in following sections.

Table AE.4 Summary agency DGRs that will be addressed by Action 1

Agency	Summary DGRs	Relevant to	Comment
OEH	The environmental outcomes should be acceptable in terms of the achievement or protection of the River Flow Objectives and Water Quality Objectives.	Aquatic biodiversity	Delivery of Action 1 would contribute to achievement of River Flow and Water Quality objectives.
	Describe the actions that will be taken to avoid or mitigate impacts or compensate to prevent unavoidable impacts of the project on threatened species, populations, ecological communities, or their habitats.	Terrestrial biodiversity	Delivery of Action 1 would compensate for unavoidable impacts to RFEF.
	Offsetting biodiversity and habitat loss would be required as identified in the threatened species guidelines.	Terrestrial biodiversity	Delivery of Action 1 would compensate for unavoidable impacts to RFEF.

Agency	Summary DGRs	Relevant to	Comment
	The development of long-term management strategies shall be considered to protect areas within the study area which are of particular importance for the subject species, populations or ecological communities likely to be affected by the proposal. This may include proposals to restore or improve habitat on site where possible.	Terrestrial biodiversity	Delivery of Action 1 would restore or improve habitat for RFEF either on site or in nearby areas.
	If significant modification of the proposal to minimise impacts on subject species, populations or ecological communities is not possible, then compensatory strategies shall be considered. These may include other off-site or local area proposals that contribute to long term conservation of the subject species, populations or ecological communities. The areas proposed to be used for compensatory strategies must be described in full including a detailed description of their biodiversity, tenure and conservation status. These areas should be assessed in accordance with the Principles for the use of biodiversity offsets in NSW.	Terrestrial biodiversity	Delivery of Action 1 would compensate for unavoidable impacts to RFEF.
NSW Office of Water (NOW)	Provide details of safeguard measures to mitigate impacts, contingency plans for the remediation and rehabilitation of riparian areas in the event of potential adverse impacts and the long term management of the riparian lands.	Terrestrial biodiversity and aquatic biodiversity	The delivery of Action 1 would in part provide a contingency for the long term management of riparian lands.
DTIRIS Fisheries	Proposed measures to mitigate, rehabilitate or compensate for such impacts ensure that there is 'no net loss' of aquatic habitats.	Aquatic biodiversity	Delivery of Action 1 would indirectly ensure that there is no net loss of aquatic habitat by reducing sediment load from creek erosion and providing large woody debris for fish habitat.
	Propose environmental compensation measures to offset the permanent loss of riparian habitats in Broughton Creek, Broughton Mill Creek and Bundewallah Creek.	Aquatic biodiversity	Delivery of Action 1 would offset permanent loss of riparian habitats in Broughton Creek, Broughton Mill Creek and Bundewallah Creek.

5.2.1 Delivery of Action 1 - Revegetation and rehabilitation of riparian vegetation in strategic locations

The optimal delivery of Action 1 would be to invest in the strategic revegetation of RFEF that addresses improvement of both terrestrial and aquatic biodiversity. A key component in the delivery of Action 1 would be to enhance native riparian vegetation connectivity at a locality scale. The recommendations provided below for the restoration or enhancement of riparian and aquatic habitats, focusing on RFEF, other coastal floodplain EECs or closely associated non threatened plant communities, are the main considerations on which Action 1 should be based. Table AE.4 below provides an estimate of the area for each of the offset suitability mapping classes in the five kilometre locality (Figures C1 to C7).

Table AE.4 Offset suitability area calculations.

Priority		Map colour	Physical attribute	Area estimate for 5km locality (hectares*)	Restoration strategy
1	a		50 m riparian zone on perennial drainage with **no native vegetation cover**	591	Revegetation to replicate RFEF
	b		50 m riparian zone on perennial drainage with native vegetation cover	155	Weed control and supplementary planting
2	a		50 m riparian zone on non - perennial drainage with **no native vegetation cover**	3578	Revegetation to replicate RFEF
	b		50 m riparian zone on non - perennial drainage with native vegetation cover	226	Weed control and supplementary planting
3	3		50 m riparian zone on perennial drainage with native vegetation cover	14	Weed control and supplementary planting

** This is an estimate of the potential area (hectares) for each mapping unit that demonstrates the availability of viable and achievable options to offset the impacts of the project.*

Broughton Creek, Broughton Mill Creek and Bundewallah Creek are assessed as Category 1 waterways (Environmental Corridor) based on RCMS classification system (DIPNR 2004). The waterways and their riparian vegetation are significant terrestrial and aquatic environmental corridors and the objective of the RCMS is to provide biodiversity linkages by maintaining unbroken connectivity and habitat for the aquatic organisms along the waterway network. The minimum core riparian zone (CRZ) width either side of Category 1 waterways should be 40 metres of fully vegetated habitat with a 10 metre buffer (DIPNR 2004).

Riparian habitat is significantly degraded at many of the aquatic ecology survey sites. Large woody trees have been removed and the understorey was often dominated by weed species. The degradation of riparian habitat and surrounding agricultural land use has significantly affected aquatic habitat and biota within the study area.

Action 1 should consider the following:

1. Restoration of riparian habitat to Category 1 level creeks on RMS owned land to enhance connectivity for terrestrial and aquatic habitats. The RMS owns land with significant frontages on Broughton Creek, Broughton Mill Creek, Bundewallah Creek and Connollys Creek.
2. Ongoing financial support for existing riparian restoration works within the region (eg programs run by Southern Rivers CMA, Shoalhaven City Council or DTIRIS).
3. The area of restoration would be guided by a simulated assessment of the project impacts and potential offsets using the BBAM with a minimum of 2:1 for riparian vegetation to meet DTIRIS requirements.

Restoration works would be carried out by accredited organisations and include, where appropriate, revegetation of native riparian species, removal of exotic species and restoration/protection of existing riparian habitat (eg fencing protection from livestock).

Restoration and rehabilitation of RFEF in areas other than land owned and managed by the RMS may be considered. These alternate locations have been identified by desktop mapping as described in Section 2.3 and presented in Figures C1 to C7. Finalisation of the exact locations for restoration of riparian vegetation to improve outcomes for both terrestrial and aquatic biodiversity would be guided by the outcomes of:

- Further investigation and specialist advice from OEH and/or the Southern Rivers CMA or other specialist ecologists.
- Consultation with the Berry Landcare Group and consideration of the strategic priorities or actions of *Berry Nature Corridor – Escarpment to Sea* (Berry Landcare Group, in preparation).

If Action 1 were to be further investigated then an appropriate instrument for ongoing management for conservation may consider one of the following legally binding arrangements:

- A Trust Agreement.
- A Conservation Agreement.
- A Property Vegetation Plan.
- A Wildlife Refuge.
- A BioBanking Agreement.

5.2.2 Delivery of Action 2 - Use an appropriate legal instrument to secure native vegetation to ensure that the land is managed for conservation

The relevant general principles outlined in Appendix F for biodiversity offsetting would form the basis for proceeding with delivery of the proposed Action 2. In addition the key aims in the delivery of Action 2 are:

- The offsets would be located within a 30 kilometre radius of the project and within the NSW Sydney Basin Bioregion.
- Offsetting native vegetation on a like for like basis.
- Offset land should comprise land that would improve connectivity between areas of remnant vegetation.
- Offset land must be suitable for ongoing management for conservation through an appropriate legal instrument.
- Where it is not feasible to offset on a like for like basis other vegetation types of a similar conservation value in the offset investigation area would be considered.

In proceeding with Action 2 and to address the 'improve or maintain' outcome, the RMS proposes to use the BBAM to guide the calculation of an appropriate offset amount for the TSC Act-listed EEC, RFEF. The BBAM contains rules to ensure the biodiversity values created on a Biobank site match those lost on a development site including offsetting the same vegetation type or another vegetation type in the same formation that contains the same predicted species; or a more cleared vegetation type that contains the same threatened species (DECC 2009). Additionally the Final Determination for RFEF states that the community may adjoin or intergrade with several other EECs, which collectively cover all remaining native vegetation on the coastal floodplains of NSW. Swamp oak floodplain forest (SOFF) is identified by the NSW Scientific Committee (2005) as a vegetation community that may adjoin or intergrade with RFEF.

Preliminary analysis using the BBAM has been carried out to propose a suitable alternate vegetation type for consideration. Table AE.5 below provides the definition of vegetation types for the Southern Rivers CMA from The Vegetation Types Database (DECCW 2008) against which the RFEF may be assessed and offset.

Table AE.5 Plant communities impacted by the project, Southern Rivers CMA vegetation types and alternative offset EECs.

Plant community (current surveys)	EEC	Southern Rivers CMA vegetation type (DECCW 2008)	Vegetation formation (Keith 2004)
Riparian forest	RFEF	River Oak open forest of major streams, Sydney Basin and South East Corner	Forested Wetlands
Floodplain swamp forest	SOFF	Swamp Oak swamp forest fringing estuaries, Sydney Basin and South East Corner	Forested Wetlands

Figures D1 to D6 highlight the location of Riparian forest and Floodplain swamp forest in a 30 kilometre radius of the project based on the DEC 2005 mapping. Figures C1 to C6 also highlight the location of conservation reserves and state forest falling within and adjacent to the 30 kilometre offset investigation area. In summary, Riparian forest is present close to the project on Broughton Creek (Figure C3). Large stands of the community are present in Kangaroo Valley on the Kangaroo River and Brogers Creek with scattered occurrences on the tributaries of these major drainages (Figure D3). The most extensive stands of Riparian forest in the offset investigation area are on the Shoalhaven River, west of Nowra (Figures D3 and D5). The main areas of Floodplain swamp forest are on the western margin of Lake Illawarra (Figure C2) and to the east and southeast of Nowra (Figure C5). The largest and most contiguous stand of Floodplain swamp forest to the project area is at Coomonderry Swamp, southeast of Berry (Figure C3).

Table AE.6 below details the potential offset vegetation types within 30 kilometres of the project. Potential offset vegetation types have been determined in accordance with the OEH Biometric database.

Table AE.6 Potential offset vegetation types within 30 kilometres of the project.

Southern Rivers CMA vegetation type (DECCW 2008)	Tenure		Total area mapped (hectares) (DECC 2005n)
	Conservation (hectares)	Private (hectares)	
River Oak open forest of major streams, Sydney Basin and South East Corner	25.4	586.4	611.8
Swamp Oak swamp forest fringing estuaries, Sydney Basin and South East Corner	202.5	1026.0	1228.5

The BBAM would be used to guide the selection of proposed offset areas to ensure the potential offset land(s) consist of appropriate vegetation type(s).

If Action 2 were to be further investigated then an appropriate instrument for ongoing management for conservation may consider one of the following legally binding arrangements.

- A Trust Agreement.
- A Conservation Agreement.
- A Property Vegetation Plan.
- A Wildlife Refuge.
- A BioBanking Agreement.

6 Biodiversity offset package

6.1 Decision making framework

Any biodiversity offsets would be located within the NSW Sydney Basin Bioregion and within 30 kilometres of the subject site, with the aim of offsetting on a like for like basis for both the RFEF vegetation community and aquatic habitats. Where it is not feasible to offset vegetation on a like for like basis other vegetation types of a similar conservation value incorporating aquatic habitats of a similar quality will need to be considered in consultation with OEH and DTIRIS.

Potential offset areas would need to be assessed and RMS owned land within the study area has preliminarily been proposed in delivery of Action 1. However it is recognised that the availability and suitability of land and associated aquatic habitat for inclusion in the offset package will be uncertain until the detailed investigation of suitable sites is completed. If the RMS owned land is not suitable to accommodate a dual terrestrial and aquatic offset then negotiations with private landholders may need to occur. Areas of riparian vegetation types that may be suitable for further investigation in the delivery of Actions 1 and 2 are highlighted in Figures C1 to C7.

In addition to the above, and dependant on the final preferred Action, other considerations as part of the decision making framework include:

- Offset should be located within a 30 kilometre radius of the project.
- Using the DTIRIS policy of 2:1 environmental compensation for direct loss of aquatic or riparian habitat as the minimum offset ratio regardless of the outcomes of a simulated BioBanking assessment proposed for further investigation of Actions 1 and 2.
- Enhancement of native riparian vegetation connectivity at locality scale.
- Offset land and Action should seek to optimise improvement of other threatened terrestrial or aquatic biodiversity habitat. For example the development of a planting schedule for Action 1 should include flora species characteristic of RFEF that provide preferred foraging resource for seasonal migratory threatened bird species.
- Commitment of resources to a defined and measurable outcome that at least maintains or ultimately improves terrestrial and aquatic biodiversity for the region.
- Further consideration of the general offset principles highlighted in Appendix F as required in the implementation of the Biodiversity Offsets Package.

6.2 Implementation

Within 12 months of approval of the project, the RMS would submit to the DP&I a Biodiversity Offset Package. The package would be prepared in consultation with OEH and DTIRIS and would include details of the final suite of measures to be implemented based on this strategy and addressing both terrestrial and aquatic biodiversity. The package would identify a timeline for implementation and the detail of measures, including arrangements for ongoing management of offset lands or other actions.

7 References

Biosis Research (2012). *Foxground and Berry bypass Environmental Assessment – Terrestrial Flora and Fauna Assessment*. Prepared for RMS September 2011. Sydney.

Cardno Ecology Lab (CEL2012). *Aquatic Ecology and Water Quality Management Assessment, Foxground and Berry bypass*. Prepared for RMS September 2011. Sydney.

DEC (2004) Draft *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities* Department of Environment and Conservation, Sydney.

DEC (2005) *'Native Vegetation Map Report Series No.4*.' Department of Environment and Conservation, Sydney.

DECCW (2008). *The Vegetation Types Database*. Department of Environment, Climate Change and Water. Sydney.

DECCW (2009). *The science behind BioBanking*. Department of Environment, Climate Change and Water. Sydney.

DECCW (2010). *South Coast Regional Conservation Plan*. Department of Environment, Climate Change and Water. Sydney.

DIPNR (2004). *Riparian Corridor Management Study (RCMS) in the Wollongong Local Government Area*. NSW Department of Infrastructure, Planning and Natural Resources.

Fairfull, S. and Witheridge, G. (2003). *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*. NSW Fisheries, Cronulla, 16 pp.

NSW DPI (2005). *Reducing the Impact of Road Crossings on Aquatic Habitat in Coastal Waterways – Southern Rivers, NSW*. Report to New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW.

NSW Scientific Committee (2005). *River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions - endangered ecological community listing. NSW Scientific Committee - final determination*. NSW Scientific Committee, Sydney.

OEH (2011). *Biodiversity offset principles*. Office of Environment and Heritage website http://www.environment.nsw.gov.au/biocertification/offsets.htm

RTA (2001). 'Compensatory Habitat Policy and Guidelines. Providing Compensatory Habitat as Amelioration for Impacts on Habitat Resulting from Road Development. Draft 7.' Roads and Traffic Authority, Sydney.

RTA (2011). Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects. Revision 0/September 2011. Roads and Traffic Authority Environment Branch. Sydney.

Smith, A. K. and Pollard, D. A. (1999). *Policy and Guidelines Aquatic Habitat Management and Fish Conservation: 1999 Update*. NSW Fisheries, Port Stephens Research Centre.

SRCMA (2005). *Southern Rivers Catchment Action Plan*. Southern Rivers Catchment Management Authority. Wollongong.

Tozer MG, Turner K, Keith DA, Tindall D, Pennay C, Simpson C, MacKenzie B, Beukers P and Cox S (2010) 'Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11(3): 359-406.'.

WCC et al (2010). *Illawarra Biodiversity Strategy 2010*. Wollongong City Council, Shellharbour City Council and Kiama Municipal Council. Wollongong.

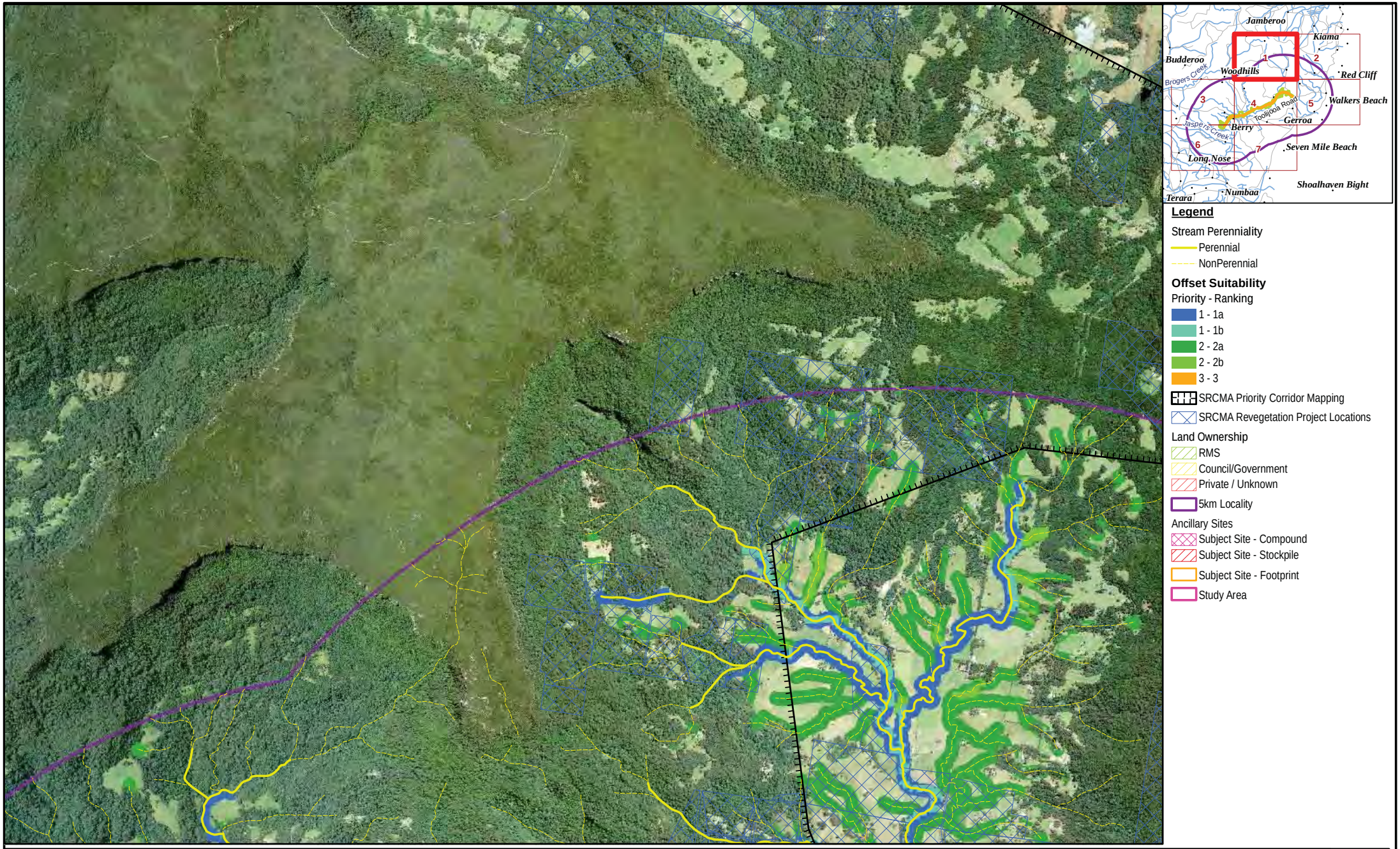

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Figure C.1: Offset Strategy Model

Date: 24 October 2012	Drawn by: RS/JMS
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 5\15039_OS_Suitability_231012.mxd	

Acknowledgements:
Vegetation mapping from DECCW
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 250 500 750 1,000
Metres

Scale: 1:25,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

Figure 3

Legend

Stream Perenniality
- Perennial
- NonPerennial

Offset Suitability
Priority - Ranking
- 1 - 1a
- 1 - 1b
- 2 - 2a
- 2 - 2b
- 3 - 3
- SRCMA Priority Corridor Mapping
- SRCMA Revegetation Project Locations

Land Ownership
- RMS
- Council/Government
- Private / Unknown
- 5km Locality

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Subject Site - Footprint
- Study Area

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Figure C.2: Offset Strategy Model

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Location: P:\15000s\15039\Mapping\Variation 5\15039_OS_Suitability_231012.mxd	

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Metres

Scale: 1:25,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

N

Figure 3

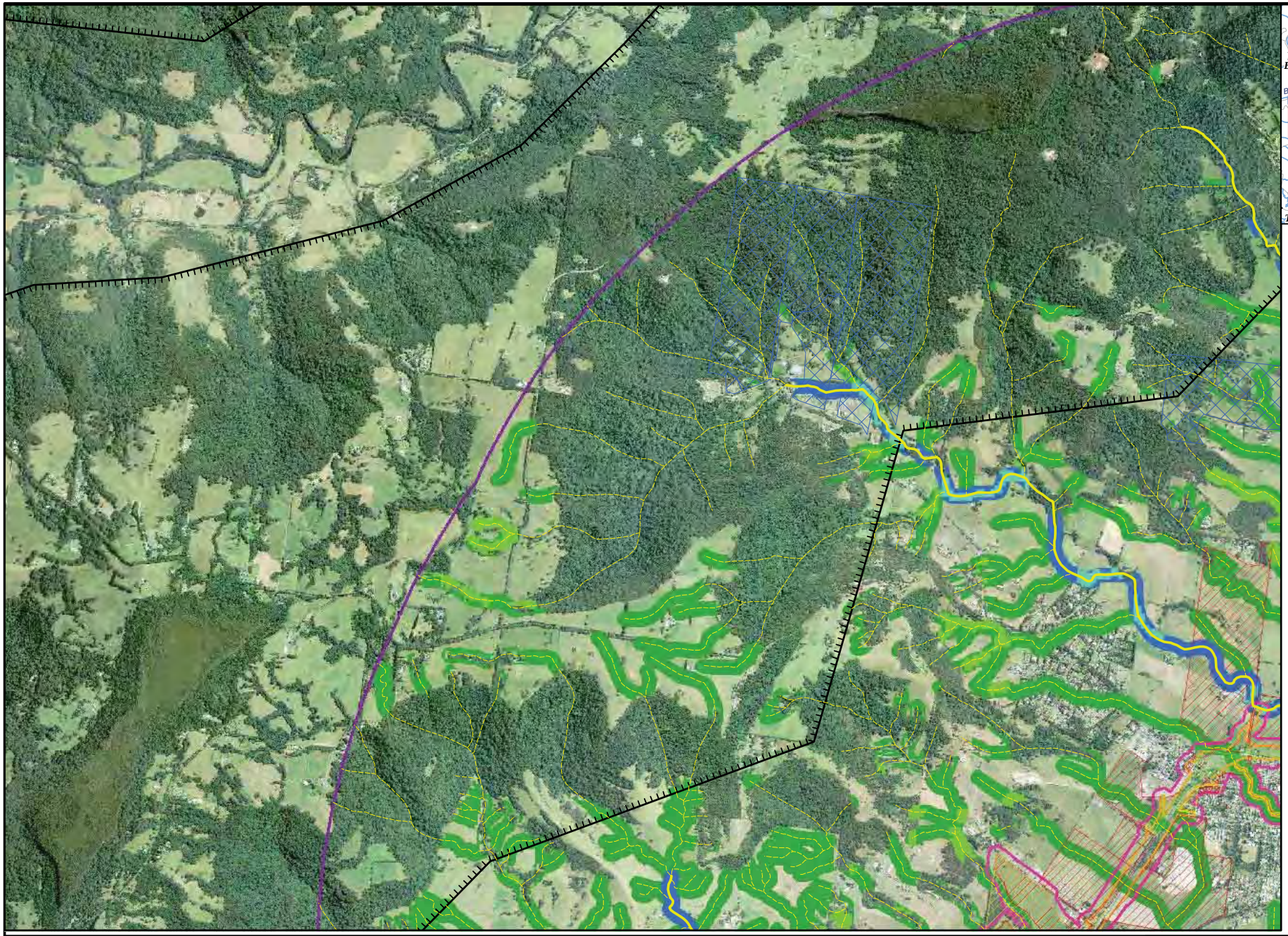

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Figure C.3: Offset Strategy Model

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Location: P:\15000s\15039\Mapping\Variation 5\15039_OS_Suitability_231012.mxd	

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Scale: 1:25,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 3

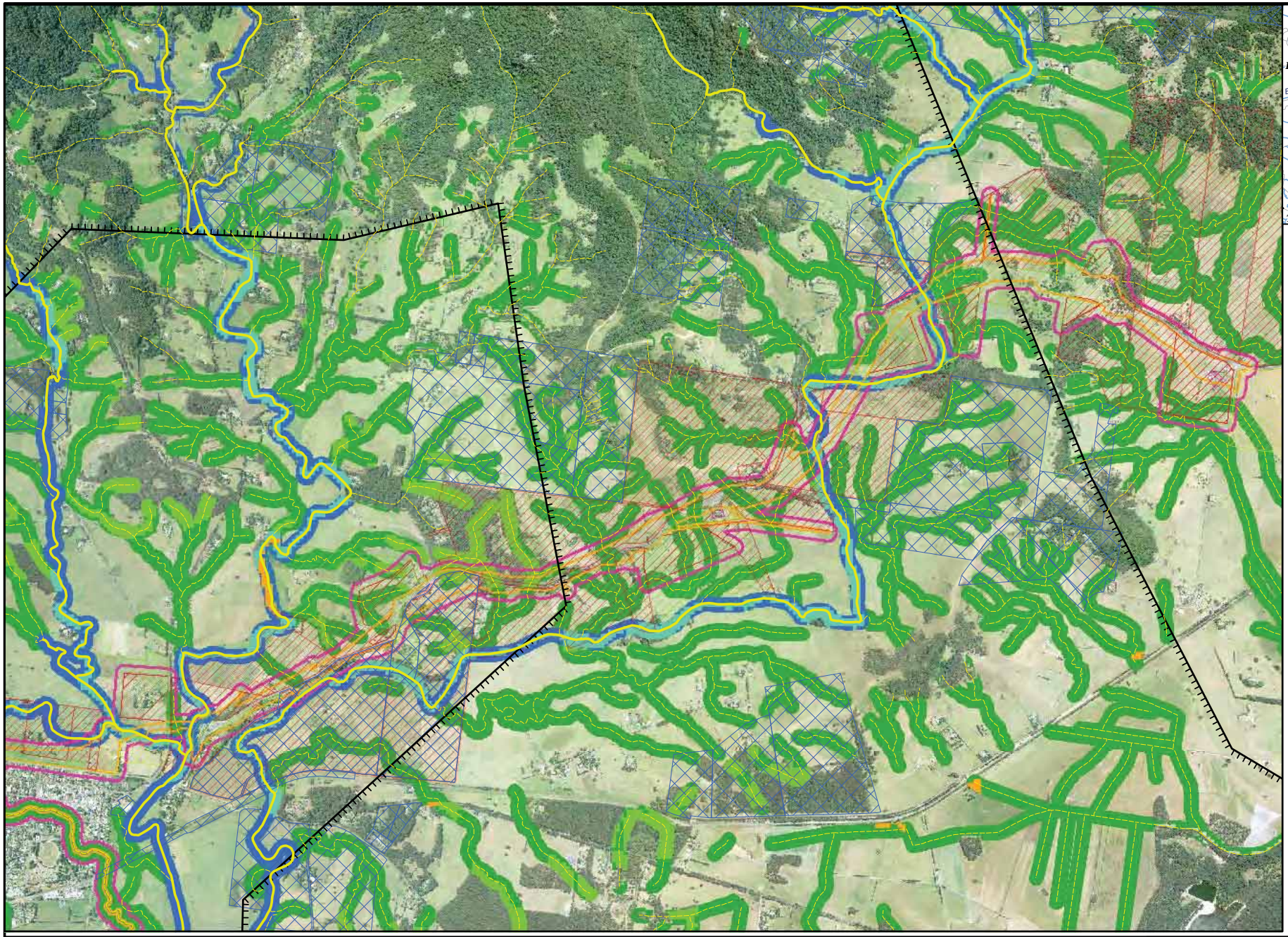

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Figure C.4: Offset Strategy Model

Date: 24 October 2012	Drawn by: RS/JMS
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 5\15039_OS_Suitability_231012.mxd	

Acknowledgements:
Vegetation mapping from DECCW
Aerial imagery provided by ARUP
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0 250 500 750 1,000
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Scale: 1:25,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 3

Legend

Stream Perenniality
- Perennial
- NonPerennial

Offset Suitability
Priority - Ranking
- 1 - 1a
- 1 - 1b
- 2 - 2a
- 2 - 2b
- 3 - 3
- SRCMA Priority Corridor Mapping
- SRCMA Revegetation Project Locations

Land Ownership
- RMS
- Council/Government
- Private / Unknown
- 5km Locality

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Subject Site - Footprint
- Study Area

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Figure C.5: Offset Strategy Model

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Location: P:\15000s\15039\Mapping\Variation 5\15039_OS_Suitability_231012.mxd	

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Figure 3

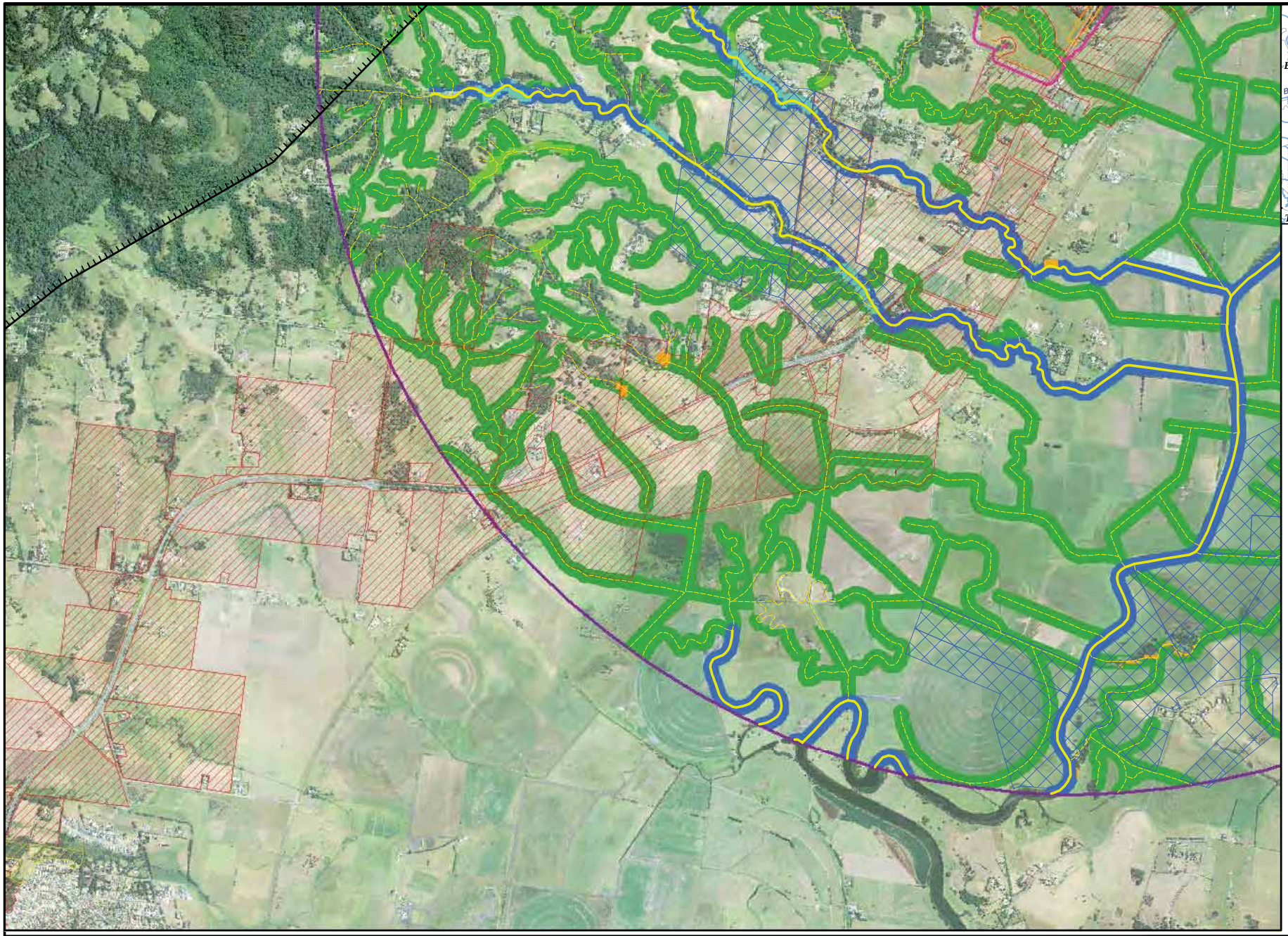

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Figure C.6: Offset Strategy Model

Date: 24 October 2012	Drawn by: RS/JMS
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Location: P:\15000s\15039\Mapping\Variation 5\15039_OS_Suitability_231012.mxd	

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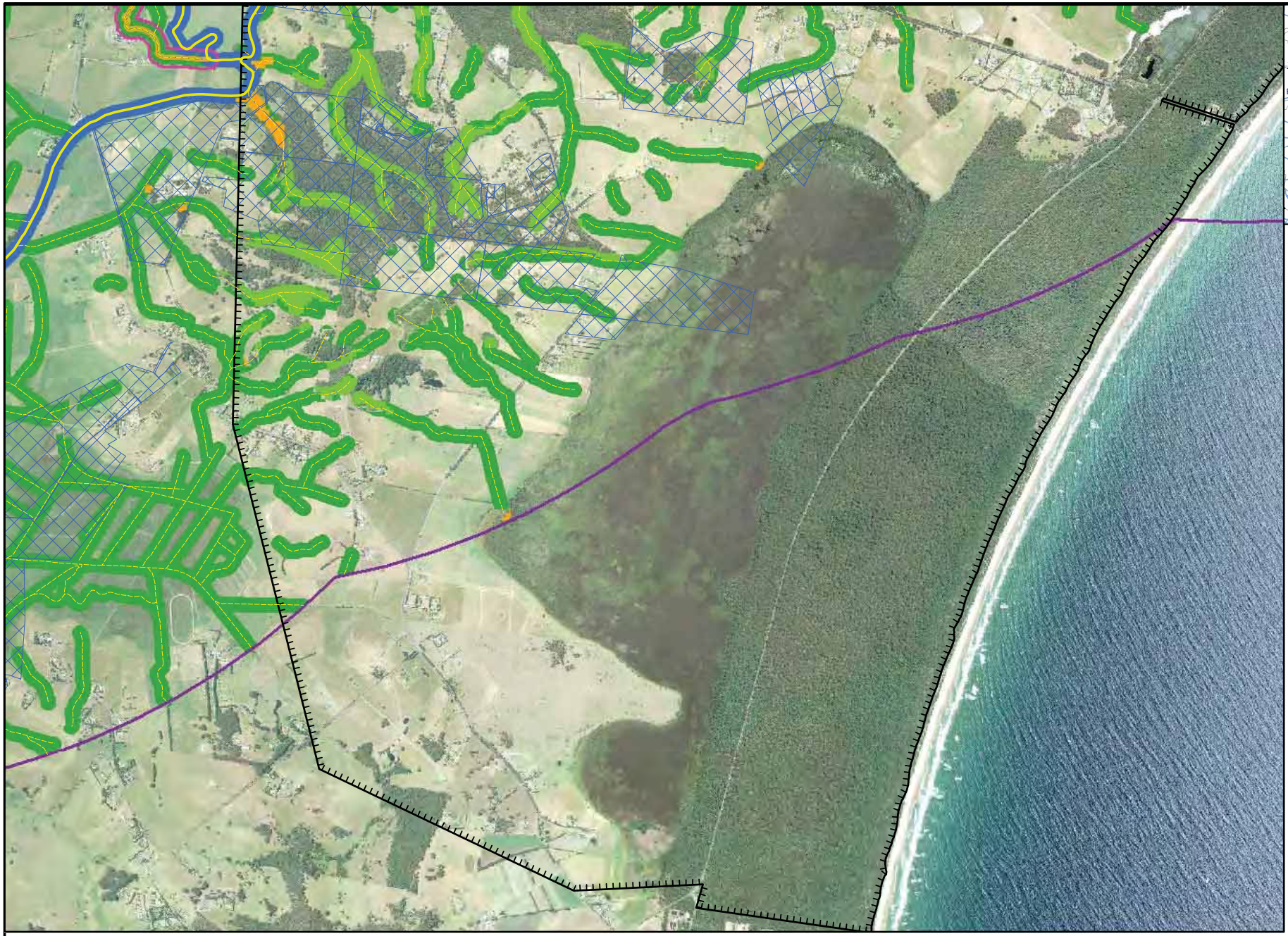

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Figure C.7: Offset Strategy Model

Date: 24 October 2012	Drawn by: RS/JMS
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Figure 3

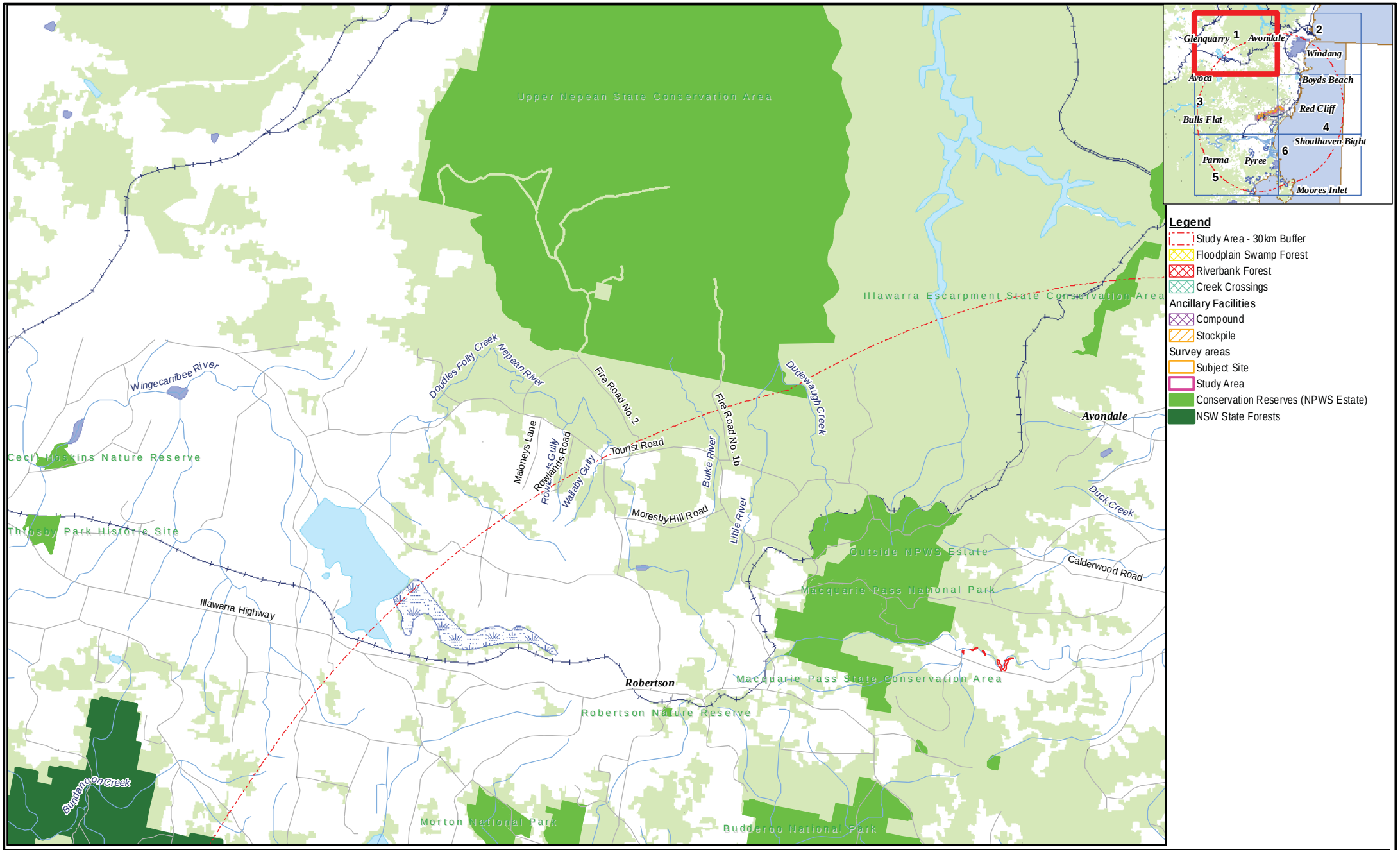

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Figure D.1: Riparian and Floodplain Vegetation within 30 km of the Study Area

Date: 14 August 2012	Drawn by: RS/JMS
File: 15039	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Offset Figures\15039_OS_FB_30kmVeg_20120814.mxd	

Acknowledgements:
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Scale: 1:100,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 55

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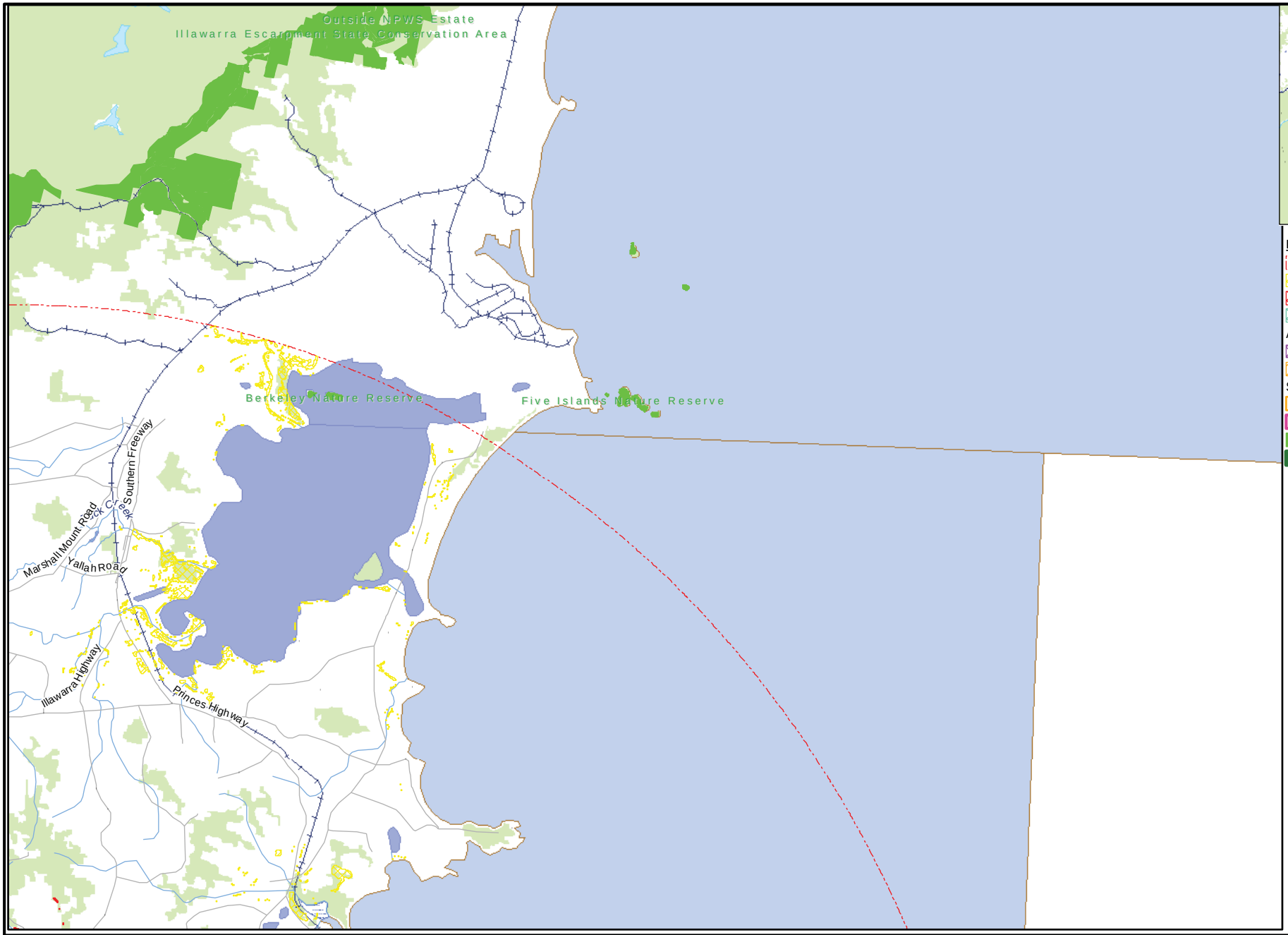
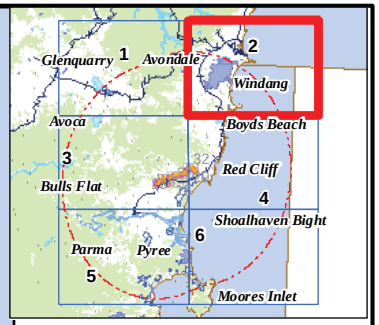
Figure B





Legend

- Study Area - 30km Buffer
- Floodplain Swamp Forest
- Riverbank Forest
- Creek Crossings

Ancillary Facilities

- Compound
- Stockpile

Survey areas

- Subject Site
- Study Area
- Conservation Reserves (NPWS Estate)
- NSW State Forests

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Figure D.2: Riparian and Floodplain Vegetation within 30 km of the Study Area

Date: 14 August 2012	Drawn by: RS/JMS
File: 15039	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Offset Figures\15039_OS_FB_30kmVeg_20120814.mxd	

Acknowledgements:
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Metres

Scale: 1:100,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 55

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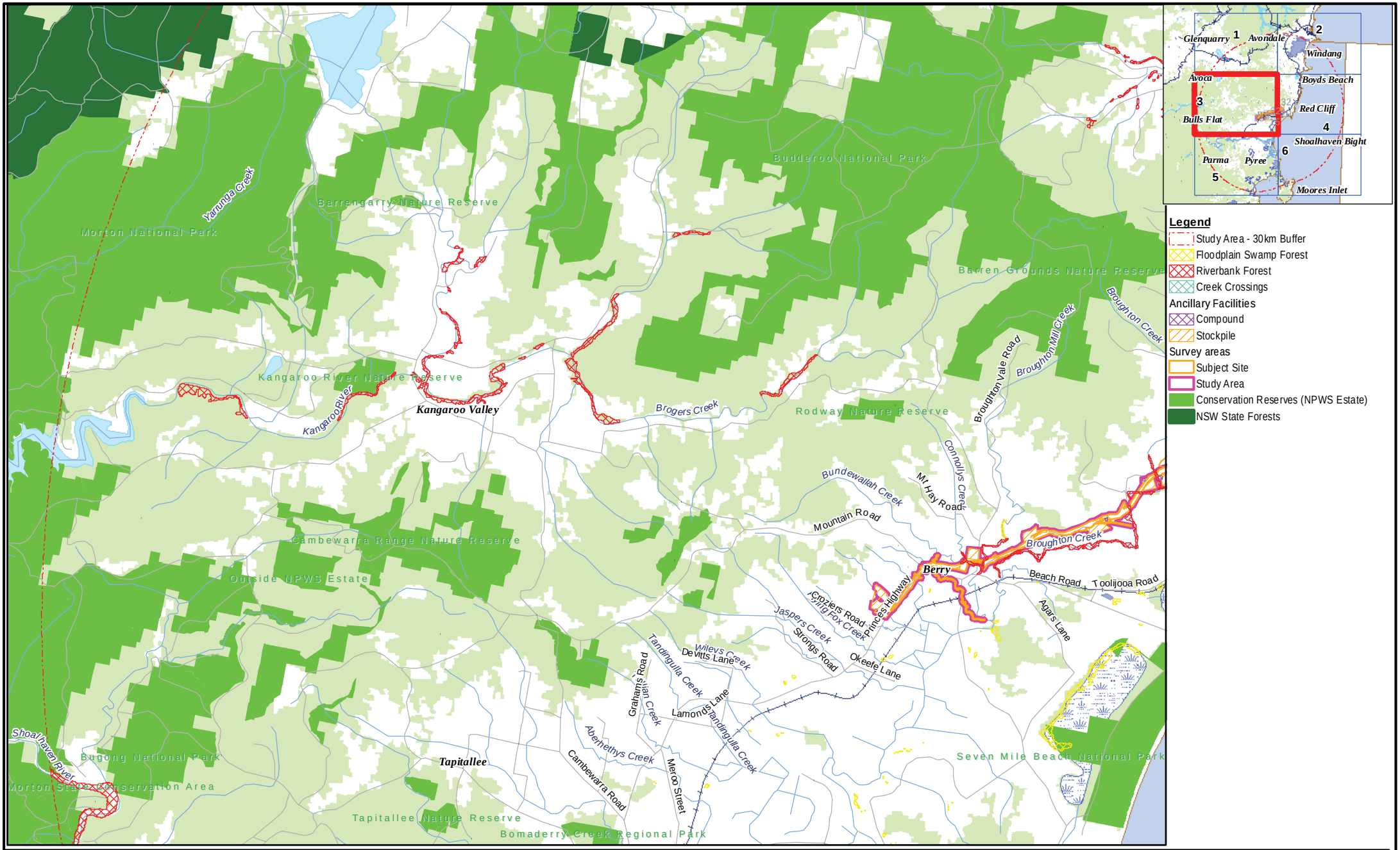

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Figure D.3: Riparian and Floodplain Vegetation within 30 km of the Study Area

Date: 14 August 2012	Drawn by: RS/JMS
File: 15039	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Offset Figures\15039_OS_FB_30kmVeg_20120814.mxd	

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Metres

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Map Projection: Transverse Mercator
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Grid: Map Grid of Australia, Zone 55

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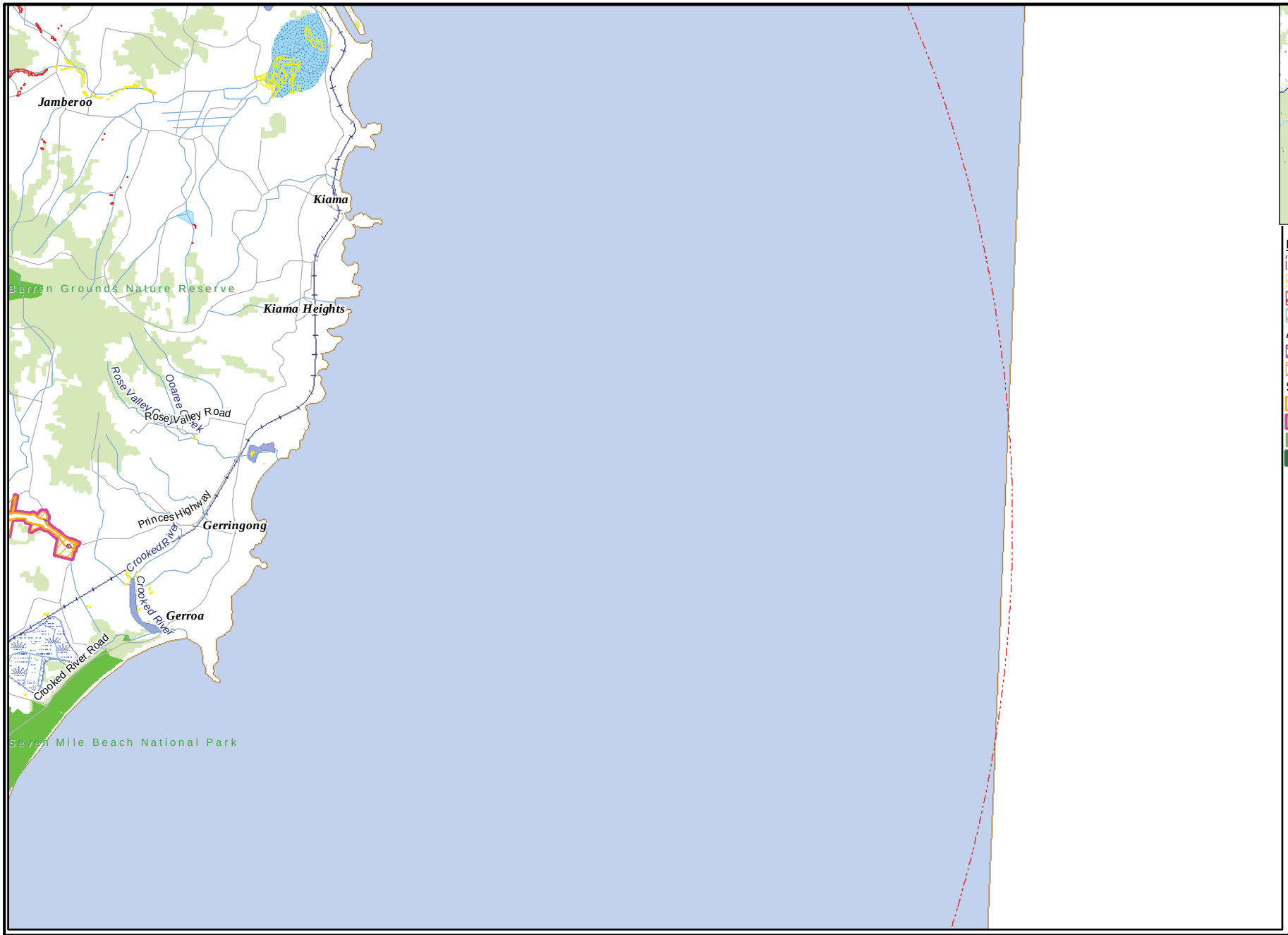

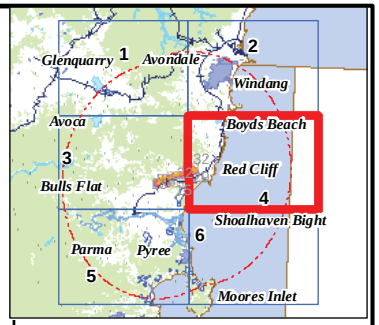

Legend

- Study Area - 30km Buffer
- Floodplain Swamp Forest
- Riverbank Forest
- Creek Crossings

Ancillary Facilities

- Compound
- Stockpile

Survey areas

- Subject Site
- Study Area
- Conservation Reserves (NPWS Estate)
- NSW State Forests

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Figure D.4: Riparian and Floodplain Vegetation within 30 km of the Study Area

Date: 14 August 2012	Drawn by: RS/JMS
File: 15039	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Offset Figures\15039_OS_FB_30kmVeg_20120814.mxd	

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Metres

Scale: 1:100,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 55

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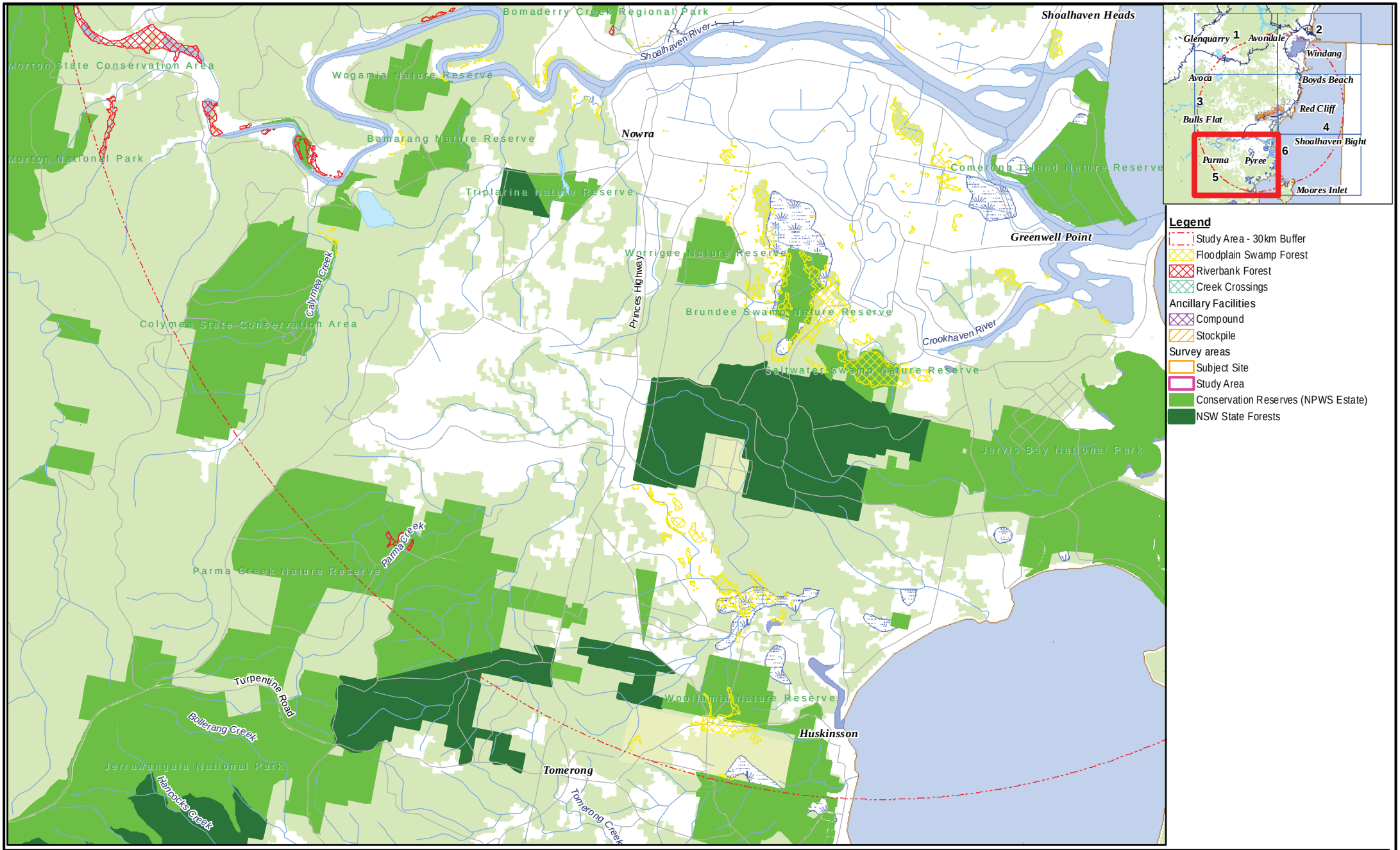

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Figure D.5: Riparian and Floodplain Vegetation within 30 km of the Study Area

Date: 14 August 2012	Drawn by: RS/JMS
File: 15039	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Offset Figures\15039_OS_FB_30kmVeg_20120814.mxd	

Acknowledgements:
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Map Projection: Transverse Mercator
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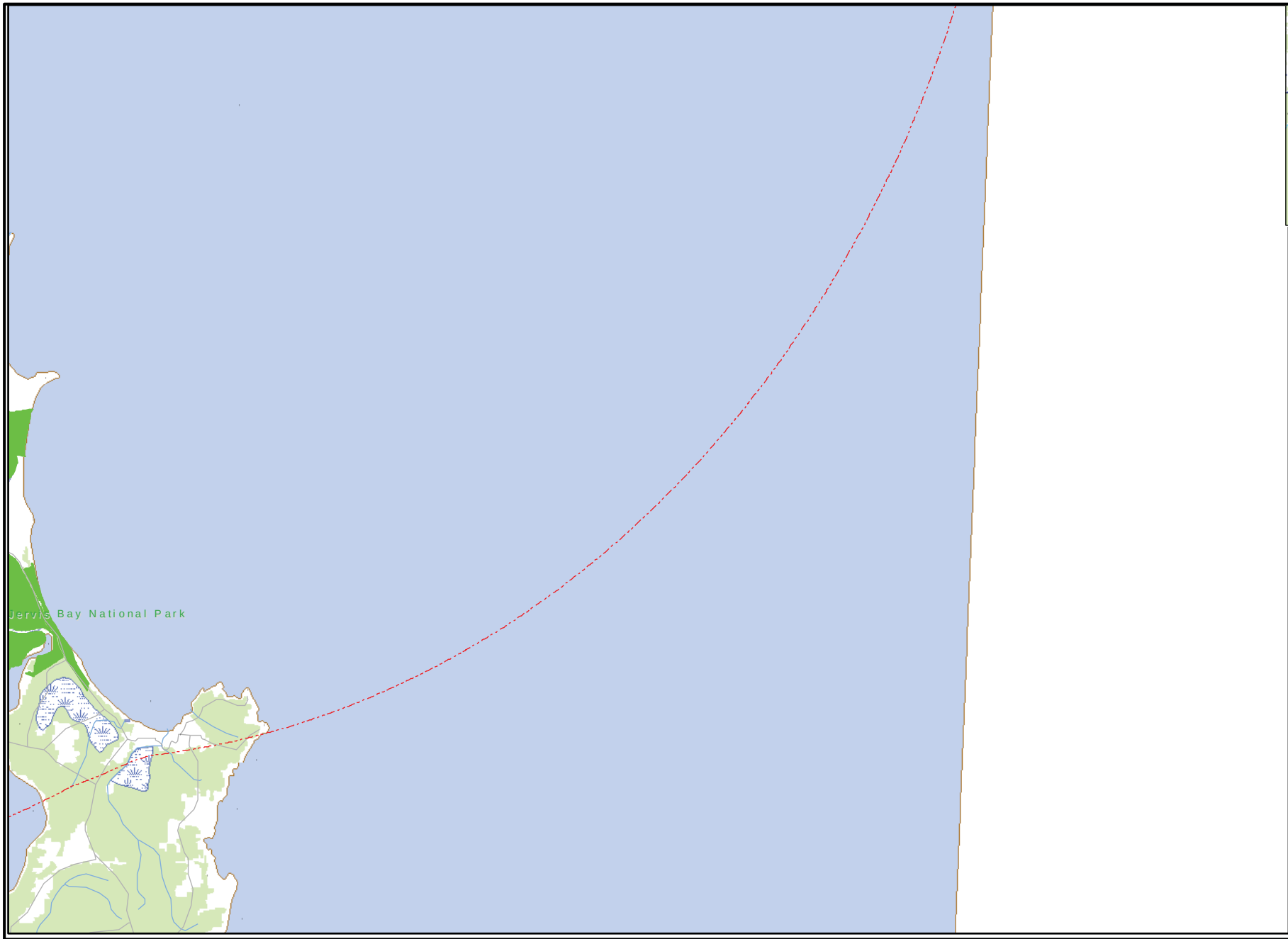

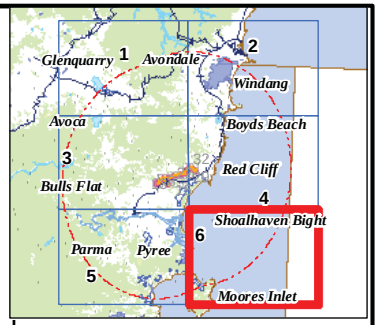

Legend

- Study Area - 30km Buffer
- Floodplain Swamp Forest
- Riverbank Forest
- Creek Crossings

Ancillary Facilities

- Compound
- Stockpile

Survey areas

- Subject Site
- Study Area
- Conservation Reserves (NPWS Estate)
- NSW State Forests

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Figure D.6: Riparian and Floodplain Vegetation within 30 km of the Study Area

Date: 14 August 2012	Drawn by: RS/JMS
File: 15039	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Offset Figures\15039_OS_FB_30kmVeg_20120814.mxd	

Acknowledgements:
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Metres

Scale: 1:100,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 55

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Figure B

Appendix F

OEH general biodiversity offset principles

OEH General biodiversity offset principles

The following principles suggested by OEH (2011) provide a framework for considering environmental impacts and developing offset proposals.

1 *Impacts must be avoided first by using prevention and mitigation measures.*

Offsets are then used to address remaining impacts. This may include modifying the proposal to avoid an area of biodiversity value or putting in place measures to prevent offsite impacts.

2 *All regulatory requirements must be met.*

Offsets cannot be used to satisfy approvals or assessments under other legislation, eg assessment requirements for Aboriginal heritage sites, pollution or other environmental impacts (unless specifically provided for by legislation or additional approvals).

3 *Offsets must never reward ongoing poor performance.*

Offset schemes should not encourage landholders to deliberately degrade or mismanage offset areas in order to increase the value from the offset.

4 *Offsets will complement other government programs.*

A range of tools is required to achieve the NSW Government's conservation objectives, including the establishment and management of new national parks, nature reserves, state conservation areas and regional parks and incentives for private landholders.

5 Offsets must be underpinned by sound ecological principles such as:

- The consideration of structure, function and compositional elements of biodiversity, including threatened species.
- Enhance biodiversity at a range of scales.
- Consider the conservation status of ecological communities.
- Ensure the long-term viability and functionality of biodiversity.

Biodiversity management actions, such as enhancement of existing habitat and securing and managing land of conservation value for biodiversity, can be suitable offsets. Reconstruction of ecological communities involves high risks and uncertainties for biodiversity outcomes and is generally less preferable than other management strategies, such as enhancing existing habitat.

6 *Offsets should aim to result in a net improvement in biodiversity over time.*

Enhancement of biodiversity in offset areas should be equal to or greater than the loss in biodiversity from the impact site. Setting aside areas for biodiversity conservation without additional management or increased security is generally not sufficient to offset against the loss of biodiversity. Factors to consider include protection of existing biodiversity (removal of threats), time-lag effects, and the uncertainties and risks associated with actions such as revegetation. Offsets may include enhancing habitat, reconstructing habitat in strategic areas to link areas of conservation value, or increasing buffer zones around areas of conservation value and removal of threats by conservation agreements or reservation.

7 *Offsets must be enduring - they must offset the impact of the development for the period that the impact occurs.*

As impacts on biodiversity are likely to be permanent, the offset should also be permanent and secured by a conservation agreement or reservation and management for biodiversity. Where land is donated to a public authority or a private conservation organisation and managed as a biodiversity offset, it should be accompanied by resources for its management. Offsetting should only proceed if an appropriate legal mechanism or instrument is used to secure the required actions.

8 *Offsets should be agreed prior to the impact occurring.*

Offsets should minimise ecological risks from time-lags. The feasibility and in-principle agreements to the necessary offset actions should be demonstrated prior to the approval of the impact. Legal commitments to the offset actions should be entered into prior to the commencement of works under approval.

9 *Offsets must be quantifiable - the impacts and benefits must be reliably estimated.*

Offsets should be based on quantitative assessment of the loss in biodiversity from the clearing or other development and the gain in biodiversity from the offset. The methodology must be based on the best available science, be reliable and used for calculating both the loss from the development and the gain from the offset. The methodology should include:

- The area of impact.
- The types of ecological communities and habitat/species affected.
- Connectivity with other areas of habitat/corridors.
- The condition of habitat.
- The conservation status and/or scarcity/rarity of ecological communities.
- Management actions.
- Level of security afforded to the offset site.

The best available information/data should be used when assessing impacts of biodiversity loss and gains from offsets. Offsets will be of greater value where:

- They protect land with high conservation significance.
- Management actions have greater benefits for biodiversity.
- The offset areas are not isolated or fragmented.
- The management for biodiversity is in perpetuity (e.g. secured through a conservation agreement).

Management actions must be deliverable and enforceable.

10 *Offsets must be targeted.*

They must offset impacts on the basis of like-for-like or better conservation outcome. Offsets should be targeted according to biodiversity priorities in the area, based on the conservation status of the ecological community, the presence of threatened species or their habitat, connectivity and the potential to enhance condition by management actions and the removal of threats. Only ecological communities that are equal or greater in conservation status to the type of ecological community lost can be used for offsets. One type of environmental benefit cannot be traded for another: for example, biodiversity offsets may also result in improvements in water quality or salinity but these benefits do not reduce the biodiversity offset requirements.

11 *Offsets must be located appropriately.*

Wherever possible, offsets should be located in areas that have the same or similar ecological characteristics as the area affected by the development.

12 *Offsets must be supplementary.*

They must be beyond existing requirements and not already funded under another scheme. Areas that have received incentive funds cannot be used for offsets. Existing protected areas on private land cannot be used for offsets unless additional security or management actions are implemented. Areas already managed by the government, such as national parks, flora reserves and public open space cannot be used as offsets.

13 *Offsets and their actions must be enforceable through development consent conditions, licence conditions, conservation agreements or a contract.*

Offsets must be audited to ensure that the actions have been carried out, and monitored to determine that the actions are leading to positive biodiversity outcomes.

Appendix G

EP&A Act Part 3A assessments of significance

EP&A Act Part 3A Assessments of Significance

Endangered ecological communities

River-flat eucalypt forest on coastal floodplain of the NSW North Coast, Sydney Basin and south east corner bioregions

River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and south east corner bioregions (RFEF) is listed as an Endangered Ecological Community in Part 3 of Schedule 1 of the TSC Act. It is equivalent to Riverbank forest which was identified along the riparian corridors of freshwater creeks including Broughton Creek (sites 17, 28 and 29).

Vegetation mapping by Shoalhaven City Council (Shoalhaven City Council, 2004), and discussions with one of the authors (M. Tozer, pers. comm. 2007) support Riverbank forest occurring within the locality. This differs from DEC 2005t mapping, which did not map Riverbank forest within the study area and has incorrectly mapped this community as Floodplain swamp forest.

The Riverbank forest in the study area was characterised by a tall native canopy of *Casuarina cunninghamiana* and an understorey completely dominated by a high density weed infestation. Natural structural layers were no longer intact and in most areas the mid storey and ground layers were completely dominated by weed species including *Ligustrum sinense, Lantana camara, Solanum mauritianum, Ageratina riparia* and *Tradescantia fluminescens*. These weed-infested areas were considered to have little capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation. Obvious disturbances to the Riverbank forest included heavy grazing and erosion.

About 65.7 hectares of Riverbank forest occurs in the locality. About 2.9 hectares would be directly impacted (2.6 ha by the roadway, 0.2 ha by temporary creek crossings and 0.1 ha by Town Creek diversion) and 7.1 hectares may be indirectly impacted (**Figure 3.1** and Appendix J).

Areas where RFEF will be impacted by either direct removal or edge effects for the construction and operation of the project including the permanent roadway, drainage diversion and temporary creek crossings are at:

- Bundewallah Creek north of Rawlings Lane (**Figure 3.1.4**, Appendix J).
- The junction of Bundewallah Creek and Connollys Creek and downstream to Broughton Mill Creek (**Figure 3.1.7**, Appendix J).
- Broughton Creek to the east of Berry on the southern side of the Princes Highway (**Figure 3.1.8**, Appendix J).
- Broughton Creek to the southeast and east of the intersection of Tomlins Road and Princes Highway, at Broughton (**Figure 3.1.12**, Appendix J).
- Broughton Creek to the east of the intersection of Thompson Road and Princes Highway, at Broughton (**Figure 3.1.13**, Appendix J).

How is the project likely to affect the lifecycle of a threatened species and/or population?

N/A – RFEF is an endangered ecological community.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

Based on the vegetation mapping (adapted from DEC 2005t), about 65.7 hectares of RFEF exists within the locality (five kilometre radius of the study area). The project would directly impact about 2.9 hectares of RFEF in the subject site, which equates to 4.41 per cent of this community in the locality. A further 7.1 hectares (10.81 per cent) of RFEF in the locality may be indirectly impacted by the project. Cumulatively up to 10 hectares, equating to 15.2 per cent of RFEF in the locality will be permanently affected by the project.

The main impact the of the project on RFEF habitat would be the reduction in width and the removal of the canopy of *Casuarina cunninghamiana* from the areas of RFEF within the subject site, and the subsequent alteration of plant community structure in the remaining areas beneath the proposed bridges.

Given the existing weed dominance in the understorey of the riparian vegetation, the project is unlikely to significantly alter the composition of the RFEF in the study area by introducing or increasing the spread of weeds. There may be some positive impacts from weed reduction and bush regeneration strategies in these areas as part of mitigation measures (Chapter 5).

The RFEF in the study area is currently grazed and highly altered by weed invasion, so further indirect impacts from edge effects are likely to be minimal.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

N/A – RFEF is an endangered ecological community.

How is the project likely to affect current disturbance regimes?

Current disturbance regimes affecting RFEF in the study area are largely related to grazing and weed invasion. Natural disturbance regimes such as fire are no longer likely to influence the extent or functioning of this community within the study area.

The understorey of RFEF within the study area is dominated by invasive weed species, with very few native species remaining. The project would remove habitat in the study area and remove grazing pressures from any potential habitat that remains. The project may have some positive effects on the RFEF in the study area through mitigation measures to reduce the existing weed infestation (Chapter 5).

The natural flow regimes of the creeks that cross the study area have been historically altered by clearing and flood mitigation works and there are currently bridges over Broughton and Bundewallah creeks. It is considered unlikely that the bridging of the creeks as part of the project would further alter these flow regimes, provided that there are sufficient setbacks from the creeks.

How is the project likely to affect habitat connectivity?

The RFEF in the study area occurs along Broughton, Broughton Mill, Connollys and Bundewallah creeks. The current condition of the riparian vegetation is highly degraded, and already impacted by fragmentation and edge effects. The project would result in some further fragmentation of the vegetation community to occur at Bundewallah creek, and at three points on Broughton Creek. Edge effects are likely to occur to a small proportion of the EEC.

Given the existing weed dominance in the understorey of the RFEF, the project is unlikely to significantly affect the movement of characteristic native flora species through this community. If native ground layer species did persist in the understorey then dispersal may be facilitated in the areas of vegetation beneath the proposed bridges (Chapter 5). The main impact of the project on habitat connectivity would be the reduction in width and the removal of the canopy of *Casuarina cunninghamiana* from the areas of RFEF within the subject site and the subsequent alteration of plant community structure in these areas.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General of Department of Environment and Climate Change maintains a Register of Critical Habitat. To date, no critical habitat has been declared for RFEF.

Conclusion

Up to 10 hectares, equating to 15.2 per cent, of this EEC within the locality will be either permanently removed or indirectly affected by the project. Mitigation measures including revegetation and rehabilitation (Chapter 5) will be undertaken to maintain or improve connectivity of RFEF. However, residual impacts (ie the permanent loss of EEC) will result from the project. An Offset Strategy (Appendix E) has been prepared to inform the development of an offset package to compensate for the loss of this EEC. The project is unlikely to result in a significant impact on RFEF in the locality provided the mitigation measures outlined in Chapter 5, and an adequate offset package, are implemented.

Illawarra lowlands grassy woodland in the Sydney Basin Bioregion

Illawarra lowlands grassy woodland in the Sydney basin bioregion (ILGW) is listed as an EEC in Part 3 of Schedule 1 of the TSC Act. This EEC is recorded in the Wollongong, Shellharbour and Kiama LGAs and occurs on relatively gently sloping to undulating lands less than about 200 metres elevation on Berry Siltstone, Budgong Sandstone and Quaternary alluvium. Eucalyptus species dominate the canopy stratum and the species composition of any stand is influenced by the size of the site and by recent disturbance history (NSW Scientific Committee 2008a).

As identified in **Table 3.1** South Coast grassy woodland (SCGW) and South Coast lowland swamp woodland (SCLSW) described by Tozer *et al* (2010) and mapped by (DEC 2005o) correspond to ILGW on the Illawarra Plain. SCGW occurs in the area from Wollongong to Milton and west to Yalwal. An extant area of 3100 hectares of SCGW, including about 180 hectares in conservation reserves, has been estimated by Tozer *et al* (2010). SCLSW is found in coastal valleys and floodplains, most extensively around Lake Illawarra and in the Moruya – Congo area, but with sporadic occurrences between including small areas near Worrigee, Kioloa and Nelligen. Tozer *et al* (2010) have estimated an extant area of 1100 hectares of SCLSW that includes 90 hectares in conservation reserves.

As a result of clearing for agriculture and other development, most ILGW remnants are small and fragmented with some remnants characterised by regrowth following clearing or other disturbances. Threats to ILGW include further clearing, grazing, weed invasion, selective logging, rubbish dumping, housing and hobby farm developments and physical damage from recreational activities (NSW Scientific Committee 2008a2).

A total of 47.6 hectares of ILGW is mapped in the locality by DEC (2005o). There is no ILGW mapped by DEC (2005o) in the study area or subject site. Field surveys have not identified ILGW on the subject site or in the study area. The nearest stands of the community mapped by DEC (2005o) are to the south of the project area in the vicinity of Harley Hill (**Figure 3.1** and Appendix J).

How is the project likely to affect the lifecycle of a threatened species and/or population?

N/A – ILGW is an endangered ecological community.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

ILGW does not occur in the subject site or study area. The project is unlikely to impact on the nearest mapped stands of ILGW in the locality. Habitat for ILGW has been identified as relatively gently sloping to undulating lands less than about 200 metres elevation on Berry Siltstone, Budgong Sandstone and Quaternary alluvium (NSW Scientific Committee 2008a). Additionally Tozer *et al* (2010) have described SCGW as being found on lower slopes in coastal rainshadow valleys below 350 metres ASL, with SCLSW occurring in coastal valleys and floodplains restricted to flats below 100 metres ASL with partially impeded drainage. Both forms of ILGW have been depleted throughout their range by land clearing and are subject to continuing impacts such as grazing and weed invasion. Habitat for the community in the locality and region has been significantly altered and the project will not affect any area of significant habitat for ILGW.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

N/A

How is the project likely to affect current disturbance regimes?

ILGW has been subject to clearing for agriculture and other development such as recreational facilities, resulting in fragmentation, grazing, weed invasion and soil compaction (NSW Scientific Committee 2008a). The project will result in clearing of native vegetation but will not affect current disturbance regimes that may threaten remnant or regrowth ILGW or its potential habitat occurring in the locality.

How is the project likely to affect habitat connectivity?

The are several stands of vegetation mapped by DEC (2005o) to the south of the project area in the vicinity of Harley Hill (Figure 3.1 and Appendix J). The majority of the stands of ILGW occur on the edges of larger patches of native vegetation that have a moderate level of connectivity. None of these larger stands of native vegetation will be impacted by the project and habitat connectivity for the mapped stands of ILGW in the locality will be maintained.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General of Department of Environment and Climate Change (now OEH) maintains a Register of Critical Habitat. To date, no critical habitat has been declared for ILGW.

Conclusion

There will not be an impact on ILGW in the locality as a result of the project as:

- ILGW is not recorded on or adjoining the study area in previous vegetation mapping or the site inspections.
- Habitat for mapped stands of ILGW in the locality will not be impacted.
- Areas of potential habitat for ILGW within or adjoining the study area have been subject to significant impacts such as vegetation clearing with these areas currently impacted by agriculture and severe weed infestation.

Illawarra subtropical rainforest in the Sydney Basin Bioregion

Illawarra subtropical rainforest in the Sydney basin bioregion (ISR) is listed as an EEC in Part 3 of Schedule 1 of the TSC Act. This EEC is recorded in the Wollongong, Shellharbour, Shoalhaven and Kiama LGA's and may occur elsewhere within the Sydney Basin Bioregion. The main occurrences of ISR are between Albion Park and Gerringong and north of Lake Illawarra on the Berkeley Hills. Outlying occurrences of ISR are known further south on the Shoalhaven River and westwards into Kangaroo Valley, where areas of Permian volcanic soils occur. The community generally occurs on the coastal plain and escarpment foothills, rarely extending onto the upper escarpment slopes (NSW Scientific Committee 2002).

Large areas of this EEC have been cleared for agriculture and the NSW Scientific Committee (2002) has determined that about 3400 hectares of the community remains, mainly on private land, with about 13 per cent of this (440 hectares) in reserved areas.

The vegetation survey and mapping by Tozer *et al* (2010) state that parts of Subtropical Dry Rainforest (SDR) and the closely related Subtropical Complex Rainforest (SCR) are considered to form ISR. As identified in **Table 3.1** of the main report, there is a total of 914.5 hectares of ISR mapped in the locality. Field surveys have not identified ISR on the subject site or in the study area. As discussed in Section 3.2.2 of the main report, ISR was recorded in the field surveys of the current investigation in the eastern area of the locality and is consistent with the DEC (2005o) vegetation mapping of **Figure 3.1** (and in Appendix J).

How is the project likely to affect the lifecycle of a threatened species and/or population?

N/A – ISR is an endangered ecological community.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

ISR does not occur in the subject site or study area. The project is unlikely to impact on the nearest mapped stands of ISR in the locality. Broad habitat for ISR has been identified by the NSW Scientific Committee (2002) as including the coastal plain and escarpment foothills, rarely extending onto the upper escarpment slopes on, but not limited to, coastal Permian volcanic soils.

The condition of the broader area of potential habitat for ISR in the locality is a reflection of the land use history of the region which is characterised by extensive clearing of the coastal plain and foothills for agriculture. The NSW Scientific Committee (2002) identified continuing impacts such as grazing and weed invasion as key threats to this EEC. Habitat for the community in the locality and region has been significantly altered and the project will not affect any area of significant habitat for ISR.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

N/A

How is the project likely to affect current disturbance regimes?

ISR has been subject to clearing for agriculture resulting in fragmentation, grazing and weed invasion. In addition to these long term impacts continuing threats to the viability of this EEC include further clearing, quarrying, inappropriate fire regimes, rubbish dumping and hobby farm developments (NSW Scientific Committee 2002).

The project will result in clearing of native vegetation. However this will not affect current disturbance regimes that may threaten remnant or regrowth ISR or its potential habitat occurring in the locality.

How is the project likely to affect habitat connectivity?

ISR generally occurs as lineal stands in larger patches of native vegetation mapped by DEC (2005o) on the low hills to the southeast and foothills extending to the Illawarra escarpment the north of the project area (**Figure 3.1** of the main report). These larger stands of native vegetation have a moderate level of connectivity within the locality. The project will affect a fragmented corridor of native vegetation including mapped areas of ISR at the eastern end of the upgrade. However at a locality scale the amount of native vegetation and habitat for ISR that will be affected will not be significant and habitat connectivity for the mapped stands of ISR in the locality will be maintained at its current moderate level.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General of Department of Environment, Climate Change and Water (now OEH) maintains a Register of Critical Habitat. To date, no critical habitat has been declared for ISR.

Conclusion

There will not be an impact on ISR of the locality as a result of the project as:

- ISR is not recorded in the study area in previous vegetation mapping or the site inspections.
- Habitat for mapped stands of ISR in the locality will not be impacted and current levels of habitat connectivity will be maintained.
- Areas of potential habitat for ISR within or adjoining the study area have been subject to significant impacts such as vegetation clearing with these areas currently impacted by agriculture and severe weed infestation.

Endangered and Vulnerable Flora

Cynanchum elegans White-flowered Wax Plant

Cynanchum elegans is listed as Endangered under the TSC Act.

Cynanchum elegans is a climber or twiner with a highly variable form and white tubular flowers (DEC 2005Š). Mature stems have a fissured corky bark and can grow to 10 metres long and 3.5 centimetres thick (DEC 2005Š). The leaves are paired (or rarely in threes), ovate to broadly ovate in shape (DEC 2005Š). The species is known to occur on the edge of dry rainforest vegetation (DEC 2005Š).

Cynanchum elegans was not recorded in the study area; the closest record of this species is about 3.5 kilometres to the north-east (DECCW 2011). However, potential habitat does exist within the study area in warm temperate layered forest. Potential habitat for *Cynanchum elegans* is considered to include coastal warm temperate rainforest, intermediate temperate rainforest, subtropical complex rainforest and subtropical dry rainforest. These vegetation communities occur as scattered patches throughout the locality.

About 6.9 hectares of potential habitat for *Cynanchum elegans* would be directly impacted as part of the project with further potential indirect impacts to an additional 5.3 hectares.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The following is known about the lifecycle of *Cynanchum elegans* (DEC 2005Š):

- Flowering occurs between August and May, with a peak in November. Flower abundance on individual plants varies from sparse to prolific.
- The fruit can take up to six months to mature.
- Seed production is variable and unreliable. Seeds are wind dispersed and released in a non-dormant state, hence are unlikely to persist in the soil seedbank.
- Plants are capable of suckering from rootstock in response to occasional slashing or grazing. The fire response of the species is unknown.

The following disturbances are thought to impact on the lifecycle of *Cynanchum elegans* (NPWS 2002):

- Loss of individuals – the project is not likely to result in the loss of any individuals of Cynanchum elegans.
- Fragmentation of habitat – the habitat for the species in the study area is already fragmented by cleared and disturbed land. The project impacts upon existing edges of potential habitat and would not increase fragmentation of potential habitat for the species.
- Modification of habitat – the potential habitat for Cynanchum elegans in the study area is already modified due to the ongoing impacts from edge effects (eg weeds) and disturbances such as grazing. The project may result in an increase in the intensity of some existing impacts.
- Damage to the soil seed bank – seeds of this species are wind dispersed and released in a non-dormant state, hence are unlikely to persist in the soil seedbank.
- Altered fire regime – the project is not likely to alter the fire regime of the local area.

Cynanchum elegans was not recorded in the study area, however the species has previously been recorded about 3.5 kilometres to the north-east of the study area. Potential habitat for the species occurs in the warm temperate layered forest in the study area. As no individuals have been recorded in the study area, it is unlikely that the project would have an adverse effect on the lifecycle of the species such that a viable population of the species would be placed at risk of extinction.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The species has not been recorded in the study area, however, potential habitat for the species occurs within warm temperate layered forest in the study area with further potential habitat in the locality occurring within coastal warm temperate rainforest, intermediate temperate rainforest, subtropical complex rainforest and subtropical dry rainforest. Vegetation mapping DEC (2005o) indicates about 2324.7 hectares of these potential habitats occur within the locality (five kilometre radius of the study area).

The potential habitat for this species within the study area is in moderate to poor condition, due to the dominance of exotic species in the understorey, altered community structure and existing fragmentation.

About 6.9 hectares of potential habitat for *Cynanchum elegans* would be directly impacted by the project. The area of potential habitat for *Cynanchum elegans* that would be removed as part of the project equates to 0.30 per cent of the extent of these plant communities in the locality.

Potential habitat for *Cynanchum elegans* that would be disturbed as part of the project occurs in the warm temperate layered forest in the north-east of the subject site. The areas to be cleared are at the edges of currently fragmented patches that were sampled as part of site 20. This vegetation was considered to be in poor condition along edges where large infestations of the noxious weed *Lantana camara* are present and have displaced most native species. These edges are likely to have little or no capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation.

The project would widen the existing cleared land, thus increase fragmentation. However it is unlikely to result in the isolation of areas of potential habitat for this species.

Given that the species has not been recorded in the study area and the relatively small area of potential habitat directly impacted compared with that in the locality, potential habitat in the study area is not considered to be vital for the long-term survival of the species in the locality.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

The study area is about 3.5 kilometres south-west of the southern most record of *Cynanchum elegans* (DECCW 2009a). Given the large areas of potential habitat to the west of this record and the existing clearing, disturbance and fragmentation of potential habitat in and adjoining the study area, it is considered unlikely that the project would further limit any range extension of this species.

How is the project likely to affect current disturbance regimes?

The current disturbance regime in the warm temperate layered forest in the study area consists of fragmentation of patches by clearing, grazing disturbance and large infestations of the noxious weed *Lantana camara* along edges.

Given the small size, fragmentation and poor condition of vegetation that would be impacted, the project is not likely to increase the impact of weed invasion in the study area. However, mitigation measures are recommended to reduce the existing weed infestation and the likelihood of increased weed invasion in the impacted patches (Chapter 5).

How is the project likely to affect habitat connectivity?

There is currently limited connectivity in the potential habitat for *Cynanchum elegans* in the study area; although the patches of warm temperate layered forest are relatively close, the vegetation was considered to be in poor condition along edges where large infestations of the noxious weed *Lantana camara* are present and have displaced most native species. The areas to be cleared for the project are at the edges of these currently fragmented patches.

The project would increase the distance between the patches of potential habitat for *Cynanchum elegans* in the study area. However, it is likely that the edges of these patches do not currently form habitat for *Cynanchum elegans* due to large infestations of *Lantana camara.*

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a Register of Critical Habitat. To date, no critical habitat has been declared for *Cynanchum elegans.*

Conclusion

The nearest known record of *Cynanchum elegans* occurs about 3.5 kilometres north-east of the study area; this record is at the southern limit of the known distribution of this species. *Cynanchum elegans* was not recorded during the field surveys for this assessment. Potential habitat for this species that would be removed by the project represents a relatively small area that is already subject to existing edge effects and disturbances. For these reasons it is considered unlikely that the project would have a significant impact on this species.

Daphnandra sp. C 'Illawarra' Illawarra Socketwood

Daphnandra sp. 'Illawarra' is listed as Endangered on the TSC Act.

Daphnandra sp. 'Illawarra' is a rainforest tree growing to 20 metres tall, with coarsely toothed opposite leaves and small, pale, greenish white flowers (DEC 2005j). This species is known to occupy the rocky hillsides and gullies of the Illawarra lowlands, occasionally extending onto the upper escarpment slopes and is associated with rainforest and moist eucalypt forest (DEC 2005j).

Daphnandra sp. 'Illawarra' was not recorded in the study area; however this species was recorded in the locality during broader surveys, about 600 metres to the south of the study area around Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest about 130 metres to the south of the study area and 400 metres to the north of the study area.

Potential habitat does exist within the study area in Illawarra gully wet forest and warm temperate layered forest communities. Potential habitat exists in the locality in the following vegetation communities: Buderoo temperate rainforest, coastal warm temperate rainforest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, warm temperate layered forest, subtropical dry rainforest, and Yarrawarra temperate rainforest. These plant communities occur as scattered patches throughout the locality covering about 3011.8 hectares.

The project would have direct impacts on about 22.3 hectares of potential habitat for *Daphnandra* sp. 'Illawarra' in the subject site with potential indirect impacts to a further 15.4 hectares in the study area.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The following is known about the lifecycle of *Daphnandra* sp. 'Illawarra' (DEC 2005j):

- Flowers briefly in September and early October with fruits taking 10 to 12 months to mature.
- Capable of vegetative reproduction from stems (coppicing) and rhizomes (suckering).
- Low levels of seed production are suspected, with stems at most sites appearing to only produce 'pseudo-fruit' which lack seeds. Seed production has been reported from just two sites, only one of which has been confirmed to produce viable seed, and the extent to which this seed is capable of surviving in the wild is unknown.
- The species is possibly killed by fire.
- The pollination mechanisms of *Daphnandra* sp. C 'Illawarra' are unknown, as is the potential role that pollen vectors may play in the transfer of genetic material within and between sites.
- The predominant means of reproduction appears to be asexual (DEC2005i).

Daphnandra sp. C 'Illawarra' was not recorded in the study area; however this species was recorded in the locality during broader surveys, about 600 metres to the south of the study area around Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest about 130 metres to the south of the study area and 400 metres to the north of the study area. Potential habitat for the species does, however, exist within warm temperate layered forest and Illawarra gully wet forest within the study area, and the rainforest and wet forest plant communities in the locality.

Given the clonal nature of *Daphnandra* sp. C 'Illawarra', it is unlikely that the project would interrupt the lifecycle of this species.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

Potential habitat *Daphnandra* sp. 'Illawarra' in the study area may occur within the Illawarra gully wet forest, and warm temperate layered forest communities, with further potential habitat in the rainforest and wet forest plant communities in the locality. Vegetation mapping by DEC (2005o) indicates about 3011.8 hectares of these potential habitats occur within the locality.

The project would directly impact about 22.3 hectares of potential habitat for *Daphnandra* sp. 'Illawarra' with potential indirect impacts to a further 15.4 hectares. These impacts would include clearing of native vegetation. The area of potential habitat that would be removed as part of the project equates to about 0.74 per cent of the extent of potential habitat for the species in the locality. This is not considered to be a significant proportion of habitat.

Given the potential habitat for this species within the study area is highly disturbed with exotic pasture and weeds, the project is considered unlikely to introduce further weed propagules to any remaining areas of habitat.

The project is not likely to have a significant effect on the habitat of the species in the locality.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

The study area is at the southern limit of the known distribution of *Daphnandra* sp. C Illawarra.

The project is to the north of the southernmost records of *Daphnandra* sp. C Illawarra on Toolijooa Ridge. Therefore the project is not likely to prevent any further southwards expansion of this species.

How is the project likely to affect current disturbance regimes?

The current disturbance regime in the warm temperate layered forest in the study area consists of fragmentation of patches by clearing, grazing disturbance and large infestations of the noxious weed *Lantana camara* along edges.

Given the small size, fragmentation and poor condition of vegetation that would be impacted, the project is not likely to increase the impact of weed invasion in the study area. However, mitigation measures are recommended to reduce the existing weed infestation and the likelihood of increased weed invasion in the impacted patches (Chapter 5).

The project is likely to remove a portion of marginal potential habitat in the study area and remove grazing pressures from any potential habitat that remains.

How is the project likely to affect habitat connectivity?

The project would further fragment the already fragmented vegetation between two known populations of *Daphnandra* sp. C 'Illawarra'. These two populations are currently separated by about 850 metres with scattered patches of vegetation in poor condition between them.

The areas to be cleared to the north of the known population of *Daphnandra* sp. C 'Illawarra' include the edges of currently fragmented patches of warm temperate layered forest in poor condition along edges where large infestations of the noxious weed *Lantana camara* are present and have displaced most native species.

The project would widen the existing area of cleared land, thus increasing fragmentation. However, given the current fragmentation and infestation of *Lantana camara,* it is unlikely that the areas to be cleared to the north of the known population represent suitable habitat for *Daphnandra* sp. C 'Illawarra'.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a Register of Critical Habitat. To date, no critical habitat has been declared for *Daphnandra* sp. C 'Illawarra'.

Conclusion

Daphnandra sp. C 'Illawarra' was not recorded in the study area; however, this species was recorded in the locality during broader surveys, about 600 metres to the south of the study area around Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest about 130 metres to the south of the study area and 400 metres to the north of the study area.

The alignment of the project avoids direct and indirect impacts on known records of this endangered species.

Potential habitat does exist within the study area in Illawarra gully wet forest and warm temperate layered forest communities. The project would have direct impacts on about 22.3 hectares of potential habitat for *Daphnandra* sp. 'Illawarra' in the subject site with potential indirect impacts to a further 15.4 hectares in the study area.

In determining the nature and magnitude of impacts on the potential habitat of *Daphnandra* sp. C 'Illawarra', the project is considered unlikely to have a significant impact as:

- The species was not recorded within the study area.
- The areas of potential habitat to be removed are currently fragmented and disturbed, particularly in the area to the north of the known population of this species on Toolijooa Ridge.

Irenepharsus trypherus Delicate Cress

Irenepharsus trypherus is listed as Endangered on the TSC Act.

Irenepharsus trypherus is a hairless annual or short-lived perennial herb that grows to 250 centimetres. It has a spreading to erect habit and is often multi-stemmed. The species typically inhabits steep rocky slopes near cliff lines and ridge tops, and less typically is found growing out of rock crevices or on narrow benches along cliff lines. The vast majority of sites are recorded from the upper slopes of the ridge systems that extend south and east of the Illawarra escarpment, although the species has also been recorded from the deep sandstone gorges of the Shoalhaven River (DEC 2005u).

Irenepharsus trypherus was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area (DECCW 2009a). However potential habitat does exist within the study area in Illawarra gully wet forest. Potential habitat for *Irenepharsus trypherus* is considered to include subtropical complex rainforest and wet sclerophyll forests. These include the following vegetation communities: coastal warm temperate rainforest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest and subtropical dry rainforest. These vegetation communities occur as scattered patches throughout the locality and cover an area of about 1690.7 hectares.

About 15.4 hectares of potential habitat for *Irenepharsus trypherus* would be directly impacted as part of the project with further potential indirect impacts to an additional 10 hectares (**Table 4.2**).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The following is known about the lifecycle of *Irenepharsus trypherus* (DEC 2005u):

- Mature plants are capable of reshooting from dry or desiccated stems following light grazing, trampling or drought.
- The species is thought to be a prolific seeder, with disturbance and light levels influencing germination.
- The fire response of this species is unknown.

Activities likely to affect the lifecycle of the species are those that contribute to the following (DEC 2005i):

- Loss of individuals – *Irenepharsus trypherus* is not known to occur in the study area, therefore the project is not likely to result in the loss of individuals of this species.
- Fragmentation of habitat – the potential habitat for *Irenepharsus trypherus* is currently fragmented by the Princes Highway. The project intersects the southern edge of a large patch of Illawarra gully wet forest at site 15, with only the currently fragmented edge being further fragmented as a result of the project.
- Modification of habitat – the potential habitat for *Irenepharsus trypherus* in the study area is already modified due to the ongoing impacts from edge effects (eg weeds) and disturbances such as grazing. The project may result in an increase in the intensity of some existing impacts.
- Damage to the soil seed bank – the project may involve the removal of some soil. This may lead to damage of the soil seed bank of the study area.
- Altered fire regimes – the project is not likely to alter the fire frequency in the locality.

On the basis of the above, the project is considered unlikely to have an adverse effect on the lifecycle of the species such that a viable local population (if one exists) of the species would be placed at risk of extinction.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The species has not been recorded in the study area nor within 10 kilometres, however, potential habitat for the species occurs within Illawarra gully wet forest in the study area with further potential habitat in the locality occurring within coastal warm temperate rainforest, escarpment foothills wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest and temperate littoral rainforest. Vegetation mapping by DEC (2005o) indicates about 1690.7 hectares of these potential habitats occur within the locality (five kilometre radius of the study area).

The potential habitat for this species within the study area ranges from poor to moderate in the south-west (sites 14 and 35), with remnant trees and a patchy or weed dominated understorey, to moderate to good condition in the central section (site 15), with a largely intact native tree, shrub and groundlayer along with infestations of woody weeds such as *Lantana camara*.

About 15.4 hectares of potential habitat for *Irenepharsus trypherus* would be directly impacted by the project. The area of potential habitat for *Irenepharsus trypherus* that would be removed as part of the project equates to 0.91 per cent of the extent of similar potential habitats mapped in the locality.

Given that the species has not been recorded in the study area and the relatively small area of potential habitat to be impacted in relation to that in the locality, potential habitat in the study area is not considered to be vital for the long-term survival of the species in the locality.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

No. The study area is to the south-east of the known distribution of *Irenepharsus trypherus.* The closest record to the study area is at Minnamurra Falls, about 15 kilometres to the north-west.

How is the project likely to affect current disturbance regimes?

The potential habitat for *Irenepharsus trypherus* is currently fragmented by the Princes Highway. The project intersects the southern edge of a large patch of Illawarra gully wet forest at site 15, with only the currently fragmented edge being further fragmented as a result of the project. This area is already modified due to the ongoing impacts from edge effects (eg weeds) and disturbances such as grazing.

How is the project likely to affect habitat connectivity?

Potential habitat for *Irenepharsus trypherus* that would be impacted by the project is part of an already fragmented and cleared landscape. The largest patch of potential habitat that would be fragmented is the Illawarra gully wet forest at site 15, where the project intersects the southern, currently fragmented edge.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for *Irenepharsus trypherus*.

Conclusion

Irenepharsus trypherus has not been recorded within 10 kilometres of the study area. In determining the nature and magnitude of impacts on the potential habitat of *Irenepharsus trypherus*, the project is considered unlikely to have a significant impact as:

- The species was not recorded during the field surveys of the study area.
- A relatively small area of potential habitat would be directly impacted.
- The project would result in minor fragmentation or isolation of the potential habitat.

However, the project has the potential to increase the operation of key threatening processes in the potential habitat of this species. On this basis, mitigation measures included in Chapter 5 of this report should be implemented in order to minimise potential indirect impacts resulting from the project

Zieria granulata Hill Zieria

Zieria granulata is listed as Endangered on the TSC Act.

This species is a tall bushy shrub that grows to six metres. The typical habitat is dry ridge tops and rocky outcrops on shallow volcanic soils, usually on Bombo Latite. Less frequently found on the moist slopes of the Illawarra escarpment and in low-lying areas on Quaternary sediments (DEC 2005'). The species is restricted to the Illawarra region. The species primarily occupies the coastal lowlands between Oak Flats and Toolijooa, in the local government areas of Shellharbour and Kiama.

Zieria granulata was not recorded in the study area, but was recorded in the locality during broader surveys, about 400 metres to the south of the study area on Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest record about 190 metres to the south-west of the study area.

Potential habitat for *Zieria granulata* does exist within the study area in Illawarra gully wet forest and warm temperate layered forest. The species also grows in highly disturbed areas such as road embankments and paddocks. Potential vegetation communities in the locality include: buderoo temperate rainforest, coastal warm temperate rainforest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest, and Yarrawarra temperate rainforest. These vegetation communities occur as scattered patches throughout the locality covering about 3011.8 hectares.

About 22.3 hectares of potential habitat for *Zieria granulata* would be directly impacted by the project with further potential indirect impacts to an additional 15.4 hectares of potential habitat.

How is the project likely to affect the lifecycle of a threatened species and/or population?

Zieria granulata was not recorded in the study area. Numerous records of this species occur within 10 kilometres of the study area, with a large population on Toolijooa Ridge to the south. The closest record is about 190 metres to the south-west of the study area, near Broughton.

The following is known about the lifecycle of *Zieria granulata* (DEC 2005'):

- Flowering occurs between early spring and summer.
- Known to possess functional pollen although deformed pollen has been recorded for the species.
- Nectar seeking flies appear to be effective pollen vectors for this species; these flies are considered to be generalist pollinators and strong fliers that are capable of traversing open spaces.
- Seed dispersal is initially through forcible ejection from the mature fruit, and it is suspected that secondary dispersal by ants also occurs.
- Response to fire not known.

The project is unlikely to affect the lifecycle of the *Zieria granulata* individuals in the population that adjoins the study area.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

Zieria granulata was not recorded in the study area. The project would result in direct impacts to about 22.3 hectares of potential habitat for the species. Based on the vegetation mapping, about 3011.8 hectares of potential habitat for *Zieria granulata* exists within the locality (five kilometre radius of the study area). The area of habitat in the study area to be directly impacted by the project equates to 0.74 per cent of similar habitat types in the locality.

The potential habitat for *Zieria granulata* in the study area is already modified due to ongoing impacts from edge effects (eg weeds) and disturbances such as grazing. The project may result in an increase in the intensity of some existing impacts.

The project is not likely to have a significant effect on the habitat of *Zieria granulata* in the locality.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

The study area is at the southern limit of the known distribution of *Zieria granulata.* The project may further isolate the southernmost records of this species from the rest of the population to the north.

Potential habitat in the locality includes the following vegetation communities: Buderoo temperate rainforest, coastal warm temperate rainforest, warm temperate layered forest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest, south coast grassy woodland and Yarrawarra temperate rainforest. These vegetation communities occur as scattered patches throughout the locality and cover an area of about 3011.8 hectares. Some of these vegetation communities occur to the south of the known southern limit of *Zieria granulata* and there are is a highly fragmented corridor across Toolijooa Ridge and Harley Hill that may facilitate any range expansion of this species.

How is the project likely to affect current disturbance regimes?

The current disturbance regime in the warm temperate layered forest in the study area consists of fragmentation of patches by clearing, grazing disturbance and large infestations of the noxious weed *Lantana camara* along edges.

Given the small size, fragmentation and poor condition of vegetation that would be impacted, the project is not likely to increase the impact of weed invasion in the study area. However, mitigation measures are recommended to reduce the existing weed infestation and the likelihood of increased weed invasion in the impacted patches (Chapter 5).

The project is likely to remove a portion of marginal potential habitat in the study area and remove grazing pressures from any potential habitat that remains.

How is the project likely to affect habitat connectivity?

The alignment of the project avoids direct and indirect impacts on a known population of *Zieria granulata*. A relatively large population of this species on Toolijooa Ridge is about 400 metres to the south of the study area and would not be fragmented by the project.

The closest known record of *Zieria granulata* to the Toolijooa Ridge population is about 1.6 kilometres to the north-west. There are currently roads, cleared grazing lands and fragmented patches of vegetation between the two populations. The project would not further isolate the Toolijooa Ridge population of *Z. granulata* from another known population.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a Register of Critical Habitat. To date, no critical habitat has been declared for *Zieria granulata*.

Conclusion

In determining the nature and magnitude of impacts on *Zieria granulata,* the project is considered unlikely to have a significant impact as:

- The species was not recorded within the study area, so there would be no impacts on known populations.
- A relatively small and disturbed area of potential habitat would be directly impacted.
- The project would not result in significant fragmentation or isolation of the potential habitat.

Pterostylis gibbosa Illawarra Greenhood

Pterostylis gibbosa is listed as Endangered on the TSC Act.

Pterostylis gibbosa is a deciduous orchid that is only visible above the ground between late summer and spring. Its rosette of leaves emerges from an underground tuberoid during late summer and autumn. A flower scape develops on mature plants over winter and flowering occurs between September and October, after which the leaf rosette withers and seed capsules develop (NPWS 2002).

Pterostylis gibbosa is currently known from five locations: Milbrodale in the Hunter Valley, Yallah (two sites) and Albion Park in the Illawarra and Nowra in the Shoalhaven. The total known population size of *Pterstylis gibbosa* in 2002 was about 4500 plants although this is likely to be higher given the extent of the Milbrodale and Worrigee Nature Reserve populations which had not been fully assessed as at the time of the publication of the Recovery Plan for the species (NPWS 2002).

The species occurs in open forest or woodland on flat or gently sloping land with poorly drained soils. Associated vegetation is usually woodland dominated by *Eucalyptus tereticornis* and *Melaleuca decora* with an open grassy understorey. Near Nowra, *Pterostylis gibbosa* is also associated with open forest dominated by *Corymbia maculata* and *Eucalyptus paniculata* with an open grassy understorey (NPWS 2002).

Pterostylis gibbosa was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area. NSW vegetation classes that the species is associated with are Coastal Valley Grassy Woodlands and Southern Lowland Wet Sclerophyll Forests (DEC 2005r). There are no plant communities in the locality that fall into the Southern Lowland Wet Sclerophyll Forests class. Two vegetation communities of the locality that fall into the Coastal Valley Grassy Woodland class are Illawarra Lowland Swamp Woodland and South Coast Grassy Woodland. Neither of these vegetation communities occur in the study area with the nearest stand of either about 2.5 kilometres south of the project. Potential habitat for the species in the locality consists of a total of 47.6 hectares of Coastal Valley Grassy Woodland.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The following is known about the lifecycle of *Pterostylis gibbosa* (NPWS 2002):

- Pterostylis species are generally pollinated by male gnats of the genus Mycomya (Fungus Gnats). Pollination occurs when the male Mycomya are deceived into attempting to copulate with the labellum. Nothing is known of the habitat requirements of Mycomya however it is suggested they are probably very common, but are not often seen due to their small size. Abundance of Mycomya is believed to peak in September, which is the main month of flowering of *Pterostylis gibbosa*. Studies on pollination rates have indicated that suitable adjoining pollinator habitat to a known site may be important for pollination success in addition to pollinator availability.
- The seed is dispersed by wind and reliant on a mycorrhizal fungus to support the first stages of growth after germination. *Pterostylis gibbosa* sheds seed in spring and is dormant until the following autumn.
- The species is capable of surviving fire, due to the regenerative capacity of its tuberoid. Occasional fire may be necessary to provide suitable conditions for the establishment of seeds and seedlings and to maintain habitat suitable for the survival of the species. Summer fires are assumed to have the least impact on Pterostylis gibbosa as the species remains dormant underground over summer, provided such fires are not of a sufficient intensity to destroy the underground tuber.

- Generally, the species is flexible in its response to climatic conditions with plants dying back in poor conditions and growing quickly in good times. Additionally, the plant may die back and reappear within a season. Grazing is thought to have either beneficial or deleterious effect on the species dependant on timing.

Activities likely to affect the lifecycle of the species are those that contribute to the following (DEC 2005i):

- Loss of individuals – *Pterostylis gibbosa* is not known to occur in the study area, therefore the project is not likely to result in the loss of individuals of this species.
- Fragmentation of habitat – there is no potential habitat for *Pterostylis gibbosa* in the study area. The potential habitat for the species in the locality is highly fragmented. The project will not contribute further fragmentation of the species potential habitat in the locality.
- Modification of habitat – the project will not affect the potential habitat of *Pterostylis gibbosa* in the locality by either direct or indirect impacts. The project is not likely to modify habitat for the species pollinators such that *Pterostylis gibbosa* would be adversely affected if were to occur in the locality.
- Damage to the soil seed bank – the project will not involve the removal or modification of the soil seed bank of potential habitat for the species in the locality.
- Altered fire regimes – the project is not likely to alter the fire frequency in the locality.

On the basis of the above, the project is considered unlikely to have an adverse effect on the lifecycle of the species such that a viable local population (if one exists) of the species would be placed at risk of extinction.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The species has not been recorded in the study area or within 10 kilometres of the project. Potential habitat for the species occurs in the Illawarra Lowland Swamp Woodland and South Coast Grassy Woodland vegetation communities of the locality. Mapping by DEC (2005o) has estimated an approximate 47.6 hectares of these potential habitats within the locality (five kilometre radius of the study area).

No area of known or potential habitat will be impacted by the project.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

The project is near Nowra which is at the southern extent of the species distribution. However *Pterostylis gibbosa* is not currently recorded in the project locality and habitat for the species in the locality will not be affected.

How is the project likely to affect current disturbance regimes?

The potential habitat for *Pterostylis gibbosa* in the locality is highly fragmented as a result of vegetation clearing and agricultural land use. Although the project will impact on native vegetation, this will not affect the potential habitat of *Pterostylis gibbosa* to the south of the project area. Disturbance regimes such as grazing and weed invasion that are likely to occur in the potential habitat for this species will not be exacerbated as a result of the project.

How is the project likely to affect habitat connectivity?

Potential habitat for *Pterostylis gibbosa* will not be impacted by the project.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for *Pterostylis gibbosa*.

Conclusion

Pterostylis gibbosa has not been recorded within 10 kilometres of the study area. In determining the nature and magnitude of impacts on the potential habitat of *Pterostylis gibbosa* the project is considered unlikely to have a significant impact as:

- The species was not recorded during the field surveys of the study area.
- The relatively small area of potential habitat for the species that occurs in the locality will not be directly or indirectly impacted.
- The project would result in minor additional fragmentation native vegetation that is not considered potential habitat for the species.

Cryptostylis hunteriana Leafless Tongue-orchid

Cryptostylis hunteriana is listed as Vulnerable on the TSC Act.

Cryptostylis hunteriana is a leafless saprophytic terrestrial orchid which produces an upright flower-stem to 45 centimetres tall, bearing five to 10 flowers. The flowering period is between November and February (DEC 2005e).

The species is known from a number of localities along the coast of NSW, Victoria and Queensland. In NSW, it appears to be most common in the Shoalhaven area (DEWHA 2008a), and observed in recent years at many sites between Batemans Bay and Nowra (DEC 2005e). *Cryptostylis hunteriana* does not appear to have well defined habitat preferences and is known from a range of communities (DEC 2005e). Associated soils include moist sands, moist to dry clay loam and occasionally in accumulated eucalypt leaves (DEWHA 2008a). The species occurs mostly in coastal heathlands, margins of coastal swamps and sedgelands, coastal forest, dry woodland, and lowland forest (DEWHA 2008a). The larger populations typically occur in woodland dominated by *Eucalyptus sclerophylla*, *E. sieberi, Corymbia gummifera* and *Allocasuarina littoralis*. The species appears to prefer open areas in the understorey of this community and is often found in association with *Cryptostylis subulata* and *Cryptostylis erecta* (DEC 2005e).

Cryptostylis hunteriana was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area. NSW vegetation classes that the species is associated with in the Sothern Rivers region are South East Dry Sclerophyll Forests, Sydney Hinterland Dry Sclerophyll Forests, Sydney Montane Dry Sclerophyll Forests, South Coast Heaths, Sydney Coastal Heaths and Sydney Montane Heaths (DEC 2005e)

Of the vegetation communities mapped in the locality Currambene-Batemans Lowlands Forest falls into the South East Dry Sclerophyll Forests class whilst Budderoo-Morton Plateau Forest falls within the Sydney Montane Dry Sclerophyll Forests class. Of these Currambene-Batemans Lowlands Forest occurs within the study area and subject site.

Potential habitat for the species in the locality consists of a total of 54.1 hectares of South East Dry Sclerophyll Forest and Sydney Montane Dry Sclerophyll Forest.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The following is known about the lifecycle of *Cryptostylis hunteriana.*

- Pollination of *Cryptostylis hunteriana* is via pseudocopulation by the male Ichneumon Wasp (*Lissopimpla excelsa*), and seeds are spread via wind transportation (DEWHA 2008a).
- The flowering period is broadly from August to February with flowering taking place earlier in Queensland than in NSW and Victoria. Estimates for time taken for a seed to germinate and flower could be from two and a half years to a more probable three or four and a half years based on existing knowledge of orchid reproduction (DEWHA 2008a).
- The species is spread either by wind transportation of seed or by seeds being dropped in the immediate vicinity once the flower head has fallen over and it is suggested that the likelihood of the species spreading by vegetative reproduction is low due to its poorly developed root system (DEWHA 2008a).
- Flowering intensity may be stimulated by previous fire events, however, fire during the flowering season has been identified as a potential threat to the species (DEWHA 2008a).
- The species may be dependent on a mychorrizal fungal association (DEWHA 2008a).

Activities likely to affect the lifecycle of the species are those that contribute to the following (DEC 2005i):

- Loss of individuals – *Cryptostylis hunteriana* is not known to occur in the study area, therefore the project is not likely to result in the loss of individuals of this species.
- Fragmentation of habitat – there is about 2.4 hectares of potential habitat for *Cryptostylis hunteriana* in the study area. The potential habitat for the species in the locality is about 54.1 hectares of highly fragmented vegetation communities. The project will not contribute further fragmentation of the species potential habitat in the locality.
- Modification of habitat – the project will affect 0.0002 hectares of potential habitat for *Cryptostylis hunteriana* in the locality by either direct or indirect impacts. The project is not likely to modify habitat for the species pollinators such that *Cryptostylis hunteriana* would be adversely affected if were to occur in the locality.
- Damage to the soil seed bank – the project will involve the removal and modification of the soil seed bank of potential habitat for the species in the locality.
- Altered fire regimes – the project is not likely to alter the fire frequency in the locality.

On the basis of the above, the project is considered unlikely to have an adverse effect on the lifecycle of the species such that a viable local population (if one exists) of the species would be placed at risk of extinction.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The species has not been recorded in the study area or within 10 kilometres of the project. Potential habitat for the species occurs in the Currambene-Batemans Lowlands Forest and Budderoo-Morton Plateau Forest communities of the locality. Mapping by DEC (2005o) has estimated an approximate 54.1 hectares of these potential habitats within the locality (five kilometre radius of the study area). Of this up to 0.0002 hectares of Currambene-Batemans Lowlands Forest may be affected by the project, equating to 0.0004 per cent of the potential habitat for the species in the locality.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

The species is distributed from near Orbost in southern Victoria to near Grafton on the NSW north coast.

How is the project likely to affect current disturbance regimes?

The potential habitat for *Cryptostylis hunteriana* in the locality is highly fragmented as a result of vegetation clearing and agricultural land use. Apart from the loss of native vegetation that forms habitat for this species disturbance regimes such as grazing and weed invasion that are likely to occur in the potential habitat for this species will not be exacerbated as a result of the project.

How is the project likely to affect habitat connectivity?

Stands of Currambene-Batemans Lowlands Forest and Budderoo-Morton Plateau Forest in the locality are highly disjunct. Although the project will result in the future isolation of habitat for the species this is not considered significant as *Cryptostylis hunteriana* is not known from the locality.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for *Cryptostylis hunteriana*.

Conclusion

Cryptostylis hunteriana has not been recorded within 10 kilometres of the study area. In determining the nature and magnitude of impacts on the potential habitat of *Cryptostylis hunteriana* the project is considered unlikely to have a significant impact as:

- The species was not recorded during the field surveys of the study area.
- The relatively small area of potential habitat for the species that occurs in the locality that will be impacted is not considered significant.
- The project would not result in significant additional fragmentation of native vegetation considered potential habitat for the species.

Genoplesium baueri

Genoplesium baueri is listed as Vulnerable under the TSC Act.

Genoplesium baueri is a terrestrial orchid about 6-15 centimetres high, with a sparse inflorescence of 1-6 flowers. Flowering time is from December to March. The species has been recorded from locations between Ulladulla and Port Stephens, with older records including Sydney suburbs of Cowan, Asquith, Wahroonga and Gladesville (DEC 2005i).

Genoplesium baueri occurs in sparse sclerophyll forest and moss gardens over sandstone (DEC 2005i). The majority of plants are found in relatively open areas but the largest population is located under a good overstorey and dense ground cover (ANOS 2008). The locations of some previous recordings are likely to now be within conservation reserves including Berowra Valley Regional Park, Royal National Park and Lane Cove National Park (DEC 2005i). Pollination of the genus Genoplesium is by small ferment flies such as the fruit fly Drosophila and flowering of the species may be enhanced by fire (Jones 2006).

Genoplesium baueri was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area. NSW vegetation classes that the species is associated with in the Sothern Rivers region are Sydney Coastal Dry Sclerophyll Forests and Sydney Montane Heaths (DEC 2005i). There are no vegetation communities mapped in the locality that fall into either of these vegetation classes.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The following is known about the lifecycle of *Genoplesium baueri*.

- Pollination of the genus Genoplesium is by small ferment flies such as the fruit fly Drosophila.
- Flowering time is from December to March.

Activities likely to affect the lifecycle of the species are those that contribute to the following (DEC 2005i):

- Loss of individuals – Genoplesium baueri is not known to occur in the study area, therefore the project is not likely to result in the loss of individuals of this species.
- Fragmentation of habitat – there is no habitat for Genoplesium baueri in the study area or locality.
- Modification of habitat – the project will not affect habitat for this species.
- Damage to the soil seed bank – the project will not involve the removal or modification of the soil seed bank of potential habitat for the species in the locality.
- Altered fire regimes – the project is not likely to alter the fire frequency in the locality.

On the basis of the above, the project is considered unlikely to have an adverse effect on the lifecycle of the species such that a viable local population (if one exists) of the species would be placed at risk of extinction.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The species has not been recorded in the study area or within 10 kilometres of the project. Potential habitat for the species includes vegetation that falls into the Sydney Coastal Dry Sclerophyll Forests and Sydney Montane Heaths NSW vegetation classes. No vegetation communities mapped in the locality fall into either of these classes.

Does the project affect any threatened species or populations that are at the limit of its known distribution?

The species occurs between Ulladulla and Port Stephens. The project area is not at the limits of the species known distribution.

How is the project likely to affect current disturbance regimes?

Although the project will impact on native vegetation, this will not affect potential habitat for the species.

How is the project likely to affect habitat connectivity?

No habitat for the species occurs in the locality.

How is the project likely to affect critical habitat?

Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for *Genoplesium baueri*.

Conclusion

Genoplesium baueri has not been recorded within 10 kilometres of the study area and the locality does not support vegetation communities that provide habitat for the species. The project will not impact *Genoplesium baueri* or its potential habitat.

Endangered and Vulnerable Fauna

Ixobrychus flavicollis Black Bittern

The Black Bittern is listed as Vulnerable under Schedule 2 of the TSC Act.

The Black Bittern has been previously recorded on the edge of the study area adjacent to Town Creek (south of Berry), in 1988. There has been one other record of the Black Bittern in the locality; from 1990, to the south-east at Black Head (DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Black Bittern inhabits coastal wetlands and littoral habitats. Freshwater wetlands, fringed with dense vegetation such as melaleuca and casuarina are preferred (Marchant and Higgins 1990a). The species utilises billabongs, pools, and estuaries and tidal reaches of coastal creeks and rivers with fringing vegetation, which may only form a narrow band of cover (Marchant and Higgins 1990a).

The Black Bittern nests in trees over wetlands and watercourses in densely vegetated areas. It forages in low, marshy vegetation, or in shadows over shallow water and roost on the ground or in leafy trees (Marchant and Higgins 1990a).

Potential habitat for this species occurs within the riparian forest and woodland, and constructed wetland habitat within the study area. The project is likely to remove and/or disturb about 14.5 hectares of potential foraging and breeding habitat for this species. However, given the extent of potential habitat (eg riparian forest and woodland, constructed wetlands and estuarine habitats) within the locality (at least 270.4 hectares), it is unlikely the loss or disturbance of 5.4 per cent of potential habitat from the locality would disrupt the life cycle of the Black Bittern.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project would directly impact 5.9 hectares of riparian forest and woodland, and constructed wetland (potential habitat) within the study area. Within the area of DEC vegetation mapping (as amended following the field surveys), this equates to only 2.2 per cent of the potential habitat available within the locality (at least 270.4 hectares). A further 8.6 hectares would be indirectly impacted. This equates to about 3.2 per cent of the potential habitat available within the locality. In total, 5.3 per cent of the available habitat in the locality would be impacted.

The riparian forest in the study area forms a local wildlife corridor that is also a component of the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The Black Bittern may use this riparian corridor to move throughout the landscape and it is therefore important for the long-term survival of the species within the locality. The proposed riparian corridor enhancement (through rehabilitation and revegetation) would help mitigate impacts on habitat connectivity for this species.

Given that the potential habitat to be removed is disturbed, the reasonable mobility of this species and provided that the mitigation measures to compensate for the loss of habitat connectivity described in Chapter 5 are implemented, it is considered unlikely that the project would have a significant impact on the habitat of the Black Bittern.

Does the project affect any threatened species that are at the limit of its known distribution?

The Black Bittern has a wide distribution, from southern New South Wales (although rarely south of Sydney), north to Cape York and along the north coast to the Kimberley region (DEC 2005b). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The Black Bittern habitat within the study area has been subjected to ongoing disturbances from grazing, recreational fishing and aquatic activities, edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and the diversion of Town Creek (permanent modification of habitat south of the diversion). Additionally, edge effects such as an increase in weeds and anthropogenic activities associated with the new highway are likely.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation; wildlife corridors in the study area, therefore, are limited. However, vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek form local corridors that are components of the regional Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The project crosses these local wildlife corridors thereby creating (or increasing) a barrier to fauna movement between areas of habitat within the locality.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) is proposed (Chapter 5). The proposed riparian corridor enhancement would help mitigate impacts on habitat connectivity for this species.

Given the mobility of the Black Bittern, and provided the mitigation measures described in Chapter 5 are implemented, it is considered unlikely that the project would significantly disrupt habitat connectivity.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Black Bittern (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Black Bittern.

Burhinus grallarius Bush Stone-curlew

The Bush Stone-curlew is listed as Endangered under Schedule 1 of the TSC Act.

The Bush Stone-curlew has not been recorded in the study area. The species has been previously recorded only once within 10 kilometres of the study area; about nine kilometres south of the study area, recorded in 1998 (DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Bush Stone-curlew is a nocturnal, ground-dwelling bird. It nests on the ground, near dead timber often within open woodlands that have a short grass or brushwood understorey. The species breeds in spring, laying two eggs in late August to mid December (DEC 2005f).

Potential habitat occurs within the forests and woodlands and surrounding farmland of the study area, particularly where there is a grassy understorey. The project is likely to directly impact about 27.8 hectares of potential habitat (eg eucalypt forest with grassy understorey and riparian forests) and indirectly impact a further 26.05 hectares. However, given the lack of records for this species in the study area and locality, and the extent of potential habitat within the locality (1282.6 hectares) it is unlikely the project would disrupt the life cycle of the Bush Stone-curlew.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The Bush Stone-curlew inhabits open forests and woodlands with a sparse grassy ground layer and fallen timber. The preferred habitat for this species consists of woodlands of casuarinas, eucalypts and acacias.

The project is likely to modify and/or remove about 53.9 hectares of potential foraging and breeding habitat for the Bush Stone-curlew. Within the area of DEC vegetation mapping (as amended following the field surveys), this equates to only 4.2 per cent of the potential habitat (eg eucalypt and casuarina grassy woodlands) available within the locality (1282.6 hectares).

The habitat to be impacted is predominantly disturbed roadside and disturbed riparian vegetation. Regardless, this disturbed habitat forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore considered to be important for the long-term survival of the Bush Stone-curlew within the locality (if present). The proposed corridor fragmentation mitigation measures (Chapter 5) may help mitigate impacts on habitat connectivity for this species.

Given that the potential habitat to be removed is disturbed, the reasonable mobility of this species and provided that the mitigation measures to compensate for the loss of habitat connectivity described in Chapter 5 are implemented, it is considered unlikely that the project would have a significant impact on the habitat of the Bush Stone-curlew.

Does the project affect any threatened species that are at the limit of its known distribution?

The Bush Stone-curlew is found throughout Australia except for the central southern coast and inland, the far south-east corner, and Tasmania (DEC 2005e). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

The project would also result in a wider barrier for fauna attempting to cross the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation; wildlife corridors in the study area, therefore, are limited. However, vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek form local corridors that are components of the regional Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The project crosses these local wildlife corridors thereby creating (or increasing) a barrier to fauna movement between areas of habitat within the locality.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) is proposed (Chapter 5). The proposed riparian corridor enhancement may help mitigate impacts on habitat connectivity for this species.

Given the mobility of the Bush Stone-curlew and provided the mitigation measures described in Chapter 5 are implemented, it is considered unlikely that the project would significantly disrupt habitat connectivity.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Bush Stone-curlew (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Bush Stone-curlew.

Callacephalon fimbriatum Gang-Gang Cockatoo

The Gang-gang Cockatoo is listed as Vulnerable under Schedule 2 of the TSC Act.

The Gang-gang Cockatoo was recorded during the field surveys south of the study area (site 8). This species has previously been recorded nine times (between 1994 and 2010) within the locality to the north, south and east of the study area. Additional records exit within 10 kilometres the north, south and west of the study area (Birds Australia 2011, DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Gang-gang Cockatoo occupies tall, montane forests and woodlands in summer, particularly in heavily timbered and mature wet sclerophyll forests (Higgins 1999). In winter, it occurs at lower altitudes in drier, more open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas (Shields and Crome 1992). The Gang-gang Cockatoo forages for seeds in the canopies of native and introduced trees, especially eucalypts (Higgins 1999). The principle foods of the species are wattle seeds, eucalypt seeds, exotic fruit and nuts and invertebrates (Cameron 2007).

Gang-gang Cockatoos nest in tree hollows (Gibbons and Lindermayer 1997), preferring live trees often near water with hollows between 70 centimetres – 200 centimetres deep and about 25 centimetres in diameter. These trees often occur in mature sclerophyll forest with a dense shrubby understorey. Although little is known about the movements of this species, it is considered to be mobile and known to migrate in response to food availability (DEC 2005p).

Potential breeding and foraging habitat for the Gang-gang Cockatoo occurs in the woodland and forest habitats of the study area. The project is likely to remove up to 27.8 hectares of this habitat with a further 26.05 hectares likely to be indirectly impacted. This may include the loss of hollows and foraging resources for the Gang-gang Cockatoo. However, given the mobility of this species and extent of habitat within the locality (3666.9 hectares), it is unlikely the loss/modification of 1.5 per cent of the available habitat for this species within the locality would disrupt the life cycle of the Gang-gang Cockatoo within the study area.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The study area contains potential foraging and breeding resources for the Gang-gang Cockatoo in the woodland and forest habitats. The project is likely to remove and/or modify about 53.9 hectares (27.8 hectares from direct impacts with a further 26.05 hectares indirectly impacted) of this potential habitat. Woodland and forest habitat are widely distributed within the locality; as such, it is unlikely the project would have a significant impact on the Gang-gang Cockatoo habitat within the locality.

Does the project affect any threatened species that are at the limit of its known distribution?

The distribution of the Gang-gang Cockatoo extends from southern Victoria through south and central-eastern New South Wales (DEC2005p). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The proposal is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation; wildlife corridors in the study area, therefore, are limited. However, vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek form local corridors that are components of the regional Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The project crosses these local wildlife corridors thereby creating (or increasing) a barrier to fauna movement between areas of habitat within the locality. The highly mobile Gang-gang Cockatoo is unlikely to be impacted by the reduced connectivity within the locality.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Gang-gang Cockatoo (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Gang-gang Cockatoo.

Calyptorhynchus lathami Glossy Black-cockatoo

The Glossy Black-cockatoo is listed as Vulnerable under Schedule 2 of the TSC Act.

The Glossy Black-cockatoo has been previously recorded once within the locality (in 2005), about four kilometres to the east of the study area (DECCW 2011). Beyond the locality and within 10 kilometres of the study area, this species has been recorded at an additional four locations to the south and west of the study area (DECCW 2011). This species was not recorded during the field surveys.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Glossy Black-cockatoo relies almost entirely on the seeds of a few species of *Allocasuarina* for food, these being *A. littoralis, A. torulosa* and *A. verticillata*. They also forage on *Angophora* fruit, sunflower seeds, pine cones and grubs in acacia and allocasuarina. This species is almost entirely arboreal coming to ground only to drink. They are dependent on large hollow-bearing trees in mature eucalypt trees for nesting (Higgins 1999).

The study area contains *Allocasuarina littoralis* and *Angophora floribunda* which are considered to be foraging trees for the Glossy Black-cockatoo. The study area may also provide breeding opportunities in the form of hollows.

The project would disturb and/or remove about 53.9 hectares (direct impacts of 27.8 hectares, indirect impacts 26.05 hectares) of the potential habitat resources for this species within the study area. However this only represents 4.2 per cent of the available habitat within the locality (1281.3 hectares). As such it is unlikely the project would disturb the life cycle of the Glossy Black-cockatoo.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The study area contains potential foraging and breeding resources for the Glossy Black-cockatoo in the woodland and forest habitats. The project is likely to remove and/or modify about 53.9 hectares (27.8 hectares from direct impacts with a further 26.05 hectares indirectly impacted) of this potential habitat. Woodland and forest habitat are widely distributed within the locality; as such, it is unlikely the project would have a significant impact on the Glossy Black-cockatoo habitat within the locality.

Does the project affect any threatened species that are at the limit of its known distribution?

The distribution of the Glossy Black-cockatoo extends from the central Queensland coast to East Gippsland in Victoria, and inland to the southern tablelands and central western plains of New South Wales (DEC 2005q). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation; wildlife corridors in the study area, therefore, are limited. However, vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek form local corridors that are components of the regional Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The project crosses these local wildlife corridors thereby creating (or increasing) a barrier to fauna movement between areas of habitat within the locality. The highly mobile Glossy Black-cockatoo is unlikely to be impacted by the reduced connectivity within the locality.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Glossy Black-cockatoo (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Glossy Black-cockatoo.

Glossopsitta pusilla Little Lorikeet

The Little Lorikeet is listed as Vulnerable under Schedule 2 of the TSC Act.

The Little Lorikeet was not recorded within the study area, however it has been previously recorded five times (between 1993 and 2010) to the south of the locality in Coomonderry Swamp and Seven Mile Beach National Park (Birds Australia 2011, DECCW 2011). Two additional records occur within 10 kilometres to the north and south of the study area.

How is the project likely to affect the lifecycle of a threatened species and/or population?

Little Lorikeets occur in dry, open eucalypt forests and woodlands. They are gregarious, usually foraging in small flocks, often with other species of lorikeet. They feed primarily on nectar and pollen in the tree canopy (flowering eucalypts), but also on a variety of other species including melaleucas and mistletoes. In coastal regions they have been known to forage on melaleucas, *Eucalyptus pilularis* (blackbutt) and *E .robusta* (swamp mahogany), the latter two being particularly important food sources for pollen and nectar respectively (NSW Scientific Committee 2008b). Little Lorikeets are generally considered to be nomadic, and move in response to food availability with irregular large or small influxes of individuals occurring at any time of year (Higgins 1999).

Little is known of the breeding requirement of the Little Lorikeet; however there are observations of nesting at heights between two metres and 15 metres, in small hollows in mostly smooth-barked eucalypts (NSW Scientific Committee 2008b).

Potential habitat trees for the Little Lorikeet in the form of melaleucas, *Eucalyptus pilularis and E. robusta* and limited breeding resources (smooth-barked *Corymbia maculata,* spotted gum) are present in the woodlands and forest habitats within the study area. The project is likely to directly disturb about 22.2 hectares of potential habitat and a further 17.5 hectares is likely to be indirectly impacted. However, breeding and foraging resources for this species are widely distributed within the locality (2425.7 hectares). Given that this species moves in response to food availability and the extent of further breeding habitat within the locality (including known habitat protected within Seven Mile Beach National Park) it is considered unlikely that the project would disrupt the life cycle of the Little Lorikeet.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project would directly modify and/or remove about 22.2 hectares of potential habitat for the Little Lorikeet, with a further 17.5 hectares likely to be indirectly impacted. This would include disturbance to foraging resources and limited breeding resources. The Little Lorikeet habitat to be modified and/or removed by the project represents about 1.6 per cent of the available habitat for this species within the locality.

Does the project affect any threatened species that are at the limit of its known distribution?

The Little Lorikeet distribution extends from north of Cairns, down the east coast of Australia, to Adelaide (NSW Scientific Committee 2008b). As a result the study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation. Wildlife corridors intersected by the study area include the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. Vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek are discontinuous parts of this corridor.

The project would involve removal of potential habitat trees from the study area. This is likely to cause some impact on local and regional wildlife corridors, particularly where the project crosses Toolijooa Ridge (once) and Broughton Creek (three times). However, given the Little Lorikeet is mobile it is unlikely the project would create new barriers or exacerbate existing barriers for this species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Little Lorikeet (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Little Lorikeet.

Lathamus discolor Swift Parrot

The Swift Parrot is listed as Endangered under Schedule 1 of the TSC Act. The species is also listed as Endangered under the EPBC Act.

The Swift Parrot has not been recorded within the study area. The species has been previously recorded once within the locality (recorded in year 2000), about 2.5 kilometres south-east of the study area within Seven Mile Beach National Park (Birds Australia 2011). Another three records of the species occur within 10 kilometres of the study area to the north and south (DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Swift Parrot is a highly nomadic species that occurs in woodlands and forests in New South Wales (Higgins 1999). It migrates in response to food availability and seasonal changes. It is often recorded in New South Wales between May and August and breeds in Tasmania during the warmer seasons (Higgins 1999).

While on the mainland, Swift Parrots occur in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations. Favoured feed trees include winter-flowering species such as swamp mahogany *Eucalyptus robusta*, spotted gum *Corymbia maculata*, red bloodwood *C. gummifera*, mugga ironbark *E. sideroxylon*, and white box *E. albens*. Commonly used lerp-infested trees include grey box *E. microcarpa*, grey box *E. moluccana* and blackbutt *E. pilularis* (DEC 2005†).

The study area provides potential foraging habitat for the Swift Parrot within the eucalypt forests and woodlands. Three favoured feed tree species (*Corymbia maculata*, *C. gummifera* and *Eucalyptus pilularis*) occur within the study area. Only one species (*E. pilularis*) is dominant within any of the plant communities (Illawarra gully wet forest). The study area does not provide potential breeding habitat as the species breeds exclusively in Tasmania (Higgins 1999).

The project would impact potential foraging habitat for the Swift Parrot through the removal of eucalypt forest and woodland. About 22.2 hectares of eucalypt forest (potential foraging habitat) would be removed from the study area with a further 17.5 hectares affected by indirect impacts (eg edge effects). This equates to less than 1.6 per cent of eucalypt forest within the locality (2425.7 hectares). Given the availability of potential foraging habitat within the locality (including known habitat protected within Seven Mile Beach National Park), that no breeding habitat would be impacted and the high mobility of this species, it is considered unlikely that the project would disrupt the life cycle of the Swift Parrot.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Swift Parrot (some of which contains preferred feed tree species). Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.9 per cent of potential habitat within the locality (2425.7 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.6 per cent of the potential habitat occurring in the locality would be impacted by the project.

Does the project affect any threatened species that are at the limit of its known distribution?

The Swift Parrot has a wide distribution as it breeds in Tasmania, but migrates to south eastern Australia from Victoria and the eastern parts of South Australia to south-east Queensland (DEC 2005 …). As a result the study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation. Wildlife corridors intersected by the study area include the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. Vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek are discontinuous parts of this corridor.

The project would involve removal of potential feed trees from the study area. The areas to be removed (predominantly roadside areas) are contiguous with intact forest that would remain. Given the availability of surrounding eucalypt forests, the small areas of proposed vegetation removal (the 22.2 hectares to be removed is made up of smaller areas spread along the 11.6 kilometres route, including proposed ancillary sites) and the high mobility of the Swift Parrot, it is considered unlikely that the project would significantly impact on the habitat connectivity for this species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Swift Parrot (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Swift Parrot.

Neophema pulchella Turquoise Parrot

The Turquoise Parrot is listed as Vulnerable under Schedule 2 of the TSC Act.

The Turquoise Parrot was not recorded during the field surveys, however it has been previously recorded (six times between 1975 and 2009) to the north of the study area in Barren Grounds Nature Reserve (Birds Australia 2011, DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

Turquoise Parrots occur in open woodlands and eucalypt forests with a ground cover of grasses and understorey of low shrubs (Morris 1980). The species is found in the foothills of the Great Divide, including steep rocky ridges and gullies (Higgins 1999).

The Turquoise Parrot is usually seen in pairs or small, possibly family, groups and has also been reported in flocks of up to thirty individuals. The species prefers to feed in the shade of trees and spends most of the day on the ground searching for the seeds of grasses and herbaceous plants, or browsing on vegetable matter (DEC, 2005). It nests in hollow-bearing trees or hollows in tree stumps and prefers to breed in open grassy forests and woodlands, and gullies which are moist (Higgins 1999).

The study area provides potential foraging and breeding habitat for the Turquoise Parrot in the open forest and woodland habitats as well as riparian vegetation. The project is likely to remove about 27.8 hectares of this habitat with a further 26.05 hectares likely to be indirectly impacted. This is likely to include both tree hollows and hollows in tree stumps and logs. Given the mobility of the Turquoise Parrot and extent of similar habitat resources within the locality (1281.3 hectares), it is unlikely the project would disrupt the life cycle of the Turquoise Parrot.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project is likely to clear potential foraging habitat in the form of flowering eucalypts and species of *Leucopogon* and *Austrodanthonia*. The Turquoise Parrot feeds on the seeds of these species and many other plant species. In addition to potential foraging habitat the project is likely to remove trees with hollows that provide breeding opportunities for the Turquoise Parrot. However given the extent of habitat resources in the locality, the loss or modification of about 4.2 per cent of available potential habitat within the locality is not considered to be significant.

Does the project affect any threatened species that are at the limit of its known distribution?

The range of the Turquoise Parrot extends from southern Queensland through to northern Victoria, along the coastal plains and to the west of the Great Dividing Range (DEC 2005•) . The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation. Wildlife corridors intersected by the study area include the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. Vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek are discontinuous parts of this corridor.

The project is likely to remove potential habitat trees for the Turquoise Parrot within the wildlife corridors. However, the Turquoise Parrot is a mobile species. In most districts there is a post-breeding dispersal of parrots and local movements may also occur as a result of rainfall and water availability, which in turn affect food availability (Forshaw and Cooper 2002). Given the mobility of the Turquoise Parrot it is unlikely the project would create new barriers or exacerbate existing barriers for this species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Turquoise Parrot (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Turquoise Parrot.

Forest Owls

The Barking Owl (*Ninox connivens*), Powerful Owl (*Ninox strenua*), Masked Owl (*Tyto novaehollandiae*) and Sooty Owl (*Tyto tenebricosa*) are each listed as Vulnerable under Schedule 2 of the TSC Act. These species have been grouped for the assessment of significance due to their similar habitat requirements.

The Barking Owl was not recorded during the field surveys. The species has been previously recorded twice within the locality, to the east and north-west of the study area in 1996 and 2007 (Bird's Australia 2011, DECCW 2011). One other record occurs 10 kilometres north of the study area, recorded in 1992 (DECCW 2011).

The Masked Owl was not recorded during the field surveys. There is one record of the Masked Owl within the locality (recorded in 1980) at Seven Mile Beach National Park, south of the study area (DECCW 2011). No other records of the species occur within 10 kilometres.

The Powerful Owl was recorded during the field surveys at site 15. The species has been previously recorded at seven other locations within the locality (dating between 1993 and 2009), occurring east and south-east of the study area (Birds Australia 2011, DECCW 2011). Beyond the locality and within 10 kilometres of the study area, an additional five records (dating between 1999 and 2001) occur to the north (Birds Australia 2011, DECCW 2011).

The Sooty Owl was not recorded during the field surveys. The species has been previously recorded at seven locations within the locality (dating between 1997 and 2008), all occurring north of the study area (Birds Australia 2011, DECCW 2011). An additional three records (dating between 1990 and 2001) exist about 10 kilometres north of the study area (Bird's Australia 2011, DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Barking Owl lives in forest and woodlands of tropical, temperate and semi-arid zones (Higgins 1999). The species has shown a preference in the area for dry ironbark woodlands (DEC 2005‡). The Masked Owl inhabits a diverse range of wooded habitat that provide tall or dense mature trees with hollows suitable for nesting and roosting, but is also recorded in woodlands adjacent to cleared areas (Higgins 1999). The Powerful Owl occupies wet and dry eucalypt forests and rainforests. It can occupy both unlogged and lightly logged forests, as well as undisturbed forests (Debus and Chafer 1994a). The species' foraging range can include urban areas. The Sooty Owl has been recorded in tall old-growth forests, including temperate and subtropical rainforests (Higgins 1999).

All the forest owls require large mature trees or stags with hollows at least 0.5 metres deep for nesting (Gibbons and Lindenmayer 1997). The Barking Owl favours nesting and roosting sites in woodland alongside watercourses (Higgins 1999). Masked Owls usually nest within dense forests or woodlands (Higgins 1999). Powerful Owls prefer hollows in large old trees rather than stags (Higgins 1999). Nest trees for this species are usually emergent with a diameter at breast height of at least 100 centimetres (Gibbons and Lindenmayer 1997). The Sooty Owl nests and roosts in hollows of tall (125 centimetres -161 centimetres in diameter) emergent trees, mainly eucalypts, in wet sclerophyll forest (Higgins 1999), often located in gullies (Gibbons and Lindenmayer 1997).

The Barking Owl is thought to have a home range of less than 200 hectares, although no detailed studies have been conducted. Masked Owl pairs have a large home-range of 500 hectares to 1000 hectares. Pairs of Powerful Owls are believed to have high fidelity to a small number of hollow-bearing nest trees and will defend a large home range of 400 hectares -1450 hectares. Sooty Owls have home ranges of between 200 hectares and 800 hectares (Higgins 1999).

Potential habitat for the forest owls occurs in the eucalypt and riparian forest and constructed wetland habitat within the study area. While it is considered likely that these species forage within the study area either regularly or occasionally, no preferred nesting habitat was observed within the area of direct impact (subject site). The project is therefore considered likely to directly impact foraging habitat only. Further foraging habitat, and potential nesting habitat may be indirectly impacted (eg edge effects) by the project. Specifically, up to 57.3 hectares of known and/or potential habitat would be modified and/or removed (30.4 hectares directly and 26.9 hectares indirectly). This equates to about 1.5 per cent of the known and/or potential habitat (eg eucalypt and riparian forest, rainforest, heathland and swamp forest) available in the locality (3805.3 hectares). Given the large home range of the forest owls; that removal of nesting habitat is unlikely; and, the extent of habitat resources available within the locality, it is unlikely that the project would disrupt the life cycle of the Barking Owl, Powerful Owl, Masked Owl or Sooty Owl.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project would remove foraging habitat for these owls including the removal of trees with hollows that provide habitat for arboreal prey species. About 30.4 hectares of foraging habitat would be removed from the subject site. An additional 26.9 hectares containing foraging habitat and potential breeding habitat would be indirectly impacted by the project. Forest owls are highly mobile and are known to have a large home range. Given the extent of foraging and breeding resources within the locality it is unlikely the disturbance of 1.5 per cent of potential habitat would be significant for the owl species.

Does the project affect any threatened species that are at the limit of its known distribution?

The Barking Owl's distribution extends across the entire mainland of Australia except for the central arid regions (DEC 2005a). The Powerful Owl is found in south eastern Australia, mainly on the coastal side of the Great Dividing Range from Mackay to south western Victoria (DEC 2005~). The Masked Owl populations are mostly found from the coast to the western plains of New South Wales (DEC 2005z), while the Sooty Owl is found along the coast, coastal escarpment and eastern tablelands of New South Wales (DEC 2005*f*). The study area is not at, or near, the limit of distribution for any of these species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation. Wildlife corridors in the study area, therefore, are limited. However, vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek form local corridors that are components of the regional Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The project crosses these local wildlife corridors thereby creating (or increasing) a barrier to fauna movement between areas of habitat within the locality. The highly mobile forest owls are unlikely to be impacted by the reduced connectivity within the locality.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Barking, Powerful, Masked or Sooty Owls (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Barking, Powerful, Masked or Sooty Owls.

Cercartetus nanus Eastern Pygmy-possum

The Eastern Pygmy-possum is listed as Vulnerable under Schedule 2 of the TSC Act.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Eastern Pygmy-possum often nests in tree hollows, but can also construct its own nests (Ward and Turner 2008). Because of its small size it is able to utilise a range of hollow sizes including very small hollows (Gibbons and Lindenmayer 1997). It has been found to shelter in rotten stumps, holes in the ground, abandoned bird-nests, ringtail possum (*Pseudocheirus peregrinus*) dreys or thickets of vegetation, (eg grass-tree skirts) (DEC 2005n). Individuals would use a number of different hollows and an individual has been recorded using up to nine nest sites within a 0.5 hectare area over a five-month period (Ward 1990). The Eastern Pygmy-possum appears to be mainly solitary with males having non-exclusive home-ranges of up to 0.75 hectare (Ward and Turner 2008) and females about 0.35 hectare (DEC 2005n).

The Eastern Pygmy-possum has not been recorded in the study area or the locality. The species has been previously recorded at eight locations within 10 kilometres of the study area (recorded between 1999 and 2007), all to the north (DECCW 2011).

The study area provides potential foraging and breeding habitat for the Eastern Pygmy-possum within the eucalypt forests and woodlands. This species may also utilise wildlife corridors within the locality to move between areas of habitat.

About 22.2 hectares of eucalypt forest (potential foraging and breeding habitat) would be removed from the study area with a further 17.5 hectares affected by indirect impacts (eg edge effects). This equates to only 1.1 per cent of potential habitat (eg eucalypt forest, heathlands and rainforest) within the locality (3532.6 hectares). The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area (see below). The project would not only result in the loss of potential habitat, it could also limit the ability of the Eastern Pygmy-possum to access other areas of habitat within the locality.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). The proposed riparian corridor enhancement and fauna under and over passes may help mitigate impacts on habitat connectivity for this species. Given the availability of potential habitat within the locality, the lack of records of the species within the locality, and provided the mitigation measures in Chapter 5 are implemented, it is considered unlikely that the project would have a significant impact on the life cycle of the Eastern Pygmy-possum.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The Eastern Pygmy-possum inhabits rainforest through to sclerophyll forest and tree heath, but in most areas woodlands and heath appear to be preferred. The species feeds largely on nectar and pollen collected from banksias, eucalypts and bottlebrushes; soft fruits are eaten when flowers are unavailable. It also feeds on insects throughout the year; this food source may be more important in habitats where flowers are less abundant such as wet forests (DEC 2005n, Ward and Turner 2008).

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Eastern Pygmy-possum. Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.6 per cent of potential habitat within the locality (3532.6 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.5 per cent of potential habitat within the locality. In total, 1.1 per cent of the potential habitat occurring in the locality would be impacted by the project.

Potential habitat in the study area forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore important for the long-term survival of the Eastern Pygmy-possum within the locality. The proposed riparian corridor enhancement (through rehabilitation and revegetation) may help mitigate impacts on habitat connectivity for this species.

It is considered unlikely that the project would have a significant impact on the habitat of the Eastern Pygmy-possum given that the potential habitat to be removed is disturbed, that similar resources occur immediately adjacent to the areas to be removed and provided that the mitigation measures to compensate for the loss of habitat connectivity described in Chapter 5 are implemented.

Does the project affect any threatened species that are at the limit of its known distribution?

The Eastern Pygmy-possum can be found throughout south-eastern Australia, from southern Queensland to eastern South Australia and Tasmania (DEC 2005n). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

The project would also result in a wider barrier for fauna attempting to cross the new highway.

How is the project likely to affect habitat connectivity?

The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of potential habitat.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). The proposed riparian corridor enhancement and fauna under and over passes may help mitigate impacts on habitat connectivity for this species.

The Eastern Pygmy-possum has been recorded to the north of the project, but not to the south. As such, the project may not impact connectivity for this species, however, the mitigation measures described in Chapter 5 would help compensate for the loss of habitat connectivity in the event the species does on occasion use habitat to the south of the upgrade.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Eastern Pygmy-possum (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Eastern Pygmy-possum.

Dasyurus maculatus maculatus Spotted-tailed Quoll

The Spotted-tailed Quoll is listed as Vulnerable under Schedule 2 of the TSC Act. The species is also listed as Endangered under the EPBC Act.

The Spotted-tailed Quoll has been previously recorded 17 times within the locality (including as close as 200 metres to the study area), predominantly north and east of the study area (although records exist in all directions beyond the locality and within 10 kilometres). These records occurred between 1980 and 2010 (DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Spotted-tailed Quoll occurs in a range of habitats including sclerophyll forest and woodlands, coastal heathlands and rainforests (Dickman and Read 1992, Edgar and Belcher 1995). Occasional sightings have been made in open country, grazing lands, rocky outcrops and other treeless areas (NPWS 1999h).

This species' habitat requirements include suitable den sites (such as hollow logs, tree hollows, rocky outcrops or caves) and an abundance of food (NPWS 1999h). The diet of juveniles is dominated by invertebrates, small mammals and birds, while the diet of adults is dominated by medium-sized mammals (Belcher *et al*. 2008). Individuals require large areas of relatively intact vegetation through which to forage (NPWS 1999h). The home range of a female is between 180 hectares – 1000 hectares, while males have larger home ranges of between 2000 hectares – 5000 hectares (Belcher *et al*. 2008).

The study area provides potential foraging and denning habitat for the Spotted-tailed Quoll within the eucalypt and riparian forests and woodlands (including hollow-bearing trees and hollow logs). This species is also likely to utilise wildlife corridors within the locality to move between areas of habitat.

About 27.8 hectares of eucalypt and riparian forest (potential habitat) would be removed from the study area. The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. Therefore, the project would not only result in the loss of potential habitat, it could also limit the ability of the Spotted-tailed Quoll to access other areas of habitat within the locality.

The project could result in either a complete halt to the movement of the Spotted-tailed Quoll across the study area or a reduced level of movement. Even a small reduction in movements can reduce genetic continuity within a population hence reducing the effective population size (Goosem 2002). In addition, the project may result in a higher rate of roadkill mortality as the species attempts to cross the wider highway.

In order to mitigate impacts of corridor fragmentation and roadkill, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). Given the availability of known and potential habitat within the locality (including protected habitat within Seven Mile Beach National Park), the high mobility of this species and provided the mitigation measures in Chapter 5 are implemented, it is considered unlikely that the project would disrupt the life cycle of the Spotted-tailed Quoll.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project would impact potential foraging and breeding habitat for the Spotted-tailed Quoll through the removal of eucalypt and riparian forest and woodland (including hollow-bearing trees and hollow logs). About 27.8 hectares of eucalypt and riparian forest (potential habitat) would be removed from the study area with a further 26.05 hectares affected by indirect impacts (eg edge effects). Within the area of DEC vegetation mapping (as amended following the field surveys), this equates to only 1.5 per cent of the potential habitat (eg eucalypt and riparian forest, rainforest and heathland) available within the locality (3667.1 hectares).

Although the Spotted-tailed Quoll is considered likely to occur in the study area, the habitat to be impacted is predominantly disturbed roadside and disturbed riparian vegetation. Regardless, this disturbed habitat forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore considered to be of high importance for the long-term survival of the Spotted-tailed Quoll within the locality. The proposed riparian corridor enhancement (through rehabilitation and revegetation) and fauna underpasses will help mitigate impacts on habitat connectivity for this species.

Does the project affect any threatened species that are at the limit of its known distribution?

Populations of the Spotted-tailed Quoll are found along both sides of the Great Dividing Range, from the Victorian to the Queensland borders (DEC 2005„). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

The project would also result in a wider barrier for the Spotted-tailed Quoll that may attempt to cross the new highway.

How is the project likely to affect habitat connectivity?

Given the distribution of records both north and south of the study area, and the close proximity of some records to the study area, it is considered likely that the Spotted-tailed Quoll occurs within and passes through the study area from time to time. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. This may result in the fragmentation of a population of Spotted-tailed Quoll into two or more populations.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna underpasses are proposed (Chapter 5). The proposed riparian corridor enhancement and underpasses will help mitigate impacts on habitat connectivity for this species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Spotted-tailed Quoll (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Spotted-tailed Quoll.

Petaurus australis Yellow-bellied Glider

The Yellow-bellied Glider is listed as Vulnerable under Schedule 2 of the TSC Act.

How is the project likely to affect the lifecycle of a threatened species and/or population?

Yellow-bellied Gliders live in family groups of between two and six individuals which commonly share a number of tree hollows. Family groups are territorial with exclusive home ranges of 30 hectares - 60 hectares depending on availability of denning hollows and food resources (NPWS 2003b). Very large expanses of forest (more than 15,000 hectares) are required to conserve viable populations (Goldingay 2008).

The Yellow-bellied Glider has not been recorded in the study area. The species has been previously recorded three times within the locality (between 1970 and 2002), twice to the north and once to the north-west (DECCW 2011). One additional record occurs about nine kilometres west of the study area and was recorded in 1970 (DECCW 2011).

The study area provides limited potential foraging habitat for the Yellow-bellied Glider within the eucalypt forests and woodlands. Based on the lack of critical habitat elements within the study area (eg sap-site trees, winter flowering eucalypts, mature trees suitable for den sites, a mosaic of different forest types and a very large expanse of forest), it is considered unlikely that the study area supports (or could support) a population of Yellow-bellied Glider. However, it is possible that the species moves through the study area on occasion between areas of potential habitat.

About 22.2 hectares of eucalypt forest (limited potential habitat) would be removed from the study area with a further 17.5 hectares affected by indirect impacts (eg edge effects). This equates to only 1.6 per cent of the potential habitat available within the locality (2425.7 hectares). The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area (see below). The project would not only result in the loss of potential habitat, it could also limit the ability of the Yellow-bellied Glider to access other areas of habitat within the locality.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). Given the availability of known and potential habitat within the locality and the reasonable mobility of this species, the project may not impact connectivity for this species. However, the mitigation measures described in Chapter 5 would help compensate for the loss of habitat connectivity in the event the species does on occasion use habitat to the south and east of the upgrade.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

Yellow-bellied Gliders are restricted to tall native forests in regions of high rainfall along the coast of NSW. Preferred habitats are productive, tall open sclerophyll forests where mature trees provide shelter and nesting hollows. The species feeds primarily on plant and insect exudates, including nectar, sap, honeydew and manna. Critical elements of habitat include sap-site trees, winter flowering eucalypts, mature trees suitable for den sites and a mosaic of different forest types (NPWS 1999j).

Known Yellow-bellied Glider feed trees (DEC 2004b) that were recorded during the field surveys include *Eucalyptus amplifolia, E. eugenioides, E. pilularis, E. saligna* and *Corymbia maculata*.

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Yellow-bellied Glider (some of which contains preferred feed tree species). Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.9 per cent of potential habitat within the locality (2425.7 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.6 per cent of the potential habitat occurring in the locality would be impacted by the project.

Potential habitat in the study area forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore important for the long-term survival of the Yellow-bellied Glider within the locality. The proposed riparian corridor enhancement (through rehabilitation and revegetation) and other measures such as rope bridges may help mitigate impacts on habitat connectivity for this species.

Given that the potential habitat to be removed is disturbed, that similar resources occur immediately adjacent to the areas to be removed and that the mitigation measures described in Chapter 5 would help compensate for the loss of habitat connectivity in the event the species does on occasion use habitat to the south and east of the upgrade, it is considered unlikely that the project would have a significant impact on the habitat of the Yellow-bellied Glider.

Does the project affect any threatened species that are at the limit of its known distribution?

The Yellow-bellied Glider can be found along the entire eastern coast of Australia from southern Queensland to Victoria (NPWS 1999j). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

The project would also result in a wider barrier for any Yellow-bellied Glider attempting to cross the new highway.

How is the project likely to affect habitat connectivity?

The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of potential habitat.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and rope bridges are proposed (Chapter 5). The proposed riparian corridor enhancement and overpasses may help mitigate impacts on habitat connectivity for this species.

The Yellow-bellied Glider has been recorded within the locality to the north of the project, but not to the south. The disturbed and patchy nature of the vegetation to the south and east of the project is not high quality habitat for this species, and it may not occur in these areas. As such, the project may not impact connectivity for this species, however, the mitigation measures described in Chapter 5 would help compensate for the loss of habitat connectivity in the event the species does on occasion use habitat to the south and east of the upgrade.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Yellow-bellied Glider (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Yellow-bellied Glider.

Phascolarctos cinereus Koala

The Koala is listed as Vulnerable under Schedule 2 of the TSC Act.

How is the project likely to affect the lifecycle of a threatened species and/or population?

Koalas live in breeding aggregations comprised of a dominant male, a small number of mature females, and juveniles (NPWS 2003a). The home range of Koalas varies depending on the quality of the habitat and the number of available food trees. Home ranges can vary from less than one hectare to 500 hectares (NPWS 2003a). Home ranges in the Pilliga State Forest overlapped for both sexes and were about 12 hectares for males and nine hectares for females. Koalas were found to continue to occupy all or part of their previous home-ranges after selective logging, and home-range sizes remained similar between logged and unlogged areas (Kavanagh *et al.* 2007).

The Koala was not recorded during the field surveys. There have been three records of the species within the locality (DECCW 2011); one record to the north and two records to the south of the study area (recorded between 2004 and 2005). Two additional records occur outside the locality but within 10 kilometres; one to the north-east (2004) and one to the south (1940).

The study area provides limited potential foraging habitat for the Koala within the eucalypt forests and woodlands. Although some preferred feed tree species were recorded during the field surveys (eg *Eucalyptus microcorys*, *E. racemosa*, *E. robusta* and *E. tereticornis*), none were dominant within the forest/woodland patches of the study area. Based on the low density of preferred feed trees and the absence of records of this well-recognised species within the study area, it is considered unlikely that the study area supports (or could support) a population of Koala. However, it is possible that the species moves through the study area on occasion between areas of potential habitat.

About 22.2 hectares of eucalypt forest (limited potential habitat) would be removed from the study area with a further 17.5 hectares affected by indirect impacts (eg edge effects). This equates to only 1.6 per cent of the potential habitat available within the locality (2425.7 hectares). The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area (see below). The project would not only result in the loss of potential habitat, it could also limit the ability of the Koala to access other areas of habitat within the locality.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). Given the availability of known and potential habitat within the locality, the reasonable mobility of this species and provided the mitigation measures in Chapter 5 are implemented, it is considered unlikely that the project would have a significant impact on the life cycle of the Koala.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The Koala inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall (Reed and Lunney 1990, NPWS 2003a). Koalas feed on the foliage of more than 70 eucalypt species and 30 non-eucalypt species, but in any one area would select preferred browse species (DEC 2005v). Primary SEPP 44 feed trees include *Eucalyptus robusta*, *E. tereticornis*, *E. punctata, E. microcorys, E. haemostoma* and *E. signata* (Department of Planning 1995). Three of these species (*E. robusta*, *E. tereticornis* and *E. microcorys*) were recorded during the field surveys. The approved recovery plan for the Koala lists additional primary and secondary feed trees for the various Koala management areas (DECC 2008b). Feed trees from the south coast management area that were recorded during the field surveys include *E. amplifolia* and *E. tereticornis* (both primary feed trees).

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Koala (some of which contains preferred feed tree species). Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.9 per cent of potential habitat within the locality (2425.7 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.6 per cent of the potential habitat occurring in the locality would be impacted by the project.

Potential habitat in the study area forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore important for the long-term survival of the Koala within the locality. The proposed riparian corridor enhancement (through rehabilitation and revegetation) and fauna underpasses may help mitigate impacts on habitat connectivity for this species.

Provided the mitigation measures described in Chapter 5 are implemented, it is considered unlikely that the project would have a significant impact on the habitat of the Koala.

Does the project affect any threatened species that are at the limit of its known distribution?

The Koala has a fragmented distribution throughout eastern Australia extending from north-east Queensland to the Eyre Peninsula in South Australia (DEC 2005v). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

The project would also result in a wider barrier for Koalas attempting to cross the new highway.

How is the project likely to affect habitat connectivity?

The Koala has been recorded within the locality to the north of the project near Foxground, and to the south near Foys Swamp and Back Forest. The Toolijooa Ridge – Harley Hill wildlife corridor may provide connectivity for this species. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of potential habitat.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). The proposed riparian corridor enhancement and fauna underpasses may help mitigate impacts on habitat connectivity for this species.

Given the availability of known and potential habitat within the locality, the reasonable mobility of this species and provided the mitigation measures in Chapter 5 are implemented, it is considered unlikely that the project would have a major impact on habitat connectivity.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Koala (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Koala.

Pototous tridactylus Long-nosed Potoroo

The Long-nosed Potoroo is listed as Vulnerable under Schedule 2 of the TSC Act. The species is also listed as Vulnerable under the EPBC Act.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Long-nosed Potoroo requires a dense understorey in heaths or forest for breeding (DEC 2005y). No heaths occur in the study area. Limited potential breeding habitat occurs within the eucalypt forest patches (the riparian forest is considered unlikely to provide potential breeding resources). The potential habitat is considered only marginal due to the disturbed nature of the habitat (ie roadside), and the lack of a nearby mosaic of micro-habitats (eg from dense, floristically simple sites for nesting, to open floristically diverse sites for obtaining food (Claridge *et al.* 2007)). Within the study area, site 15 provides the most opportunities given its reasonable size and connectivity to other areas of habitat. The project would result in the removal of only roadside vegetation from site 15, leaving the remainder of the patch intact.

The Long-nosed Potoroo has been previously recorded four times within the locality (twice in 1970 and twice in 1992), both to the north and south of the study area (DECCW 2011); although only one record occurs south of the study area. Beyond the locality and within 10 kilometres, additional records exist north of the study area with a large congregation in Barren Grounds Nature Reserve.

Given that the potential habitat to be removed is disturbed, that similar resources occur immediately adjacent to the areas to be removed and provided that the mitigation measures to compensate for the loss of habitat connectivity described in Chapter 5 are implemented, it is considered unlikely that the project would affect the lifecycle of the Long-nosed Potoroo.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The Long-nosed Potoroo inhabits coastal heaths and dry and wet sclerophyll forests. In NSW it is generally restricted to coastal heaths and forests east of the Great Dividing Range, with an annual rainfall exceeding 760 mm. Dense understorey with occasional open areas is an essential part of habitat, and may consist of grass-trees, sedges, ferns or heath, or of low shrubs of tea-trees or melaleucas. A sandy loam soil is also a common feature (Johnston 2008). One study of the species found that the Long-nosed Potoroo required a mosaic of micro-habitats, from dense, floristically simple sites for nesting, to open floristically diverse sites for obtaining food. This species appears to benefit from a lack of recent disturbance, including fire (Claridge *et al.* 2007). The Long-nosed Potoroo is sedentary and tends to be solitary, although would also aggregate in small groups. The Long-nosed Potoroo forages for fleshy fruit, seeds and plant tissue, arthropods, fungi, digging in the soil much like a bandicoot (Johnston 2008).

The project would directly impact up to 27.8 hectares of limited potential foraging and breeding habitat (eucalypt and riparian forest) for the Long-nosed Potoroo. Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.8 per cent of potential habitat within the locality (3628.0 hectares). A further 26.05 hectares of eucalypt and riparian forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.5 per cent of the potential habitat occurring in the locality would be impacted by the project.

Although the Long-nosed Potoroo has the potential to occur in the study area, the habitat to be impacted is predominantly disturbed roadside and disturbed riparian vegetation. Regardless, this disturbed habitat forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore considered to be of high importance for the long-term survival of the Long-nosed Potoroo within the locality. The proposed riparian corridor enhancement (through rehabilitation and revegetation) and fauna underpasses may help mitigate impacts on habitat connectivity for this species.

Does the project affect any threatened species that are at the limit of its known distribution?

The area of occupancy of the Long-nosed Potoroo extends from Queensland to eastern Victoria and Tasmania. Within New South Wales, there is a gap in records between Gosford and Kiama of almost 150 kilometres (NSW Government 2009). While the study area does not lie at or near the limit of the overall area of occupancy of the Long-nosed Potoroo, it does occur close to the southern edge of the record gap in New South Wales.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

The project would also result in a wider barrier for the Long-nosed Potoroo that may attempt to cross the new highway.

How is the project likely to affect habitat connectivity?

Given the distribution of records both north and south of the study area it is considered possible that the Long-nosed Potoroo occurs within and passes through the study area from time to time. The fact that only one record occurs south of the study area (from 1992) may indicate the species is unlikely to cross the study area frequently or may be the result of insufficient survey in the area. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna underpasses are proposed (Chapter 5). The proposed riparian corridor enhancement and underpasses may help mitigate impacts on habitat connectivity for this species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Long-nosed Potoroo (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Long-nosed Potoroo.

Pteropus poliocephalus Grey-headed Flying-fox

The Grey-headed Flying-fox is listed as Vulnerable under Schedule 2 of the TSC Act. The species is also listed as Vulnerable under the EPBC Act.

The Grey-headed Flying-fox was recorded foraging at site 15 during the field surveys. The species has also been previously recorded six times within the locality, predominantly to the south but also to the north-east and west. These records occurred between 1994 and 2008 (DECCW 2011).

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Grey-headed Flying-fox is found in a variety of habitats, including rainforest, mangroves, paperbark swamps, wet and dry sclerophyll forests and cultivated areas (Churchill 1998). The species is a canopy-feeding frugivore and nectarivore. Their major food source is Myrtaceae blossom (mostly eucalypt) and fruits such as native figs (*Ficus* spp.) and cultivated fruit orchards (Churchill 1998). Bats commute daily to foraging areas, usually within 15 kilometres of the day roost (Strahan 1995), although some individuals may travel up to 70 kilometres.

The study area provides known and potential foraging habitat for the Grey-headed Flying-fox within the eucalypt and riparian forests and woodlands. The project would result in the removal of about 27.8 hectares of foraging habitat for this species. An additional 26.05 hectares would be indirectly impacted (eg edge effects).

No evidence of a camp site (breeding habitat) was found within the study area. No Grey-headed Flying-fox colonies have been mapped within the locality; although the Bomaderry Creek camp is located approximately 10.5 kilometres southwest of Berry, and at Comerong Island approximately 12.2 kilometres south of the study area (DECCW 2008). Given the high mobility of the Grey-headed Flying-fox (able to travel up to 70 kilometres from a camp site) and the availability of known and potential habitat in the locality (including protected habitat within Seven Mile Beach National Park), the loss of 27.8 hectares eucalypt and riparian forest (predominantly disturbed roadside and disturbed riparian habitat) is unlikely to significantly disrupt the feeding behaviour and life history of the Grey-headed Flying-fox within the study area or locality.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project would impact potential foraging habitat for the Grey-headed Flying-fox through the removal of eucalypt and riparian forest and woodland. About 27.8 hectares of eucalypt and riparian forest (known and/or potential foraging habitat) would be removed from the study area with a further 26.05 hectares affected by indirect impacts (eg edge effects). This equates to only 1.4 per cent of the potential habitat (eg eucalypt and riparian forest, rainforest, mangroves and paperbark swamps) available within the locality (3792.6 hectares). Given the availability of known and potential habitat within the locality (including protected habitat within Seven Mile Beach National Park), that no breeding habitat would be impacted and the high mobility of this species, it is considered unlikely that the project would have significant negative impacts on the Grey-headed Flying-fox habitat within the locality.

Does the project affect any threatened species that are at the limit of its known distribution?

Populations of the Grey-headed Flying-fox are found within 200 kilometres of the eastern coast of Australia, from Bundaberg in Queensland to Melbourne in Victoria (DEC 2005t). The study area is not at, or near, the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

Current disturbance regimes within the study area include grazing, edge effects from the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The project is likely to remove and/or modify about 53.9 hectares (27.8 hectares from direct impacts with a further 26.05 hectares indirectly impacted) of known and potential foraging habitat from the study area. The areas to be removed (predominantly roadside and riparian areas) are contiguous with intact forest that would remain. Given the availability of surrounding eucalypt and riparian forests, the small areas of proposed vegetation removal (the 27.8 hectares to be removed is made up of smaller areas spread along the 11.6 kilometres route including proposed ancillary sites) and the high mobility of the Grey-headed Flying-fox, it is considered unlikely that the project would create or exacerbate barriers for this species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Grey-headed Flying-fox (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Grey-headed Flying-fox.

Cave-dependent Micro-bats

The Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis*) and the Southern Myotis (*Myotis macropus*) are both listed as Vulnerable under Schedule 2 of the TSC Act. These two species have been considered together for this assessment based on their similar habitat requirements (ie cave-dependant).

The Eastern Bentwing-bat was detected during the field surveys at sites 3, 17, 28, 32 and close to 8. An additional four records occur within 10 kilometres of the study area (recorded between 1987 and 2007) to the north, south-east and south-west of the study area (DECCW 2011). Three of these records occur within the locality.

The Southern Myotis was recorded during the field surveys at sites 3, 15, 17, 28, 32 and close to 8. An additional three records occur within the locality (recorded between 2007 and 2008), south and south-west of the study area (DECCW 2011). No other records occur within 10 kilometres.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The Eastern Bentwing-bat and the Southern Myotis both utilise caves as roost sites. The Eastern Bentwing-bat uses a broad range of habitats including rainforests, wet and dry sclerophyll forests, open woodlands and open grasslands (Churchill 2008). The species roosts in caves, but can also use man-made structures such as mines and road culverts (Churchill 2008, Dwyer 1995). Specific caves are used as nursery caves, containing a large number of individuals, which can be used year after year (Churchill 2008, Dwyer 1995).

The Southern Myotis requires permanent water bodies, including streams, lakes and reservoirs for foraging (Churchill 2008). The Southern Myotis most commonly forages by raking the surface of waterbodies with their large, clawed feet to catch aquatic insects and small fish (Churchill 2008, Richards *et al.* 2008). This species also forages aerially taking prey such as moths, beetles, crickets and flies (Churchill 2008, Richards *et al.* 2008). The Southern Myotis roosts in caves, mines or tunnels, under bridges, in buildings, tree hollows, and even in dense foliage (Richards *et al.* 2008).

The study area provides known and/or potential foraging habitat in the form of eucalypt and riparian forests and constructed wetlands. No breeding or preferred roosting habitat (ie caves) occurs in the study area. Both species may roost under bridges or in culverts within the study area (although no evidence of roosting bats was observed under bridges or in culverts during the field surveys). The Southern Myotis may also roost in tree hollows within the study area, particularly near water bodies.

The project is likely to directly remove and/or modify about 27.8 hectares of potential foraging and roosting habitat for these species with a further 26.05 hectares likely to be indirectly impacted. It is unlikely that the project would remove or disturb caves within the study area; as such breeding habitat is unlikely to be impacted Although no evidence of roosting bats was observed under bridges or in culverts during the field surveys, pre-decommission surveys immediately prior to works have been detailed in the mitigation measures described in Chapter 5. Given the mobility of these species, the extent of available foraging and roosting habitat within the locality (3792.6 hectares) and the establishment of bat roost boxes, it is unlikely the lifecycle of the Eastern Bentwing-bat or Southern Myotis would be affected by the project.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

Potential foraging grounds and potential roost sites for the two bat species may be impacted by vegetation clearing and run-off into waterways due to the project. Sedimentation barriers are expected to be installed as part of the construction phase which would reduce run-off into waterways.

About 27.8 hectares of potential habitat would be directly impacted with a further 26.05 hectares likely to be indirectly impacted. Potential habitats are widely distributed within the locality (3792.6 hectares); the project would result in the loss and/or disturbance of up to 1.4 per cent of these habitats. As such it is unlikely the habitat to be affected by the project (which is predominantly disturbed roadside and disturbed riparian vegetation) would be considered significant.

Does the project affect any threatened species that are at the limit of its known distribution?

Eastern Bentwing-bat populations are found along the east and north-west coasts of Australia (DEC 2005k) while Southern Myotis populations are found along the coast from the north-west of Australia, across the top-end and south to western Victoria (DEC 2005w). The study area is not at, or near, the limit of distribution for either of these species.

How is the project likely to affect the current disturbance regimes?

The study area has been subjected to ongoing disturbances from grazing and edge effects due to the current highway, rural development and associated infrastructure. The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation; wildlife corridors in the study area, therefore, are limited. However, vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek form local corridors that are components of the regional Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. The project crosses these local wildlife corridors thereby creating (or increasing) a barrier to fauna movement between areas of habitat within the locality. The Eastern Bentwing-bat and the Southern Myotis are highly mobile; therefore it is unlikely that these two bat species would be impacted by the reduced connectivity within the locality.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Eastern Bentwing-bat or the Southern Myotis (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Eastern Bentwing-bat or Southern Myotis.

Hollow-dependent Micro-bats

The Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*), Eastern Freetail Bat (*Mormopterus norfolkensis*), Eastern False Pipistrelle (*Falsistrellus tasmaniensis*) and Greater Broad-nosed Bat (*Scoteanax rueppellii*) are listed as Vulnerable under Schedule 2 of the TSC Act. These four species have been considered together for this assessment based on their similar habitat requirements (ie tree hollow-dependant).

Note: a taxonomic revision of Australian molossids has led to a change of the Eastern Freetail Bat's scientific name from *Mormopterus norfolkensis* to *Micronomus norfolkensis* (Churchill 2008) however, as Census of Australian Vertebrates and OEH are yet to adopt the name change, *Mormopterus norfolkensis* is used in this report.

The Yellow-bellied Sheathtail-bat was detected during the field surveys at sites 3, 17, 28 and close to site 8. Four other records occur within 10 kilometres of the study area (recorded in 1995 and 2007) to the south and south-west of the study area (DECCW 2011). Two of these records occur within the locality.

The Eastern Freetail Bat was detected during the field surveys at sites 3, 17, 28, 32 and close to site 8. An additional three records occur within the locality (recorded between 2007 and 2008), south and south-west of the study area (DECCW 2011). No other records occur within 10 kilometres.

The Eastern False Pipistrelle was recorded during the field surveys at site 15. An additional three records occur within 10 kilometres of the study area (recorded between 1999 and 2008) to the north-east, south-east and south of the study area (DECCW 2011). Two of these records occur within the locality and the third occurs just outside the locality.

The Greater Broad-nosed Bat was detected during the field surveys at sites 3, 15, 18, 32 and close to site 8. An additional four records occur within the locality (recorded between 1995 and 2007), north, south and south-west of the study area (DECCW 2011). No other records occur within 10 kilometres.

How is the project likely to affect the lifecycle of a threatened species and/or population?

All four bat species are known to be tree-hollow dependent (Churchill 2008). The Greater Broad-nosed Bat and Eastern Freetail Bat tend to forage along gaps and edges of forests and bushland patches (Churchill 2008), whereas the Eastern False Pipistrelle and Yellow-bellied Sheathtail-bat are faster fliers with greater manoeuvrability. The Eastern False Pipistrelle forages below or within the forest canopy while the Yellow-bellied Sheathtail-bat forages above the canopy (Churchill 2008).

The study area provides known and/or potential foraging and breeding habitat for the four bat species within the eucalypt and riparian forests and constructed wetlands. The project is likely to remove and/or disturb trees that provide potential breeding habitat for these species, and known/potential foraging grounds. Potential habitat to be disturbed by the project represents about 1.4 per cent of the available habitat (eg eucalypt and riparian forest, rainforest, heathland, swamp forest and wetlands) within the locality (3792.6 hectares). Given the four bat species are mobile, the extent of further breeding and foraging resources within the locality and the establishment of bat roost boxes, it is unlikely the project would disrupt the life cycle of the Yellow-bellied Sheathtail-bat, Eastern Freetail Bat, Eastern False Pipistrelle or Greater Broad-nosed Bat.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

The project is likely to remove and/or disturb potential breeding and foraging resources for the four species within the study area. About 27.8 hectares of potential habitat would be directly impacted with a further 26.05 hectares likely to be indirectly impacted. Potential breeding and foraging habitats are widely distributed within the locality (3792.6 hectares); as such it is unlikely the habitat to be affected by the project (which is predominantly disturbed roadside and disturbed riparian vegetation) would be considered significant.

Does the project affect any threatened species that are at the limit of its known distribution?

The Yellow-bellied Sheathtail-bat has a large distribution extending across northern and eastern Australia (DEC 2005•) . The Eastern Freetail Bat is found along the entire east coast from south Queensland to southern New South Wales (DEC 2005m). The Eastern False Pipistrelle has populations occurring from southern Queensland to Victoria and Tasmania (DEC 2005l), while the Greater Broad-nosed Bat is also found along coastal eastern Australia from north-eastern Victoria to the Atherton Tableland, Queensland (DEC 2005r). As a result the study area is not at, or near, the limit of distribution for any of these species.

How is the project likely to affect the current disturbance regimes?

Current disturbance regimes include grazing and edge effects associated with the existing highway (rural residential development and infrastructure). The project is likely to result in further disturbance from the road construction, although this would be temporary, and additional edge effects such as an increase in weeds and anthropogenic activities associated with the new highway.

How is the project likely to affect habitat connectivity?

The majority of the study area is covered by cleared areas and grazed paddocks that contain little native vegetation. Wildlife corridors intersected by the study area include the Seven Mile Beach National Park – Barren Grounds Nature Reserve wildlife corridor. Vegetation remnants at Toolijooa Ridge, Broughton Creek, site 15, Broughton Mill Creek and Bundewallah Creek are discontinuous parts of this corridor.

The project would involve removal of potential habitat from the study area. This is likely to cause some impact on local wildlife corridors, particularly where the project crosses Toolijooa Ridge (once) and Broughton Creek (three times). However, given the mobility of the four bat species, it is unlikely the project would create new barriers or exacerbate existing barriers for these species.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Yellow-bellied Sheathtail-bat, Eastern Freetail Bat, Eastern False Pipistrelle or the Greater Broad-nosed Bat (DECC 2008a).

Conclusion

Based on the above assessment the project is considered unlikely to have a significant impact on the Yellow-bellied Sheathtail-bat, Eastern Freetail Bat, Eastern False Pipistrelle or Greater Broad-nosed Bat.

Litoria aurea **Green and Golden Bell Frog**

The Green and Golden Bell Frog is listed as endangered under Schedule 1 of the TSC Act and vulnerable under the EPBC Act.

Literature detailing Green and Golden Bell Frog habitat in NSW suggests that suitable breeding habitat for the species consists of ponds or slowly moving water bodies that are shallow (i.e. less than one metre deep), sunny (i.e. exposed to direct sunlight for at least six hours a day during the spring/summer season), fish-free, contain open water and emergent vegetation, and experience certain kinds of disturbance regimes such as fluctuating water level or inflow of salty water (Pyke and White 1996; Pike and White 2010; White and Pyke 2008; Pyke *et al.* 2002). The species also requires foraging and sheltering habitat in the form of low vegetation or solid object such as rock, timber and other human artefacts as well as submerged and floating vegetation over the water body. The species is known to disperse over large distances between suitable waterbodies. It is likely that the species disperses from core populations during seasons of high reproductive success.

The Green and Golden Bell Frog is known to breed during late winter to early autumn with a peak around January-February after heavy rain or storms (DSEWPaC 2011; Daly 1995; White 2001). Males call mostly at night, but occasionally by day (NSW DEC 2005g). The Green and Golden Bell Frog has a high fecundity with average clutch sizes containing approximately 3700 eggs (Pyke and White 2001; DSEWPaC 2011). Spawn is laid among aquatic vegetation and has been observed in December, January and February (Daly 1995). Metamorphosis appears to take six weeks on average following the hatching of eggs (Anstis 2002; DEWPaC 2011).

Gambusia are capable of preying on hatchlings and tadpoles of the Green and Golden Bell Frog and, in 1999 the NSW Science Committee determined that predation by Gambusia poses a serious threat to the survival of threatened species. It is now listed as a key threatening process under Schedule 3 of the TSC Act 1995 (NSW NPWS 2003).

Green and Golden Bell Frog populations in NSW have undergone a significant decline in numbers over the past few decades. Of the 31 populations known to exist in 1995, seven are considered to be extinct and four to be probably extinct leaving only 20 known populations comprised of 24 sub-populations (White and Pyke 2008).

The subject site and study area provide limited potential breeding, foraging and sheltering habitat. Constructed wetlands with emergent reeds provide sub-optimal breeding habitat, while areas surrounding these wetlands provide suitable foraging habitat. Farm dams and sections of Town Creek, Broughton Creek and Broughton Mill Creek with no fringing or emergent vegetation are considered unlikely to provide suitable breeding habitat for this species but may provide dispersal habitat on occasion. The predatory fish, *Gambusia holbrooki* (The Plague Minnow), was recorded in all constructed wetlands across the study area and in Town Creek. Following targeted surveys for the species at sites considered to provide potential habitat, the Green and Golden Bell Frog was not detected during surveys,

Given the presence of potential breeding, foraging and sheltering habitat throughout the study area (**Table 6.1**) and the potential for the species to disperse through the subject site on occasion, a precautionary approach has been adopted and the following Part 3A assessment of significance has been undertaken on the basis of the potential for temporary modification of non-limiting dispersal habitat.

How is the project likely to affect the lifecycle of a threatened species and/or population?

The subject site does not provide breeding habitat, and no impacts to breeding habitat are likely to occur.

A Key Population of Green and Golden Bell Frog is located approximately three to five kilometres south of the study area at Coomonderry Swamp (and associated farm dams and swamps). This area is considered to be the most extensive wetland in which the frog has been recorded in New South Wales (DECC 2007). It is possible that individuals disperse from this core population to aquatic habitats of the study area in seasons of high reproductive success.

A total of 0.4 hectares (0.2 hectares as a result of the roadway and 0.2 hectares as a result of the Town Creek diversion) of constructed wetland habitat will be permanently removed as a result of the project, while an additional 0.3 hectares is considered to be indirectly impacted as a result of edge effects. The flow along the current Town Creek alignment will be maintained to an ecologically sustainable level and the management and mitigation measures in Section 5 of this report specific to other waterways will be implemented.

Given that the species was not detected during surveys, the lack of previous records in the Study area, the presence of Gambusia, and the temporary nature of impacts the project is not considered likely to impact the lifecycle for this species.

How is the project likely to affect the habitat of a threatened species, population or ecological community?

As detailed above, limited breeding and foraging habitat is present within the study area and sheltering and dispersal habitat is present in the subject site and study area. There is potential for the GGBF to disperse through the subject site and study area on occasion, particularly in seasons of high reproductive success at the nearby (3-5 km) Coomonderry Swamp population.

The potential impacts of the project are described in Section 4 of this report. No impacts to potential breeding habitat are likely to occur. The Town Creek diversion will intersect potential dispersal habitat, and although this may result in local changes to hydrology and disturbance of 0.2 hectares of constructed wetland forming part of the existing creek, the species is unlikely to regularly utilise this habitat for breeding, foraging, sheltering or over-wintering purposes due to the current disturbance regimes. Furthermore, impacts will be temporary in nature and are unlikely to permanently affect the current state of habitat. An additional 0.2 hectares of constructed habitat will be permanently removed as a result of the roadway. A number of mitigation measures have been recommended including bridges (underpasses) at each crossing of Broughton Creek and the retention and protection of existing riparian vegetation to allow for continued dispersal routes and refuge.

Given that impacts to dispersal habitat in the subject site will be temporary in nature, the flow along the current Town Creek alignment will be maintained to an ecologically sustainable level and provided that the management and mitigation measures in Section 5 of this report are adhered to, the project is not considered likely to significantly affect the habitat of this species.

Does the project affect any threatened species that are at the limit of its known distribution?

The Green and Golden Bell Frog predominately occurs in coastal lowland between Yuragir National Park in northern New South Wales and Lake Wellington in Victoria. Some inland populations occur in NSW (DECC 2008).

The study area is not at or near the limit of distribution for this species.

How is the project likely to affect the current disturbance regimes?

Disturbance regimes thought to account for the recent disappearance and overall decline Green and Golden Bell Frog numbers in NSW outlined in the *Best Practice Guidelines for Green and Golden Bell Frog habitat* (DECC 2008) are thought to include:

- Loss of habitat;
- Disease (frog chytrid fungus);
- Introduced fish (e.g. plague minnow *Gambusia holbrooki* and carp *Cyprinus carpio*, which eat the eggs, tadpoles and hatchlings;
- Competition of habitat resources.

The subject site and study area have been subjected to ongoing disturbances from the township of Berry, existing Princes Highway, grazing, farming, drainage canals across the Shoalhaven flood plain and the deliberate introduction of Gambusia and Carp (Cyprinus carpio) into privately owned aquatic habitats (Daly 1996).

The project is likely to result in the removal of 0.2 hectares of potential dispersal habitat as part of the new road alignment and modify an additional 0.2 hectares of potential dispersal habitat through the diversion of Town Creek (also thought to contain Gambusia).

Given the presence of Chytrid fungus in nearby Green and Golden Bell Frog populations (F.Lemckert pers. comm,) and the presence of Gambusia in the subject site and study area, the project is unlikely to significantly exacerbate these disturbance regimes further.

How is the project likely to affect habitat connectivity?

Eleven Key Populations are known to occur in the Shoalhaven LGA (DEC 2005). A Key Population is located approximately three to five kilometres east of the study area at Coomonderry Swamp and is considered to be the most extensive wetland in which the frog has been recorded in New South Wales (DECC 2007). It is possible that individuals may disperse from this core population to aquatic habitats of the study area in seasons of high reproductive success.

The Town Creek diversion will intersect the low-lying closed grassland habitat throughout the study area. It is considered that this flood prone land, as well as the current established aquatic environments of the Study Area such as Town Creek, Broughton Mill Creek, Bundewallah Creek may provide dispersal habitat for the Green and Golden Bell Frog on occasion. A number of mitigation measures have been recommended including bridges (underpasses) at each crossing of Broughton Creek and the retention and protection of existing riparian vegetation to allow for continued dispersal routes and refuge.

Given that impacts to dispersal habitat in the study area will be temporary in nature, the flow along the current Town Creek alignment would be maintained to an ecologically sustainable level and provided that the dispersal opportunities are retained throughout other waterbodies (e.g. Broughton Creek underpasses), the project is not considered likely to affect habitat connectivity for the Green and Golden Bell Frog.

How is the project likely to affect critical habitat?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. Under the TSC Act, the Director-General maintains a register of critical habitat. To date, no critical habitat has been declared for the Green and Golden Bell Frog and the proposed action would not impact any other critical habitat.

Conclusion

Based on the above assessment and the 'key thresholds' listed in the steps of the assessment processes, the project is considered unlikely to have a significant impact on the Green and Golden Bell Frog as:

- The project is not likely to reduce the long-term viability of a local population of the Green and Golden Bell Frog in the Shoalhaven LGA, specifically at the Coomonderry Swamp Key Population;
- The project is not likely to accelerate the extinction of the Green and Golden Bell Frog or place it at risk of extinction; and
- The project will not adversely affect critical habitat for the Green and Golden Bell Frog.

Appendix H

Threatened fauna Part 3A assessment requirements

Potential impacts on threatened fauna and Part 3A assessment requirements

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Green and Golden Bell Frog	V	E1	Unlikely	No	No	**Yes – undertaken as a precautionary measure**	Found in marshes, dams and stream sides, particularly those containing bulrushes or spikerushes. Can also occur in highly disturbed areas including industrial sites (NPWS 1999e, White and Pyke 1996). The Green and Golden Bell Frog has been recorded south of the study area within Foys and Coomonderry Swamps. Limited potential habitat occurs within the study area in the form of constructed wetlands with emergent reeds. Farm dams with no fringing or emergent vegetation and creeklines within the study area are considered unlikely to provide potential habitat for this species. Given the isolated nature of potentially suitable wetlands within the study area, and the absence of records of this conspicuous species, it is considered unlikely that the study area supports breeding habitat. The loss of about 0.4 hectares of constructed wetland habitat (**Table 4.1**) from the subject site is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.
Spotted Harrier	-	V	Unlikely	No	No	No	The species occurs in open and wooded country with grassland nearby for hunting. It is more common in drier inland areas. Nests in trees (Marchant and Higgins 1993). Previously recorded north and south of the study area. The Spotted Harrier is likely to forage over farmland and possibly nest in forest or woodland patches within the study area. However, no limiting breeding or foraging resources would be impacted. The loss of about 27.8 hectares of non-limiting forest habitat (see **Table 4.1** directly impacted forest and woodland) over 11.6 kilometres of the project and non-limiting farmland is not likely to impact this species which is highly mobile. A Part 3A assessment of significance is not considered necessary.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Little Eagle	-	V	Unlikely	No	No	No	Most abundant in lightly timbered areas with open areas nearby, including farmland. May nest in farmland, woodland and forest in tall trees (Marchant and Higgins 1993). Previously recorded north, east and south-west of the study area. The Little Eagle is likely to forage over farmland and possibly nest in forest or woodland patches within the study area. However, no limiting breeding or foraging resources would be impacted. The loss of about 27.8 hectares of non-limiting forest habitat (see **Table 4.1** directly impacted forest and woodland) over 11.6 kilometres of the project and non-limiting farmland is not likely to impact this species which occupies a large territory. A Part 3A assessment of significance is not considered necessary.
Square-tailed Kite	-	V	Unlikely	No	No	No	Typically inhabits coastal forested and wooded lands of tropical and temperate Australia. They require large living trees for breeding, particularly near water with surrounding woodland or forest close by for foraging habitat (Marchant and Higgins 1993). Previously recorded south of the study area at Coomonderry Swamp and 10 kilometres to the south-west. The Square-tailed Kite may forage within the forests and woodlands of the study area for passerines and insects in the outer foliage and may nest in large trees along Broughton Creek. However, no limiting breeding or foraging resources would be impacted. The loss of about 27.8 hectares of non-limiting forest habitat (see **Table 4.1** directly impacted forest and woodland) over 11.6 kilometres of the project is not likely to impact this species which is known to forage within a hunting range of more than 100 square kilometres. A Part 3A assessment of significance is not considered necessary.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Osprey	M	V	Unlikely	No	No	No	The Osprey occurs in coastal waters, inlets, estuaries and offshore islands as well as terrestrial wetlands and coastal lands, catching fish for prey. It generally uses marine cliffs as nesting and roosting sites however nests can also be made high up in trees, usually within one kilometre of the sea (Marchant and Higgins 1993). The Osprey has been previously recorded south of the study area at Seven Mile Beach National Park. The species may occasionally forage over Broughton Creek within the study area. The loss of about 2.9 hectares of non-limiting Riverbank forest habitat (see **Table 4.1**) and associated creekline is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.
Blue-billed Duck Freckled Duck	-	V	Unlikely	No	No	No	The Blue-billed Duck and Freckled Duck breed in deep water in large, permanent wetlands that are heavily vegetated (Simpson and Day 1996). Neither species has been previously recorded within 10 kilometres of the study area. Limited potential habitat occurs within the study area in the form of constructed wetlands with dense fringing and emergent vegetation. Farm dams with no fringing or emergent vegetation and creeklines within the study area are considered unlikely to provide potential habitat for these species (except perhaps in times of drought). Given the poor quality of potential habitat in the study area, the absence of records of both species within 10 kilometres of the study area and the presence of more potential habitat in the locality, it is considered unlikely that the loss of about 0.4 hectares of constructed wetland habitat (**Table 4.1**) would impact these species. Part 3A assessments of significance are not considered necessary for these two ducks.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Australasian Bittern	-	V	Unlikely	No	No	No	Inhabits terrestrial and estuarine wetlands, preferring wetlands with dense vegetation including rushes and reeds (NPWS 1999a). Previously recorded north-east, south-east and south of the study area (including within Coomonderry Swamp). Limited potential habitat occurs within the study area in the form of constructed wetlands with dense fringing and emergent vegetation. Farm dams with no fringing or emergent vegetation and creeklines within the study area are considered unlikely to provide potential habitat for this species. Given the poor quality of potential habitat in the study area and the presence of higher quality known habitat in the locality, it is considered unlikely that the loss of about 0.4 hectares of constructed wetland habitat (**Table 4.1**) would impact this species. A Part 3A assessment of significance is not considered necessary.
Black Bittern	-	V	Unlikely	No	No	**Yes**	Found along timbered watercourses, in wetlands with fringing trees and shrub vegetation. The sites where they occur are characterised by dense waterside vegetation (NPWS 1999b). Previously recorded on the edge of the study area adjacent to Town Creek (south of Berry) and south-east of the study area at Black Head. Limited potential habitat occurs within the study area in the form of creeklines and constructed wetlands where dense fringing and emergent vegetation occurs. Not all sections of creekline within the study area contain dense waterside vegetation and therefore, not all sections of creekline within the study area are considered potential habitat. Although no limiting breeding or foraging resources would be impacted, the project has the potential to affect connectivity between areas of potential habitat for the Black Bittern. Therefore a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Bush Stone-curlew	-	E1	Unlikely	No	No	**Yes**	Prefers lightly timbered open forest and woodland, or partly cleared farmland with remnants of woodland (Marchant and Higgins 1993). Previously recorded once, about nine kilometres south of the study area. Potential habitat occurs within the forests and woodlands and surrounding farmland of the study area. Although no limiting breeding or foraging resources would be impacted, the project has the potential to affect connectivity between areas of potential habitat for the Bush Stone-curlew. Therefore a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.
Gang-gang cockatoo	-	V	Possible	No	Yes	**Yes**	In low altitudes occurs in drier, more open eucalypt forests and woodlands. Breeds in tree hollows in montane forests (Higgins 1999). The Gang-gang Cockatoo was recorded during the field surveys south of the study area at site 8. The species has also been previously recorded north, south, east and west of the study area. The Gang-gang Cockatoo may forage within the forests and woodlands and nest in tree hollows of the study area. Given the number of records of the species in the locality and the loss of potential limiting breeding resources (ie tree hollows), a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.
Glossy Black-cockatoo	-	V	Possible	Yes	Yes	**Yes**	Inhabits forest with low nutrients, characteristically with key *Allocasuarina* spp. Breeds in tree hollows (NPWS 1999c). The Glossy Black-cockatoo was recorded during field surveys undertaken within the study area. The species has also been previously recorded north, south, east and west of the study area (although never within the locality; five kilometres). The Glossy Black-cockatoo may forage within the forests and woodlands and nest in tree hollows of the study area. Given the distribution of records of the species in relation to the study area and the loss of potential limiting breeding (ie tree hollows) and foraging (ie *Allocasuarina littoralis*) resources, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Greater Sand Plover	M	V	Unlikely	No	No	No	Forages on intertidal sand and mudflats in estuaries, roosting during high tide on sandy beaches or rocky shores. Occasional sightings have also occurred on near-coast saltlakes, brackish swamps, shallow freshwater wetlands and grassed paddocks (NPWS 1999d). Previously recorded once, south-east of the study area at Seven Mile Beach National Park. No limiting breeding or foraging resources would be impacted and therefore a Part 3A assessment of significance is not considered necessary.
Black-necked Stork	-	E1	Unlikely	No	No	No	Found in swamps, mangroves and mudflats. Can also occur in dry floodplains and irrigated lands and occasionally forages in open grassy woodland. Nests in live or dead trees usually near water (Pizzey and Knight 1997). Previously recorded south-east of the study area at Crooked River and south of the study area at Coomonderry Swamp (records over 30 years old). Within the study area, the species may forage within farmland (including farm dams) and nest in trees along Broughton Creek. However, no limiting breeding or foraging resources would be impacted. The loss of non-limiting farmland habitat and about 2.9 hectares of non-limiting Riverbank forest habitat (**Table 4.1**) is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.
Wompoo Fruit-dove Rose-crowned Fruit-dove Superb Fruit-dove	-	V	Unlikely	Yes	No	No	These species occur in rainforests and forage on fruit-bearing trees (Higgins and Davies 1996) such as those present within subtropical complex rainforest in the locality. Neither the Wompoo nor Rose-crowned Fruit-doves have been previously recorded within 10 kilometres of the study area. One record of the Superb Fruit-dove occurs outside the locality. Limited potential habitat occurs in the study area where fruit-bearing trees occur within forest close to rainforest. However, as no rainforest habitat (and therefore no limiting resources) would be impacted by the project, a Part 3A assessment of significance is not considered necessary for these species.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Pied Oystercatcher	-	V	Unlikely	No	No	No	An intertidal forager found on undisturbed sandy beaches and spits, tidal mudflats and estuaries. Occasionally found in paddocks near the coast (Pizzey and Knight 1997). Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp. No limiting breeding or foraging resources would be impacted by the project and therefore a Part 3A assessment of significance is not considered necessary.
Comb-crested Jacana	-	V	Unlikely	No	No	No	Occurs in freshwater wetlands, lagoons, Billabongs, swamps, lakes, rivers and reservoirs, generally with abundant floating aquatic vegetation (Marchant and Higgins 1993). The Comb-crested Jacana has not been previously recorded within 10 kilometres of the study area. Given the poor quality of potential habitat in the study area and the presence of higher quality known habitat in the locality, it is considered unlikely that the loss of about 0.4 hectares of constructed wetland habitat (Table 4.1) would impact this species. A Part 3A assessment of significance is not considered necessary.
Regent Honeyeater	E	E1	Unlikely	No	No	No	A semi-nomadic species occurring in temperate eucalypt woodlands and open forests. Most records are from box-ironbark eucalypt forest associations and wet lowland coastal forests (NPWS 1999g, Pizzey and Knight 1997). Previously recorded south of the study area at Seven Mile Beach National Park. The study area does not contain any of the preferred forest types for the Regent Honeyeater. The species may occasionally forage within the eucalypt forests of the study area however, no limiting foraging resources would be impacted. Further, the study area does not provide any breeding habitat for the species. The loss of about 22.2 hectares of non-limiting eucalypt forest/woodland habitat (see **Table 4.1** directly impacted eucalypt forest) is considered unlikely to impact this mobile species. Therefore a Part 3A assessment of significance is not considered necessary.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
White-fronted Chat	-	V	Unlikely	No	No	No	The White-fronted Chat breeds and forages in saltmarsh and mangroves. The species may forage in open grasslands and sometimes in low shrubs bordering wetland areas. The White-fronted Chat has been previously recorded south of the study area in Coomonderry Swamp. The study area does not support preferred habitat however marginal potential habitat may occur in open grasslands surrounding constructed wetland habitat. Given the poor quality of potential habitat in the study area and the presence of higher quality known habitat in the locality, it is considered unlikely that the loss of about 0.4 hectares of constructed wetland habitat (**Table 4.1**) would impact this species. A Part 3A assessment of significance is not considered necessary.
Varied Sittella	-	V	Unlikely	No	No	No	Inhabit a wide variety of dry eucalypt forests and woodlands (Higgins and Peter 2002). Build nests in upright tree forks. Previously recorded north and south of the study area. Potential habitat occurs for this species within the study area in eucalypt forests and woodlands. The direct and permanent loss of about 22.2 hectares of non-limiting eucalypt forest/woodland habitat (see **Table 4.1**) is considered unlikely to impact this mobile species. Therefore a Part 3A assessment of significance is not considered necessary.
Olive Whistler	-	V	Unlikely	No	No	No	Found in a range of habitats including alpine thickets, wetter rainforest/woodlands, riparian vegetation and heaths (Pizzey and Knight 1997). Previously recorded north and south of the study area. Within the study area the species may forage within the forest/woodland patches (including riparian forest) and nest in forks of low shrubs. However, no limiting foraging or breeding resources would be impacted. The direct and permanent loss of about 27.8 hectares of non-limiting forest and woodland habitat (see **Table 4.1**) over 11.6 kilometres of the project is not likely to impact this mobile species. A Part 3A assessment of significance is not considered necessary.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Eastern Bristlebird	E	E1	Unlikely	No	No	No	Found in coastal woodlands, dense scrub and heathlands, particularly where it borders taller woodlands (Pizzey and Knight 1997). One recent record (2010) occurs north of the study area in Broughton. Also previously recorded north of the study area at Barren Grounds Nature Reserve. The study area does not contain preferred breeding or foraging habitat for this species (dense heath/sedgeland). The loss of non-limiting farmland predominantly bordering existing roadside is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.
Diamond Firetail	-	V	Unlikely	No	No	No	Found in a range of habitat types including open eucalypt forest, mallee and acacia scrubs (Pizzey and Knight 1997). Often occur in vegetation along watercourses (Higgins *et al.* 2006). The study area may provide potential habitat in the form of eucalypt woodlands with a grassy understorey however no preferred habitat occurs in the study area. Further, the Diamond Firetail has not been previously recorded within 10 kilometres of the study area. The direct and permanent loss of about 27.8 hectares non-limiting forest and woodland habitat (see **Table 4.1**) over 11.6 kilometres of the project and non-limiting farmland is not likely to impact this mobile species. A Part 3A assessment of significance is not considered necessary.
Scarlet Robin	-	V	Unlikely	No	No	No	Occurs in forests, woodlands; and heavier vegetation when breeding. During autumn and winter occurs in more open and cleared areas (Morcombe 2003). Previously recorded north and south of the study area, but not within the locality. The Scarlet Robin may forage within the forests, woodlands and farmland of the study area for invertebrates and may build a nest within a fork of a tree (NSW Scientific Committee 2009b). However, no limiting breeding or foraging resources would be impacted. The direct and permanent loss of about 27.8 hectares non-limiting forest and woodland habitat (see **Table 4.1**) over 11.6 kilometres of the project and non-limiting farmland is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Flame Robin	-	V	Unlikely	No	No	No	The preferred habitat in summer includes eucalyptus forests and woodland, whilst in winter prefers open woodlands and farmlands (Morecombe 2003). Previously recorded north of the study area, but not within the locality. The Flame Robin may forage within the forests, woodlands and farmland of the study area for invertebrates and may build a nest near the ground in a sheltered niche, ledge or shallow cavity in a tree, stump or bank (NSW Scientific Committee 2009a). However, no limiting breeding or foraging resources would be impacted. The direct and permanent loss of about 27.8 hectares non-limiting forest and woodland habitat (see **Table 4.1**) over 11.6 kilometres of the project and non-limiting farmland is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.
Little Lorikeet	-	V	Possible	No	Yes	**Yes**	Mostly occurs in dry, open eucalypt forests and woodlands. Nests in hollows, particularly in *Eucalyptus viminalis*, *E. blakelyi* and *E. dealbata* (NSW Scientific Committee 2008b). Previously recorded south of the study area at Seven Mile Beach National Park and Coomonderry Swamp as well as 10 kilometres to the north of the study area. Within the study area the species may forage on nectar and pollen within the forest/woodland patches and nest in tree hollows (although none of the preferred tree species occur in the study area). Given the loss of potential limiting breeding resources (ie tree hollows), a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Swift Parrot	E	E1	Unlikely	Yes	No	**Yes**	The Swift Parrot occurs in woodlands and forests of NSW from May to August, where it feeds on eucalypt nectar, pollen and associated insects (Forshaw and Cooper 1981). Breeds in Tasmania (Pizzey and Knight 1997). Previously recorded north and south of the study area. Within the study area the Swift Parrot may forage within the eucalypt forest/woodland patches on/among tree species such as *Corymbia maculata, C. gummifera* and *Eucalyptus pilularis*. Although no breeding habitat occurs, given the loss of preferred feed tree species, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.
Orange-bellied Parrot	ZM	C1	Unlikely	No	No	No	A coastal species inhabiting saltmarshes, sedgeplains, coastal dunes, pastures, shrublands and moorlands, generally within 10 kilometres of the coast. Breeds in Tasmania (OBPRT 1998). Previously recorded once, 9.5 kilometres south of study area. Within the study area the Orange-bellied Parrot may forage within farmland, however the species is more likely to utilise pastures adjacent to saltmarshes, which are absent from the study area. No limiting breeding or foraging resources would be impacted and therefore a Part 3A assessment of significance is not considered necessary.
Turquoise Parrot	-	V	Unlikely	No	Yes	**Yes**	Occurs in open woodlands and eucalypt forests with a ground cover of grasses and understorey of low shrubs (Morris 1980). Nest in hollow-bearing trees, either dead or alive; also in hollows in tree stumps (Higgins 1999). Previously recorded north of the study area at Barren Grounds Nature Reserve. Within the study area the Turquoise Parrot may forage within the forests and woodlands and surrounding farmland, and nest in tree hollows. Given the loss of potential limiting breeding resources (ie tree hollows), a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Eastern Ground Parrot	-	V	Unlikely	No	No	No	Mainly found in heathland, sedgeland or buttongrass plains providing medium to dense cover (Higgins 1999). One recent record (2010) occurs north of the study area in Broughton. Also previously recorded north of the study area at Barren Grounds Nature Reserve and once to the south at Seven Mile Beach National Park. The study area does not contain preferred breeding or foraging habitat for this species (dense heath/sedgeland). The loss of non-limiting farmland predominantly bordering existing roadside is not likely to impact this species. Therefore, a Part 3A assessment of significance is not considered necessary.
Australian Painted Snipe	V	E1	Unlikely	No	No	No	Prefers freshwater wetlands, ephemeral or permanent, although they have been recorded in brackish waters (Marchant and Higgins 1993). Not previously recorded within 10 kilometres of the study area. Potential habitat occurs within the study area in the form of constructed wetlands with emergent vegetation. Some farm dams surrounded by a grassy seepage area may also provide potential habitat for this species. Given the poor quality of potential habitat in the study area, the absence of records of the species within 10 kilometres and the presence of higher quality potential habitat in the locality (eg Foys and Coomonderry Swamps), it is considered unlikely that the loss of about 0.4 hectare of constructed wetland habitat (**Table 4.1**) and non-limiting farmland would impact this species. A Part 3A assessment of significance is not considered necessary.
Barking Owl Powerful Owl Masked Owl Sooty Owl	-	V	Possible	No	Yes	**Yes**	Inhabit a range of wooded habitats, including rainforest (Higgins 1999). All species have been previously recorded in the locality and the Powerful Owl was recorded during the field surveys (from site 15). These species forage over large home ranges for ground-dwelling and/or arboreal mammals. However, the foraging habitat within the study area is not considered to be limiting for these mobile species. These owls breed in tree hollows. Given the loss of potential limiting breeding resources (ie tree hollows), a Part 3A assessment of significance has been completed for these species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Eastern Pygmy-possum	-	V	Unlikely	No	No	**Yes**	Inhabits rainforest through to sclerophyll forest and tree heath. Banksias and myrtaceous shrubs and trees are a favoured food source (Turner and Ward 1995). Previously recorded between six kilometres and 10 kilometres north of the study area, but not within the locality. The Eastern Pygmy-possum breeds in hollows, cracks or fissures more than two centimetres diameter in trees, stumps or logs, or disused bird's nests or accumulations of shredded bark or leaf clumps in tree forks or under loose bark of eucalypts (DEC 2005n). Further, individuals will use a number of different hollows/nest sites (Ward 1990). Given this, the study area is considered unlikely to provide limiting breeding resources. The Eastern Pygmy-possum feeds largely on nectar and pollen collected from banksias, eucalypts and bottlebrushes (DEC 2005n). The study area is also considered unlikely to provide limiting foraging resources. Although no limiting breeding or foraging resources would be impacted, the project has the potential to affect connectivity between areas of potential habitat for the Eastern Pygmy-possum. Therefore, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.
Spotted-tailed Quoll	E	V	Unlikely	No	Yes	**Yes**	Uses a range of habitats including sclerophyll forests and woodlands, coastal heathlands and rainforests (Dickman and Read 1992). Habitat requirements include suitable den sites, including hollow logs, hollow-bearing trees, rock crevices and caves, an abundance of food and an area of intact vegetation in which to forage (Edgar and Belcher 1995). Previously recorded just north of the study area at Broughton (east of site 15) and 0.5 kilometres south-east of the Toolijooa Road and Princes Highway intersection. Records further north and south exist also. In addition to the loss of a limiting breeding resource (ie tree hollows), the project has the potential to affect connectivity between areas of potential habitat for the Spotted-tailed Quoll. Therefore, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
White-footed Dunnart	-	V	Unlikely	No	No	No	Found in coastal dune vegetation, coastal forest, tussock grassland and sedgeland, heathland, woodland and forest. Shelter in a variety of microhabitats including hollows at the base of trees or fallen timber, burrows, grass clumps and rock crevices. The White-footed Dunnart is an opportunistic carnivore that feeds on a variety of ground-dwelling invertebrates and, occasionally, small lizards (DEC 2005Ž). Individuals occupy very small, discrete home ranges (80 metres–100 metres in length). Not previously recorded within 10 kilometres of the study area. The closest records occur about 23 kilometres north-west and south-west of the study area and are almost 15 years old. Within the study area, potential habitat is considered limited at best but may occur within the forest and woodland patches. No limiting breeding or foraging resources would be impacted. Given the above, it is considered unlikely that the White-footed Dunnart would be impacted by the project and therefore, a Part 3A assessment of significance is not considered necessary.
Yellow-bellied Glider	-	V	Unlikely	No	No	**Yes**	Preferred habitats are productive, tall open sclerophyll forests where mature trees provide shelter and nesting hollows. Critical elements of habitat include sap-site trees, winter flowering eucalypts, mature trees suitable for den sites and a mosaic of different forest types (NPWS 1999j). Very large expanses of forest (more than 15,000 hectares) are required to conserve viable populations (Goldingay 2008). Previously recorded north and north-west of the study area, within the locality. Based on the lack of key habitat elements within the study area, it is considered unlikely that the study area supports (or could support) a population of Yellow-bellied Glider. However, it is possible that the species moves through the study area on occasion between areas of potential habitat. Therefore, as the project has the potential to affect connectivity between areas of potential habitat for the Yellow-bellied Glider, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Koala	V	V	Unlikely	No	No	**Yes**	Koalas feed almost exclusively on eucalypt foliage, and their preferences vary regionally (Martin *et al*. 2008). Primary feed trees include *Eucalyptus robusta, E. tereticornis, E. punctata, E. haemostoma* and *E. signata* (Department of Planning 1995). The Koala has been previously recorded north and south of the study area. Although some preferred feed tree species were recorded during the field surveys (eg *Eucalyptus microcorys, E. racemosa, E. robusta and E. tereticornis*), none were dominant within the forest/woodland patches of the study area. Based on the low density of preferred feed trees and the absence of records of this conspicuous species within the study area, it is considered unlikely that the study area supports (or could support) a population of Koala. However, it is possible that the species moves through the study area on occasion between areas of potential habitat. Therefore, as the project has the potential to affect connectivity between areas of potential habitat for the Koala, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.
Long-nosed Potoroo	V	V	Unlikely	No	No	**Yes**	Inhabits coastal heath and wet and dry sclerophyll forests. Requires relatively thick ground cover where the soil is light and sandy. Previously recorded north and south of the study area, including within the locality. Potential habitat within the study area is considered to be limited but may occur within the forest and woodland patches. Although no limiting breeding or foraging resources would be impacted, the project has the potential to affect connectivity between areas of potential habitat for the Long-nosed Potoroo. Therefore, a Part 3A assessment of significance has been completed for this species and is provided in Appendix G to this report.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Grey-headed Flying-fox	V	V	Unlikely	No	No	**Yes**	This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and banksia woodlands. Roosts in large colonies (camps), commonly in dense riparian vegetation (Tidemann 1995). Recorded during field surveys at site 15. Also previously recorded north, south and south-west of the study area. Known camp site within Coomonderry Swamp. Although no limiting breeding or foraging resources would be impacted and the highly mobile species is unlikely to be impacted by habitat fragmentation, a Part 3A assessment of significance has been completed due to the known presence of the species within the study area and is provided at Appendix G to this report.
Large-eared Pied Bat	V	V	Unlikely	No	No	No	This species roosts in caves, Fairy Martin nests and mines, and beneath rock overhangs. Primarily found in dry sclerophyll forests and woodlands, but also found in rainforest fringes and subalpine woodlands (Churchill 2008, Hoye and Schulz 2008). Recorded once during 2007 surveys west of the current study area. One other record occurs 10 kilometres north of the study area. Potential habitat for the Large-eared Pied Bat within the study area is restricted to non-limiting foraging habitat (eg forest and woodland). The direct and permanent loss of about 27.8 hectares non-limiting forest and woodland habitat (see **Table 4.1**) over 11.6 kilometres of the project is not likely to impact this species. A Part 3A assessment of significance is not considered necessary.

Common name	EPBC Act	TSC Act	Potential impacts on threatened species			EP&A Act Part 3A assessment of significance required?	Reasoning
			Individual death or injury?	Loss or disturbance of limiting foraging resources?	Loss or disturbance of limiting breeding resources?		
Eastern Bentwing-bat Southern Myotis	-	V	Unlikely	No	No	**Yes**	Form maternity roosts in caves and mines. Also roost in culverts, buildings and under bridges. The Southern Myotis will also roost in tree hollows. They occur in a broad range of habitats including rainforest, wet and dry sclerophyll forest, paperbark forest and open grasslands (Churchill 2008). Forage aerially for insects. Both species were recorded during the field surveys within the study area. Although no limiting breeding or foraging resources would be impacted, given the known occurrence of the species within the study area and that the Southern Myotis may roost in tree hollows and man-made structures such as culverts, a Part 3A assessment of significance has been completed for these species and is provided in Appendix G to this report.
Yellow-bellied Sheathtail Bat Eastern Freetail Bat Eastern False Pipistrelle Greater Broad-nosed Bat	-	V	Possible	No	Yes	**Yes**	These species primarily roost and breed within tree hollows. All four microbats forage aerially for insects and may fly through the study areas hunting for moths, beetles, weevils, etc. However, the foraging habitat within the study area is not considered to be limiting for these mobile species. All four species were recorded during the field surveys within the study area. Given the loss of potential limiting breeding resources (ie tree hollows), a Part 3A assessment of significance has been completed for these species and is provided at Appendix G to this report.

Appendix I

EPBC Act Significant Impact Criteria Assessments

EPBC Act Significant Impact Criteria Assessments

Endangered and vulnerable flora species

Cynanchum elegans White-flowered Wax Plant

Cynanchum elegans is listed as a nationally Endangered species under the EPBC Act.

Potential habitat for this species is considered to exist within the warm temperate layered forest within the study area.

Is the action likely to lead to a long-term decrease in the size of a population of a species?

No individuals of *Cynanchum elegans* were recorded in the study area. The closest record to the study area, about 3.5 kilometres to the north-east, is the southernmost record of this species. The project is unlikely to lead to any decrease in this population.

Potential habitat within the study area is considered to exist within warm temperate layered forest. The project would directly impact 6.9 hectares of potential habitat for *Cynanchum elegans*. Potential habitat for the species in the locality (five kilometre radius of the study area) is 2,342.7 hectares. The project is therefore unlikely to lead to a long-term decrease in the size of an important population in the study area.

Is the action likely to reduce the area of occupancy of a species?

The closest record of *Cynanchum elegans* to the study area, about 3.5 kilometres to the north-east, is the southernmost record of this species. The study area does not currently represent an area of occupancy for this species. The warm temperate layered forest in the study area is considered potential habitat for this species.

Given the large areas of potential habitat to the west of the southernmost record of *Cynanchum elegans*, and the existing clearing, disturbance and fragmentation of potential habitat in and adjoining the study area, it is considered unlikely that the project would further limit any range extension of this species.

Is the action likely to fragment an existing population into two or more populations?

No known populations of *Cynanchum elegans* occur in the study area. Potential habitat for *Cynanchum elegans* occurs in warm temperate layered forest in the study area. The project would result in limited fragmentation, as the area of potential habitat has already been fragmented and impacted by cleared/grazing land. Therefore the project is unlikely to fragment an existing population into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

The Commonwealth Environment Minister may identify and list habitat critical to the survival of a listed threatened species or ecological community. Details of this identified habitat are recorded in the Register of Critical Habitat. To date no areas of critical habitat have been listed for *Cynanchum elegans.*

Is the action likely to disrupt the breeding cycle of a population?

Cynanchum elegans was not recorded in the study area. The closest known record of the species is about 3.5 kilometres to the northeast of the study area

The following is known about the lifecycle of *Cynanchum elegans* (DEC 2005Š):

- Flowering occurs between August and May, with a peak in November. Flower abundance on individual plants varies from sparse to prolific.
- The fruit can take up to six months to mature.
- Seed production is variable and unreliable. Seeds are wind dispersed and released in a non-dormant state, hence are unlikely to persist in the soil seedbank.
- Plants are capable of suckering from rootstock in response to occasional slashing or grazing. The fire response of the species is unknown.

As no individuals have been recorded in the study area and there are unlikely to be individuals in the soil seed bank, the project is unlikely to disrupt the breeding cycle of an important population of this species.

Is the action likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would result in direct impacts to about 6.9 hectares of potential habitat for *Cynanchum elegans*. Potential habitat for the species in the locality (five kilometre radius of the study area) is 2,342.7 hectares. The area of potential habitat that would be removed as part of the proposed development equates to 0.3 per cent of the extent of these plant communities in the locality.

The potential habitat for this species within the study area is in moderate to poor condition, due to the dominance of exotic species in the understorey, altered community structure and existing fragmentation. The project may result in an increase in the intensity of some existing impacts. However the project is not likely to result in the isolation or decrease in the availability of habitat for the species such that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat?

The project may increase the threat of weed invasion particularly given the presence of exotic perennial grasses along existing disturbed edges in the study area.

Is the action likely to introduce disease that may cause the species to decline?

The removal of about 6.9 hectares of potential habitat is not likely to introduce disease that may cause the species to decline. As a precaution, construction/earth moving vehicles should be washed down prior to use on site; this would help prevent the infection of native plants by the fungus, *Phytophthora cinnamomi*.

Is the action likely to interfere with the recovery of the species?

No recovery plan as published by DSEWPaC is available for *Cynanchum elegans.* The threatened species profile for *Cynanchum elegans* refers to nine priority actions to assist in recovery of the species (DEC 2005‰). Those relevant to the project include:

- Consider off-site impacts in the assessment of nearby developments.
- Install fencing to exclude livestock and machinery, and control access where required.
- Protect areas of known and potential habitat from clearing and further fragmentation.
- Restore degraded habitat using bush regeneration techniques.
- Mark sites and potential habitat onto maps used for planning maintenance work.
- Map known sites and conduct searches of potential habitat for new sites.

With the exception of the removal of a small area of potential habitat, the project is not inconsistent with the priority actions that relate to the recovery of *Cynanchum elegans*.

Conclusion
Based on the above assessment, *Cynanchum elegans* is unlikely to be significantly impacted by the project and, as such, a referral under the provisions of the EPBC Act is not recommended for this species.

Daphnandra sp. C 'Illawarra' Illawarra Socketwood

Daphnandra sp.C 'Illawarra' is listed as a nationally Endangered species under the EPBC Act.

Is the action likely to lead to a long-term decrease in the size of a population?

Daphnandra sp. C 'Illawarra' was not recorded in the study area; however this species was recorded in the locality during broader surveys, about 600 metres to the south of the study area around Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest about 130 metres to the south of the study area and 400 metres to the north of the study area.

Potential habitat exists within the study area in Illawarra gully wet forest and warm temperate layered forest communities. Potential habitat exists in the locality in the following vegetation communities: Buderoo temperate rainforest, coastal warm temperate rainforest, escarpment foothills wet forest, littoral thicket, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, warm temperate layered forest, subtropical dry rainforest and Yarrawarra temperate rainforest. These vegetation communities occur as scattered patches throughout the locality covering about 3011.8 hectares.

About 22.3 hectares of potential habitat for *Daphnandra* sp. C 'Illawarra' would be directly impacted as part of the project with further potential indirect impacts to an additional 15.4 hectares of potential habitat.

Direct impacts to 22.3 hectares of potential habitat for *Daphnandra* sp. C 'Illawarra' is not likely to lead to a long-term decrease in the size of a population.

Is the action likely to reduce the area of occupancy of the species?

Daphnandra sp. C 'Illawarra' is known to occupy the rocky hillsides and gullies of the Illawarra lowlands, occasionally extending onto the upper escarpment slopes and is associated with rainforest and moist eucalypt forest (DEC 2005j). The study area is at the southern limit of the known distribution of this species. The project may further isolate the southernmost records of this species from the rest of the population to the north.

Potential habitat in the locality includes the following vegetation communities: Buderoo temperate rainforest, coastal warm temperate rainforest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, warm temperate layered forest, subtropical dry rainforest and Yarrawarra temperate rainforest. These vegetation communities occur as scattered patches throughout the locality and cover an area of about 3011.8 hectares. These vegetation communities occur to the south of the known southern limit of *Daphnandra* sp. C 'Illawarra' and there are is a highly fragmented corridor across Toolijooa Ridge and Harley Hill that may facilitate any range expansion of this species.

The project is not considered likely to reduce the area of occupancy of *Daphnandra* sp. C 'Illawarra'.

Is the action likely to fragment an existing population into two or more populations?

The alignment of the project avoids direct and indirect impacts on a known population of *Daphnandra* sp. C 'Illawarra'.

The project would further fragment the already fragmented vegetation between two known populations of *Daphnandra* sp. C 'Illawarra'. These two populations are currently separated by about 850 metres with scattered patches of vegetation in poor condition between them.

Is the action likely to adversely affect habitat critical to the survival of a species?

The Commonwealth Environment Minister may identify and list habitat critical to the survival of a listed threatened species or ecological community. Details of this identified habitat are recorded in the Register of Critical Habitat. To date no areas of critical habitat has been listed for *Daphnandra* sp. C 'Illawarra'.

Is the action likely to disrupt the breeding cycle of a population?

Daphnandra sp. C 'Illawarra' was not recorded in the study area; however, this species was recorded in the locality during broader surveys, about 600 metres to the south of the study area around Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest about 130 metres to the south of the study area and 400 metres to the north of the study area.

The following is known about the breeding cycle of *Daphnandra* sp. 'Illawarra' (DEC 2005j):

- Flowers briefly in September and early October with fruits taking 10 to 12 months to mature.
- Capable of vegetative reproduction from stems (coppicing) and rhizomes (suckering).
- Low levels of seed production are suspected, with stems at most sites appearing to only produce 'pseudo-fruit' which lack seeds. Seed production has been reported from just two sites, only one of which has been confirmed to produce viable seed, and the extent to which this seed is capable of surviving in the wild is unknown.
- The pollination mechanisms of *Daphnandra* sp. C 'Illawarra' are unknown, as is the potential role that pollen vectors may play in the transfer of genetic material within and between sites.
- The predominant means of reproduction appears to be asexual (DEC 2005i).

The project is unlikely to disrupt the breeding cycle of the population of *Daphnandra* sp. C 'Illawarra' to the south of the study area.

Is the action likely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would result in direct impacts to about 22.3 hectares of potential habitat for *Daphnandra* sp. C 'Illawarra'.

The areas to be cleared to the north of the known population of *Daphnandra* sp. C 'Illawarra' include the edges of currently fragmented patches of warm temperate layered forest in poor condition along edges where large infestations of the noxious weed *Lantana camara* are present and have displaced most native species. These edges are likely to have little or no capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation.

The project would widen the existing area of cleared land, thus increasing fragmentation. However given the current fragmentation and infestation of *Lantana camara,* it is unlikely that the areas to be cleared to the north of the known population represent suitable habitat for *Daphnandra* sp. C 'Illawarra'.

On this basis, the project is not likely to result in the isolation or decrease in the availability of habitat for *Daphnandra* sp. C 'Illawarra' such that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species´ habitat?

The warm temperate layered forest to be cleared to the north of the known population of *Daphnandra* sp. C 'Illawarra' is in poor condition with large infestations of the noxious weed *Lantana camara* present. These edges are likely to have little or no capacity for the regeneration of natural vegetation without significant resources allocated to weed control and revegetation.

The project is likely to remove the portion of marginal potential habitat in the study area and remove grazing pressures from any potential habitat that remains.

Is the action likely to introduce disease that may cause the species to decline?

The direct removal of about 22.3 hectares of potential habitat is not likely to introduce disease that may cause the species to decline. As a precaution, construction/earth moving vehicles should be washed down prior to use on site; this would help prevent the infection of native plants by the fungus, *Phytophthora cinnamomi*.

Is the action likely to interfere with the recovery of the species?

A recovery plan for *Daphnandra* sp. C 'Illawarra' has been published by DSEWPaC. The threatened species profile for *Daphnandra* sp. C 'Illawarra' refers to nine priority actions to assist in recovery of the species (DEC 2005v). Those relevant to the project include (DEC 2005Š):

- Consider off-site impacts in the assessment of nearby developments.
- Install fencing to exclude livestock and machinery, and control access where required.
- Protect areas of known and potential habitat from clearing and further fragmentation.
- Restore degraded habitat using bush regeneration techniques.
- Mark sites and potential habitat onto maps used for planning maintenance work.
- Map known sites and conduct searches of potential habitat for new sites.

With the exception of the removal of 22.3 hectares of potential habitat, the project is not inconsistent with the priority actions that relate to the recovery of *Daphnandra* sp. C 'Illawarra'.

Conclusion

Based on the above assessment, *Daphnandra* sp. C 'Illawarra' is unlikely to be significantly impacted by the project and, as such, a referral under the provisions of the EPBC Act is not recommended for this species.

Irenepharsus trypherus Delicate Cress

Irenepharsus trypherus is listed as a nationally Endangered species under the EPBC Act.

Is the action likely to lead to a long-term decrease in the size of a population?

Irenepharsus trypherus was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area (DECCW 2009a). However, potential habitat does exist within the study area in Illawarra gully wet forest. Potential habitat for *Irenepharsus trypherus* is considered to include subtropical complex rainforest and wet sclerophyll forests. These include the following vegetation communities: coastal warm temperate rainforest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest, and temperate littoral rainforest. These vegetation communities occur as scattered patches throughout the locality and cover an area of about 1690.7 hectares.

About 15.4 hectares of potential habitat for *Irenepharsus trypherus* would be directly impacted as part of the project with further potential indirect impacts to an additional 10 hectares.

Direct impacts to 15.4 hectares of potential habitat for *Irenepharsus trypherus* is not likely to lead to a long-term decrease in the size of a population.

Is the action likely to reduce the area of occupancy of the species?

Irenepharsus trypherus is mostly recorded from the upper slopes of the ridge systems that extend south and east of the Illawarra escarpment, although the species has also been recorded from the deep sandstone gorges of the Shoalhaven River (DEC 2005u). There have been no recordings of the species within 10 kilometres of the study area.

The removal of 15.4 hectares of potential habitat for the species in the study area is not likely to reduce the area of occupancy of the species. Potential habitat in the locality includes the following vegetation communities: coastal warm temperate rainforest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest and temperate littoral rainforest. These vegetation communities occur as scattered patches throughout the locality and cover an area of about 1690.7 hectares.

Is the action likely to fragment an existing population into two or more populations?

No known populations of *Irenepharsus trypherus* occur in the study area. Potential habitat for *Irenepharsus trypherus* occurs in Illawarra gully wet forest in the study area. The project intersects the southern edge of a large patch of Illawarra gully wet forest at site 15, with only the currently fragmented edge being further fragmented as a result of the project. Therefore the project is unlikely to fragment an existing population into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

The Commonwealth Environment Minister may identify and list habitat critical to the survival of a listed threatened species or ecological community. Details of this identified habitat are recorded in the Register of Critical Habitat. To date no areas of critical habitat has been listed for *Irenepharsus trypherus*.

Is the action likely to disrupt the breeding cycle of a population?

The following is known about the lifecycle of *Irenepharsus trypherus* (DEC 2005u):

- Mature plants are capable of reshooting from dry or desiccated stems following light grazing, trampling, or drought.
- The species is thought to be a prolific seeder, with disturbance and light levels influencing germination.
- The fire response of this species is unknown.

Irenepharsus trypherus was not recorded in the study area, nor within a 10 kilometre radius of the study area. Since no individuals have been recorded in the study area, nor the locality, the project is unlikely to disrupt the breeding cycle of a population.

Is the action likely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The species has not been recorded in the study area nor within 10 kilometres, however potential habitat for the species occurs within Illawarra gully wet forest in the study area with further potential habitat in the locality occurring within coastal warm temperate rainforest, escarpment foothills wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest, and temperate littoral rainforest. Vegetation mapping by DEC (2005o) indicates about 1690.7 hectares of these potential habitats occur within the locality (five kilometre radius of the study area).

The potential habitat for this species within the study area ranges from poor to moderate in the southwest (sites 14 and 35), with remnant trees and a patchy or weed dominated understorey, to moderate to good condition in the central section (site 15), with a largely intact native tree, shrub and groundlayer along with infestations of woody weeds such as *Lantana camara*.

About 15.4 hectares of potential habitat for *Irenepharsus trypherus* would be directly impacted by the proposed development. The area of potential habitat for *Irenepharsus trypherus* that would be removed as part of the project equates to 0.9 per cent of the extent of similar potential habitats mapped in the locality.

Given that the species has not been recorded in the study area and the relatively small area of potential habitat to be impacted in relation to that in the locality, the project is not likely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species´ habitat?

The proposed development may increase the threat of weed invasion particularly given the presence of exotic perennial grasses along existing disturbed edges in the study area.

Is the action likely to introduce disease that may cause the species to decline?

The direct removal of about 15.4 hectares of potential habitat is not likely to introduce disease that may cause the species to decline. As a precaution, construction/earth moving vehicles should be washed down prior to use on site; this would help prevent the infection of native plants by the fungus, *Phytophthora cinnamomi*.

Is the action likely to interfere with the recovery of the species?

A recovery plan published by DSEWPaC is available for *Irenepharsus trypherus*. The threatened species profile for *Irenepharsus trypherus* refers to nine priority actions to assist in recovery of the species (DEC 2005v). Those relevant to the project include (DEC 2005Š):

- Consider off-site impacts in the assessment of nearby developments.
- Install fencing to exclude livestock and machinery, and control access where required.
- Protect areas of known and potential habitat from clearing and further fragmentation.
- Restore degraded habitat using bush regeneration techniques.
- Mark sites and potential habitat onto maps used for planning maintenance work.
- Map known sites and conduct searches of potential habitat for new sites.

The project and associated mitigation measures are not inconsistent with the above listed recovery actions.

With the exception of the removal of 15.4 hectares of potential habitat, the project is not inconsistent with the priority actions that relate to the recovery of *Irenepharsus trypherus*.

Conclusion

Based on the above assessment, *Irenepharsus trypherus* is unlikely to be significantly impacted by the project and, as such, a referral under the provisions of the EPBC Act is not recommended for this species.

Pterostylis gibbosa

Pterostylis gibbosa is listed as a nationally Endangered species under the EPBC Act.

Is the action likely to lead to a long-term decrease in the size of a population of the species?

Pterostylis gibbosa was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area (**Figure 3.2**).

The nearest populations of the species in the Shoalhaven LGA are at Worrigee Nature Reserve to the south of the study area. To the north the populations of the species are known at Albion Park in Shellharbour LGA and at Yallah in Wollongong LGA. There are no known populations of the species in the Kiama LGA.

The project will not directly or indirectly result in the decrease in the size a known population of the species in the study area, the locality, or the Sydney Basin Bioregion.

Is the action likely to reduce the area of occupancy of a population?

The study area and locality do not support a known population of the species. The project will not reduce the area of occupancy of the nearest known populations in the Shoalhaven, Shellharbour or Wollongong LGA's.

Is the action likely to fragment an existing population into two or more populations?

The study area and locality do not support a population of the species. The nearest known populations of Pterostylis gibbosa in the Shoalhaven, Shellharbour and Wollongong LGA's and elsewhere in the Sydney Basin Bioregion will not be fragmented into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

There is an approved recovery plan for *Pterostylis gibbosa* (NPWS 2002) but no habitat critical for the survival of the species has been listed on the Register of Critical Habitat maintained by the Minister for the Environment under the EPBC Act. There is no potential habitat identified for this species on the in the study area. Potential habitat for the species in the locality is not considered to be habitat critical for survival of the species. Habitat that is important for the survival of the species in the Shoalhaven, Shellharbour and Wollongong LGA's will not be adversely affected by the project. Additionally the project is unlikely to significantly affect the habitat of flora and fauna species associated with Pterostylis gibbosa to compromise its survival at a local, regional or bioregional scale.

Is the action likely to disrupt the breeding cycle of a population?

The study area and locality are not known to support an important population of *Pterostylis gibbosa*. Pterostylis species are generally pollinated by male gnats of the genus Mycomya (Fungus Gnats). Nothing is known of the habitat requirements of Mycomya however it is suggested they are probably very common, but are not often seen due to their small size. Abundance of Mycomya is believed to peak in September, which is the main month of flowering of *Pterostylis gibbosa* (NPWS 2002). Studies on pollination rates have indicated that suitable adjoining pollinator habitat to a known site may be important for pollination success in addition to pollinator availability (NPWS 2002). The seed is dispersed by wind and reliant on a mycorrhizal fungus to support the first stages of growth after germination. The species is capable of surviving fire, due to the regenerative capacity of its tuberoid.

No potential habitat for the species will be affected by the project. Additionally the majority of vegetated corridors in the locality will be retained that maintain pathways for the dispersal and exchange of genetic reproductive material and organisms that may be important components of the species lifecycle throughout the locality. This would include but not be limited to habitat for invertebrate or vertebrates providing pollination and seed dispersal for plant species that characterise vegetation *Pterostylis gibbosa* is strongly associated with.

The project is unlikely to affect fire frequency and intensity or the presence of mycorrhizal fungi the species is associated with such that the breeding cycle of an important population in the region is disrupted.

Is the action likely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Pterostylis gibbosa was not recorded in the study area and has not been previously recorded in the locality (**Figure 3.2**). There is no potential habitat for the species in the study area. Additionally the project will not result in direct or indirect impacts to any potential habitat for the species in the locality. The quality of potential habitat for *Pterostylis gibbosa* in the locality area is likely to be significantly modified due to the ongoing impacts from edge effects (eg weeds) and disturbances such as grazing.

In the locality and to the east of the project the conservation reserve Seven Mile Beach National Park is likely to support one or multiple vegetation communities that provide good quality habitat for the species.

In consideration of the above, the project is not likely to result in the isolation or decrease in the availability of habitat for the species such that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species´ habitat?

Native plant communities in the locality including those that may provide potential habitat for the species are affected by invasive exotic flora and fauna species as a result of current and previous land management. The project is unlikely to result in the further establishment of invasive flora and fauna species in the potential habitats of *Pterostylis gibbosa* in the locality.

Is the action likely to introduce disease that may cause the species to decline?

No diseases have been identified as threats to *Pterostylis gibbosa* by OEH or DSEWPaC. It is considered unlikely that the proposal would introduce any diseases that may cause the species to decline.

Is the action likely to interfere substantially with the recovery of the species?

The proposal is unlikely to interfere substantially with the recovery of *Pterostylis gibbosa* at a local, regional or bioregional level.

Conclusion

Based on the above assessment, *Pterostylis gibbosa* is unlikely to be significantly impacted by the proposal, and as such, a Referral under the provisions of the EPBC Act is not recommended for these species.

Cryptostylis hunteriana

Cryptostylis hunteriana is listed as a nationally Vulnerable species under the EPBC Act.

Is the action likely to lead to a long-term decrease in the size of an important population?

Cryptostylis hunteriana was not recorded in the study area, nor were there records for this species within a 10 kilometre radius of the study area (**Figure 3.2**).

There are no known populations of the species in the Kiama LGA. Important populations of the species to the south in Shoalhaven LGA are at Jervis Bay National Park, Triplarina Nature Reserve and Cambewarra Nature Reserve. In addition to these other important populations of the species in the Sydney Basin Bioregion are the largest known Australian population at Bulahdelah, and those at Ku-ring-gai Chase and Morton National Parks (DEWHA 2008a).

The project will not directly or indirectly result in the decrease in the size important or viable populations of the species in the study area, the locality, or the Sydney Basin Bioregion.

Is the action likely to reduce the area of occupancy of an important population?

The study area and locality do not support an important population of the species. The project will not reduce the area of occupancy of important populations in the Shoalhaven LGA, or Sydney Basin Bioregion.

Is the action likely to fragment an existing important population into two or more populations?

The study area and locality do not support an important population of the species. Important populations of *Cryptostylis hunteriana* in the Shoalhaven LGA and elsewhere in the Sydney Basin Bioregion will not be fragmented into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

No habitat critical for the survival of the species has been listed on the Register of Critical Habitat maintained by the minister under the EPBC Act. The potential habitat identified for this species on the subject site and in the study area is not considered to be habitat critical for survival of the species. Additionally the proposed action is unlikely to significantly affect the habitat of flora and fauna species associated with *Cryptostylis hunteriana* to compromise its survival at a regional or bioregional scale.

Is the action likely to disrupt the breeding cycle of an important population?

The study area and locality do not support an important population of *Cryptostylis hunteriana*. Key features of the breading cycle of the species include pollination by the male Ichneumon Wasp (*Lissopimpla excelsa*) and seeds are spread via wind transportation (DEWHA 2010a). Flowering intensity may be stimulated by previous fire events, however, fire during the flowering season has been identified as a potential threat to the species (DEWHA 2008a). The species may be dependent on a mycorrhizal fungal association (DEWHA 2008a).

Although potential habitat for the species will be affected by the proposal the majority of vegetated corridors in the locality will be retained that maintain pathways for the dispersal and exchange of genetic reproductive material and organisms that are important components of the species lifecycle throughout the locality. This would include but not be limited to habitat for the Ichneumon Wasp and other invertebrate or vertebrates providing pollination and seed dispersal for plant species that characterise vegetation *Cryptostylis hunteriana* is strongly associated with.

The project is unlikely to affect fire frequency and intensity or the presence of mycorrhizal fungi the species is associated with such that the breeding cycle of an important population in the region is disrupted.

Is the action likely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Cryptostylis hunteriana was not recorded in the study area and has not been previously recorded in the locality (**Figure 3.2**). The project would result in direct impacts to about 0.0002 hectares and indirect impacts to about 2.4 hectares of potential habitat for the species. The potential habitat for *Cryptostylis hunteriana* in the study area is significantly modified due to the ongoing impacts from edge effects (eg weeds) and disturbances such as grazing. The project may result in an increase in the intensity of some existing impacts.

In the locality and to the east of the project the conservation reserve Seven Mile Beach National Park is likely to support one or multiple vegetation communities that provide good quality habitat for the species.

In consideration of the above, the project is not likely to result in the isolation or decrease in the availability of habitat for the species such that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species habitat?

Native plant communities throughout the study area and locality including those that may provide potential habitat for the species are affected by invasive exotic flora and fauna species as a result of current and previous land management. The project is unlikely to result in the further establishment of invasive flora and fauna species in the potential habitats of *Cryptostylis hunteriana*.

Is the action likely to introduce disease that may cause the species to decline?

No diseases have been identified as threats to *Cryptostylis hunteriana* by OEH or DSEWPaC. It is considered unlikely that the proposal would introduce any diseases that may cause the species to decline.

Is the action likely to interfere substantially with the recovery of the species?

The proposal is unlikely to interfere substantially with the recovery of *Cryptostylis hunteriana* at a regional or bioregional level.

Conclusion

Based on the above assessment, *Cryptostylis hunteriana* is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for these species.

Zieria granulata Hill Zieria

Zieria granulata is listed as a nationally Vulnerable species under the EPBC Act.

Is the action likely to lead to a long-term decrease in the size of an important population?

The alignment of the project avoids direct and indirect impacts on a known population of *Zieria granulata*. This species was not recorded in the study area, but was recorded in the locality during broader surveys, about 400 metres to the south of the study area on Toolijooa Ridge. There are also a number of OEH Atlas records of this species in the locality, with the closest record about 190 metres to the south-west of the study area.

Potential habitat for *Zieria granulata* exists within rainforest, grassy woodland and wet forest communities. These include the vegetation communities: Buderoo temperate rainforest, coastal warm temperate rainforest, escarpment foothills wet forest, Littoral thickets, warm temperate layered forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest, south coast grassy woodland and Yarrawarra temperate rainforest. These vegetation communities occur as scattered patches throughout the locality covering about 3011.8 hectares. Furthermore, *Zieria granulata* can also occur in highly disturbed areas with no or limiting vegetation (DEC 2005').

About 22.3 hectares of potential habitat for *Zieria granulata* would be directly impacted by the project with further potential indirect impacts to an additional 15.4 hectares of potential habitat.

Direct impacts to about 0.7 per cent of potential habitat occurring in the locality for *Zieria granulata* is not likely to lead to a long-term decrease in the size of a population.

Is the action likely to reduce the area of occupancy of the species?

The study area is at the southern limit of the known distribution of *Zieria granulata*. The project may further isolate the southernmost records of this species from the rest of the population to the north.

Potential habitat in the locality includes the following vegetation communities: Buderoo temperate rainforest, coastal warm temperate rainforest, warm temperate layered forest, escarpment foothills wet forest, Illawarra gully wet forest, intermediate temperate rainforest, subtropical complex rainforest, subtropical dry rainforest, south coast grassy woodland and Yarrawarra temperate rainforest. These vegetation communities occur as scattered patches throughout the locality and cover an area of about 3011.8 hectares. Some of these vegetation communities occur to the south of the known southern limit of *Zieria granulata* and there are is a highly fragmented corridor across Toolijooa Ridge and Harley Hill that may facilitate any range expansion of this species.

The project is not considered likely to reduce the area of occupancy of *Zieria granulata*.

Is the action likely to fragment an existing population into two or more populations?

The alignment of the project avoids direct and indirect impacts on a known population of *Zieria granulata*. A relatively large population of this species on Toolijooa Ridge is about 400 metres to the south of the study area and would not be fragmented by the project.

The closest known record of *Zieria granulata* to the Toolijooa Ridge population is about 1.6 kilometres to the north-west. There are currently roads, cleared grazing lands and fragmented patches of vegetation between the two populations. The project would not further isolate the Toolijooa Ridge population of *Z. granulata* from another known population.

Is the action likely to adversely affect habitat critical to the survival of a species?

The Commonwealth Environment Minister may identify and list habitat critical to the survival of a listed threatened species or ecological community. Details of this identified habitat are recorded in the Register of Critical Habitat. To date no areas of critical habitat have been listed for *Zieria granulata*.

Is the action likely to disrupt the breeding cycle of a population?

Zieria granulata was not recorded in the study area. Numerous records of this species occur within 10 kilometres of the study area, with a large population on Toolijooa Ridge to the south. The closest record is about 190 metres to the south-west of the study area, near Broughton.

The following is known about the breeding cycle of *Zieria granulata* (DEC 2005):

- Flowering occurs between early spring and summer.
- Known to possess functional pollen although deformed pollen has been recorded for the species.
- Nectar seeking flies appear to be effective pollen vectors for this species; these flies are considered to be generalist pollinators and strong fliers that are capable of traversing open spaces.
- Seed dispersal is initially through forcible ejection from the mature fruit, and it is suspected that secondary dispersal by ants also occurs.

The project is unlikely to disrupt the breeding cycle of a population.

Is the action likely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Zieria granulata was not recorded in the study area. The project would result in direct impacts to about 22.3 hectares of potential habitat for the species. The potential habitat for *Zieria granulata* in the study area is already modified due to the ongoing impacts from edge effects (eg weeds) and disturbances such as grazing. The project may result in an increase in the intensity of some existing impacts. On this basis, the project is not likely to result in the isolation or decrease in the availability of habitat for the species such that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to vulnerable species becoming established in the vulnerable species´ habitat?

Many of the patches of vegetation within the study area contain exotic weeds as a dominant understorey, or have a significant amount of weeds in stratums. This is due to historic clearing and grazing in the area.

The project is likely to remove the portion of marginal potential habitat in the study area and remove grazing pressures from any potential habitat that remains.

Is the action likely to introduce disease that may cause the species to decline?

The direct removal of about 22.3 hectares of potential habitat is not likely to introduce disease that may cause the species to decline. As a precaution, construction/earth moving vehicles should be washed down prior to use on site; this would help prevent the infection of native plants by the fungus, *Phytophthora cinnamomi*.

Is the action likely to interfere with the recovery of the species?

A recovery plan published by DECC is available for *Zieria granulata*. The threatened species profile for *Zieria granulata* refers to thirteen priority actions to assist in recovery of the species (DEC 2005‘). Those relevant to the project include (DEC 2005‘):

- Consider off-site impacts in the assessment of nearby developments.
- Install fencing to exclude livestock and machinery, and control access where required.
- Protect areas of known and potential habitat from clearing and further fragmentation.
- Restore degraded habitat using bush regeneration techniques.
- Mark sites and potential habitat onto maps used for planning maintenance work.
- Map known sites and conduct searches of potential habitat for new sites.

With the exception of the removal of 22.3 hectares of potential habitat, the project is not inconsistent with the priority actions that relate to the recovery of *Zieria granulata*.

Conclusion

Based on the above assessment, *Zieria granulata* is unlikely to be significantly impacted by the project and, as such, a referral under the provisions of the EPBC Act is not recommended for this species.

Endangered and vulnerable fauna species

Lathamus discolor **Swift Parrot**

The Swift Parrot is listed as Endangered under the EPBC Act. The species is also listed as Endangered under the TSC Act.

Is there a real chance or a possibility that the action will lead to a long-term decrease in the size of a population of the species?

The Swift Parrot is a highly nomadic species that occurs in woodlands and forests in NSW (Higgins 1999). It migrates in response to food availability and seasonal changes. It is often recorded in NSW between May and August and breeds in Tasmania during the warmer seasons (Higgins 1999).

While on the mainland, Swift Parrots occur in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations. Favoured feed trees include winter-flowering species such as swamp mahogany *Eucalyptus robusta*, spotted gum *Corymbia maculata*, red bloodwood *C. gummifera*, mugga ironbark *E. sideroxylon*, and white box *E. albens*. Commonly used lerp-infested trees include grey box *E. microcarpa*, grey box *E. moluccana* and blackbutt *E. pilularis* (DEC 2005†).

The Swift Parrot has not been recorded within the study area. The species has been previously recorded once within the locality (recorded in year 2000), about 2.5 kilometres south-east of the study area within Seven Mile Beach National Park (Bird's Australia 2011). Another three records of the species occur within 10 kilometres of the study area to the north and south (DECCW 2011).

The study area provides potential foraging habitat for the Swift Parrot within the eucalypt forests and woodlands. Three favoured feed tree species (*Corymbia maculata*, *C. gummifera* and *Eucalyptus pilularis*) occur within the study area. Only one species (*E. pilularis*) is dominant within any of the plant communities (Illawarra gully wet forest). The study area does not provide potential breeding habitat as the species breeds exclusively in Tasmania (Higgins 1999).

The project would impact potential foraging habitat for the Swift Parrot through the removal of eucalypt forest and woodland. About 22.2 hectares of eucalypt forest (potential foraging habitat) would be removed from the study area with a further 17.5 hectares affected by indirect impacts (eg edge effects). This equates to less than 1.6 per cent of eucalypt forest within the locality (2425.7 hectares). Given the availability of potential foraging habitat within the locality (including known habitat protected within Seven Mile Beach National Park), that no breeding habitat would be impacted and the high mobility of this species, it is considered unlikely that the project would lead to a long-term decrease in the size of a population of the Swift Parrot.

Is there a real chance or a possibility that the action will reduce the area of occupancy of the species?

The study area does not lie at or near the limit of the area of occupancy of the Swift Parrot, which extends from south-east Queensland through New South Wales, Victoria to South Australia and Tasmania.

Given the distribution of records of the Swift Parrot within 10 kilometres of the study area and the presence of preferred feed tree species, it is possible the parrot may utilise resources within the study area from time to time. However, given the high mobility of the Swift Parrot (able to migrate between Tasmania and south eastern mainland) and the availability of known and potential habitat in the locality (including protected habitat within Seven Mile Beach National Park), the loss of 22.2 hectares eucalypt forest (predominantly disturbed roadside habitat) is unlikely to reduce the area of occupancy of the species.

Is there a real chance or a possibility that the action will fragment an existing population into two or more populations?

Swift Parrots are winter migrants to NSW, and travel to foraging sites on a cyclic basis depending on food availability (DEC 2005†). The project would involve removal of potential feed trees from the study area. The areas to be removed (predominantly roadside areas) are contiguous with intact forest that would remain. Given the availability of surrounding eucalypt forests, the small areas of proposed vegetation removal (the 22.2 hectares to be removed is made up of smaller areas spread along the 11.6 kilometre route including proposed ancillary sites) and the high mobility of the Swift Parrot, it is considered unlikely that the project would fragment an existing population into two or more populations.

Is there a real chance or a possibility that the action will adversely affect habitat critical to the survival of the species?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. A Register of Critical Habitat is maintained by the Minister under the EPBC Act. To date, no critical habitat has been declared for the Swift Parrot (DEWHA 2009d).

Critical habitat can also refer to areas that are necessary for activities such as foraging, breeding or dispersal; for the long-term maintenance of the species; to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species (DEWHA 2009d).

The project would impact potential foraging habitat for the Swift Parrot through the removal of eucalypt forest and woodland, but no breeding habitat would be impacted as this species breeds in Tasmania. The project is considered unlikely to affect habitat critical to the survival of the species, given the mobility of the species, the availability of surrounding eucalypt forests, and the small areas of proposed vegetation removal.

Is there a real chance or a possibility that the action will disrupt the breeding cycle of a population of the species?

The Swift Parrot breeds exclusively in Tasmania during the warmer seasons (Higgins 1999). It is a highly nomadic species that occurs in woodlands and forests in NSW during winter, and migrates in response to food availability and seasonal changes (Higgins 1999).

Given the impacts to potential foraging habitat are unlikely to lead to a long-term decrease in the size of a population of the Swift Parrot (described above) and that no breeding habitat would be impacted (as the species breeds exclusively in Tasmania), it is considered unlikely that the project would disrupt the breeding cycle of a population of the Swift Parrot.

Is there a real chance or a possibility that the action will modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Swift Parrot (some of which contains preferred feed tree species). Within the area of OEH vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.9 per cent of potential habitat within the locality (2425.7 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.6 per cent of the potential habitat occurring in the locality would be impacted by the project.

Although some preferred feed tree species of the Swift Parrot occur in the study area (*Corymbia maculata*, *C. gummifera* and *Eucalyptus pilularis*), the habitat to be impacted is predominantly disturbed, roadside vegetation and is considered to be of low importance for the long-term survival of the Swift Parrot. Given this, the absence of records of the species within the study area and the species' high mobility, the loss and/or disturbance of 1.6 per cent of potential habitat within the locality is considered unlikely to modify, destroy, remove,

isolate or decrease the availability or quality of habitat to the extent that the Swift Parrot is likely to decline.

Is there a real chance or a possibility that the action will result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species habitat?

Predation or competition by invasive species is not listed as a threat to the Swift Parrot by the OEH or DSEWPaC (Swift Parrot Recovery Team 2001). The project is unlikely to result in the introduction or exacerbation of any invasive species that is harmful to the Swift Parrot in the study area.

Is there a real chance or a possibility that the action will introduce disease that may cause the species to decline?

Infection by *Psittacine circoviral* (beak and feather) disease (PCD) affecting endangered psittacine species is listed as a key threatening process (NSW Scientific Committee 2008a, DEH 2005b). Swift parrots are considered to have a high potential for being adversely impacted by PCD due to their low population numbers and the fact that PCD has been recorded in wild birds in NSW (NSW Scientific Committee 2008a). The project is unlikely to result in the introduction of PCD into the study area, or increase the incidence of PCD in birds in NSW.

Is there a real chance or a possibility that the action will interfere with the recovery of the species?

DSEWPaC has developed a national recovery plan for the Swift Parrot (Swift Parrot Recovery Team 2001). One recovery objective outlined in this plan relevant to the project is:

- Implement management strategies at the landscape scale to protect and improve priority habitats and sites resulting in a sustained improvement in carrying capacity.

No breeding habitat would be impacted. Although a number of preferred feed tree species occur within the study area, only one species (*E. pilularis*) is dominant within any of the plant communities (Illawarra gully wet forest). Further, most of the potential habitat to be removed is disturbed roadside vegetation. Given the above, the low importance of the potential habitat within the study area and that only 1.6 per cent of potential habitat within the locality would be impacted, it is unlikely that the project would interfere with this recovery objective.

Conclusion

Based on the above assessment the Swift Parrot is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for this species.

Dasyurus maculatus maculatus Spotted-tailed Quoll

The Spotted-tailed Quoll is listed as Endangered under the EPBC Act. The species is also listed as Vulnerable under the TSC Act.

Is there a real chance or a possibility that the action will lead to a long-term decrease in the size of a population of the species?

The Spotted-tailed Quoll occurs in a range of habitats including sclerophyll forest and woodlands, coastal heathlands and rainforests (Dickman and Read 1992, Edgar and Belcher 1995). Occasional sightings have been made in open country, grazing lands, rocky outcrops and other treeless areas (NPWS 1999h).

This species' habitat requirements include suitable den sites (such as hollow logs, tree hollows, rocky outcrops or caves) and an abundance of food (NPWS 1999h). The diet of juveniles is dominated by invertebrates, small mammals and birds, while the diet of adults is dominated by medium-sized mammals (Belcher *et al.* 2008). Individuals require large areas of relatively intact vegetation through which to forage (NPWS 1999h). The home range of a female is between 180 hectares – 1000 hectares, while males have larger home ranges of between 2000 hectares – 5000 hectares (Belcher *et al.* 2008).

The Spotted-tailed Quoll has been previously recorded 17 times within the locality (including as close as 200 metres to the study area), predominantly north and east of the study area (although records exist in all directions beyond the locality and within 10 kilometres). These records occurred between 1980 and 2010 (DECCW 2011).

The study area provides potential foraging and denning habitat for the Spotted-tailed Quoll within the eucalypt and riparian forests and woodlands. This species is also likely to utilise wildlife corridors within the locality to move between areas of habitat.

About 27.8 hectares of eucalypt and riparian forest (potential habitat) would be removed from the study area with a further 26.05 hectares affected by indirect impacts (eg edge effects). This equates to only 1.5 per cent of the potential habitat (eg eucalypt and riparian forest, rainforest and heathland) available within the locality (3667.1 hectares). The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. Therefore, the project would not only result in the loss of potential habitat, it could also limit the ability of the Spotted-tailed Quoll to access other areas of habitat within the locality.

The project could result in either a complete halt to the movement of the Spotted-tailed Quoll across the study area or a reduced level of movement. Even a small reduction in movements can reduce genetic continuity within a population hence reducing the effective population size (Goosem 2002). In addition, the project may result in a higher rate of roadkill mortality as the species attempts to cross the wider highway. However, provided the dedicated fauna underpasses, riparian corridor enhancement and bridges over creek crossings are implemented (see Chapter 5), the project is unlikely to result in a long-term decrease in the size of a population of the Spotted-tailed Quoll.

Is there a real chance or a possibility that the action will reduce the area of occupancy of the species?

The study area does not lie at or near the limit of the area of occupancy of the Spotted-tailed Quoll, which extends between the Victorian and Queensland borders in New South Wales.

The study area lies south of a broader distribution of records of the species (eg between Barren Grounds Nature Reserve and Cambewarra Range Nature Reserve) that extend north and south of the study area. Impacts to the Spotted-tailed Quoll occurring within the study area and surrounds are unlikely to reduce the species' extent through this broader distribution of records. Given this, and that the study area does not occur at or near the limit of the area of occupancy of the Spotted-tailed Quoll, the project is unlikely to reduce the area of occupancy for this species.

Is there a real chance or a possibility that the action will fragment an existing population into two or more populations?

Given the distribution of records both north and south of the study area, and the close proximity of some records to the study area, it is considered likely that the Spotted-tailed Quoll occurs within and passes through the study area from time to time. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. This may result in the fragmentation of a population of Spotted-tailed Quoll into two or more populations.

However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is there a real chance or a possibility that the action will adversely affect habitat critical to the survival of the species?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. A Register of Critical Habitat is maintained by the Minister under the EPBC Act. To date, no critical habitat has been declared for the Spotted-tailed Quoll (DEWHA 2009d).

Critical habitat can also refer to areas that are necessary for activities such as foraging, breeding or dispersal; for the long-term maintenance of the species; to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species (DEWHA 2009d).

It is considered likely that the Spotted-tailed Quoll occurs within and passes through the study area from time to time. By crossing the Toolijooa Ridge – Harley Hill and Broughton Creek wildlife corridors, as well as a number of smaller riparian and roadside corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. This may result in the fragmentation of a population of Spotted-tailed Quoll into two or more populations, which could limit the genetic diversity of the populations. However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is there a real chance or a possibility that the action will disrupt the breeding cycle of a population of the species?

The Spotted-tailed Quoll requires suitable den sites (such as hollow logs, tree hollows, rock outcrops or caves) for breeding (DEC 2005). Within the study area, hollow-bearing trees and hollow logs provide potential breeding habitat for this species. Most of the areas to be removed that contain such breeding resources are disturbed due to the existing road and ongoing agricultural practices. The patches of vegetation to be removed are contiguous, however, with intact forest that also contains the same potential breeding resources.

The project is unlikely to impact high quality potential breeding resources for the Spotted-tailed Quoll within the study area, however, the impacts to the local wildlife corridors could affect dispersal of the species. This could result in reduced breeding success of a local population. However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate any potential impacts on habitat connectivity for this species.

Is there a real chance or a possibility that the action will modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would directly impact up to 27.8 hectares of potential foraging and breeding habitat (eucalypt and riparian forest) for the Spotted-tailed Quoll. Within the area of OEH vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.8 per cent of potential habitat within the locality (3667.1 hectares). A further 26.05 hectares of eucalypt and riparian forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, about 1.5 per cent of the potential habitat occurring in the locality would be impacted by the project.

Although the Spotted-tailed Quoll is considered likely to occur in the study area, the habitat to be modified, destroyed and/or removed is predominantly disturbed roadside and disturbed riparian vegetation. The project is considered unlikely to decrease the availability or quality of habitat to the extent that the species may decline. Regardless, this disturbed habitat forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore considered to be of high importance for the long-term survival of the Spotted-tailed Quoll occurring within the study area and surrounds. It is considered possible that the project would isolate areas of habitat (through the creation of a movement barrier; ie the highway) to the extent that the Spotted-tailed Quoll may decline.

However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is there a real chance or a possibility that the action will result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species habitat?

DSEWPaC identifies predation and competition by/with the red fox (*Vulpes vulpes*), dingo (*Canis lupus dingo*), domestic dog (*Canis lupus familiaris*) and cats (*Felis catus*) as a threat to the Spotted-tailed Quoll (DEWHA 2009e). These species are likely to be already present within the study area and may already be having an effect on the Spotted-tailed Quoll. Further, the project has the ability to increase their extent or abundance within the study area via the use of underpasses.

Although only anecdotal evidence exists, DSEWPaC identifies poisoning by the cane toad (*Bufo marinus*) as a potential threat to the Spotted-tailed Quoll (DEWHA 2009e). However, the study area occurs well south of the southern limit of the cane toad's current distribution and the project is unlikely to result in this species becoming established in the study area or locality. It is recommended that the vegetation management plan states no use of sugar cane mulch in revegetation and/or landscaping works (to reduce the risk of cane toad transportation).

Is there a real chance or a possibility that the action will introduce disease that may cause the species to decline?

DSEWPaC does not list disease as a threat to the Spotted-tailed Quoll (DEWHA 2009e). The project is unlikely to lead to the introduction of a disease that would cause a decline in the Spotted-tailed Quoll.

Is there a real chance or a possibility that the action will interfere with the recovery of the species?

There is currently no published recovery plan for the Spotted-tailed Quoll. DSEWPaC identify the red fox, feral cat and cane toad as threats to the recovery of the Spotted-tailed Quoll within respective threat abatement plans (DEWHA 2008d, DEWHA 2008c, DSEWPaC 2011). Dedicated fauna underpasses, whilst serving to main connectivity either side of the highway for native fauna, may encourage exotic pest species such as cats and foxes to cross the highway also. Maintaining habitat connectivity for the Spotted-tailed Quoll provides the opportunity for dispersal and to maintain and/or strengthen genetic continuity and an effective population size, thus giving the species a fighting chance against existing pest species.

As mentioned above, the cane toad may also pose a threat to the recovery of the Spotted-tailed Quoll. However, the study area occurs well south of the southern limit of the cane toad's current distribution and the project is unlikely to result in this species becoming established in the study area or locality. It is recommended that the vegetation management plan states no use of sugar cane mulch in revegetation and/or landscaping works (to reduce the risk of cane toad transportation).

The project would result in the removal of some forested areas containing hollow-bearing trees and hollows logs, including riparian vegetation. However, as discussed above, the areas to be removed are already disturbed. Similar habitat resources occur and would remain adjacent to the cleared areas. A vegetation management plan (including weed control) is proposed to help minimise impacts on fauna and fauna habitats (Chapter 5).

The project could result in a higher rate of roadkill for the Spotted-tailed Quoll however the inclusion of dedicated fauna underpasses with fauna fencing (see Chapter 5) is likely to reduce this risk. Monitoring of road kill could be undertaken during the operational phase of the project and if identified as an issue, additional fauna fencing may be required.

Conclusion

Based on the above assessment, and provided the mitigation measures outlined above and detailed in Chapter 5 are implemented, the Spotted-tailed Quoll is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for this species.

Potorous tridactylus Long-nosed Potoroo

The Long-nosed Potoroo is listed as Vulnerable under the EPBC Act. The species is also listed as Vulnerable under the TSC Act.

A population of this species occurring in the study area and/or locality may be considered an 'important population' as it may be necessary for maintaining genetic diversity.

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

The Long-nosed Potoroo inhabits coastal heaths and dry and wet sclerophyll forests. In NSW it is generally restricted to coastal heaths and forests east of the Great Dividing Range, with an annual rainfall exceeding 760 mm. Dense understorey with occasional open areas is an essential part of habitat, and may consist of grass-trees, sedges, ferns or heath, or of low shrubs of tea-trees or melaleucas. A sandy loam soil is also a common feature (Johnston 2008). One study of the species found that the Long-nosed Potoroo required a mosaic of micro-habitats, from dense, floristically simple sites for nesting, to open floristically diverse sites for obtaining food. This species appears to benefit from a lack of recent disturbance, including fire (Claridge *et al.* 2007). The Long-nosed Potoroo is sedentary and tends to be solitary, although would also aggregate in small groups. The Long-nosed Potoroo forages for fleshy fruit, seeds and plant tissue, arthropods, fungi, digging in the soil much like a bandicoot (Johnston 2008).

The Long-nosed Potoroo has been previously recorded four times within the locality (twice in 1970 and twice in 1992), both to the north and south of the study area (DECCW 2011); although only one record occurs south of the study area. Beyond the locality and within 10 kilometres, additional records exist north of the study area with a large congregation in Barren Grounds Nature Reserve.

The study area provides limited potential foraging and nesting habitat for the Long-nosed Potoroo within the eucalypt and riparian forests. This species may also utilise wildlife corridors within the locality to move between areas of habitat.

About 27.8 hectares of eucalypt and riparian forest (limited potential habitat) would be removed from the study area with a further 26.05 hectares affected by indirect impacts (eg edge effects). This equates to only 1.5 per cent of the potential habitat (eg eucalypt and riparian forest, rainforest, melaleuca forest and heathland) available within the locality (3628.0 hectares). The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. Therefore, the project would not only result in the loss of potential habitat, it could also limit the ability of the Long-nosed Potoroo to access other areas of habitat within the locality.

The project could result in either a complete halt to the movement of the Long-nosed Potoroo across the study area or a reduced level of movement. Even a small reduction in movements can reduce genetic continuity within a population hence reducing the effective population size (Goosem 2002). In addition, the project may result in a higher rate of roadkill mortality if the species attempts to cross the wider highway. However, provided the dedicated fauna underpasses, riparian corridor enhancement and bridges over creek crossings are implemented (see Chapter 5), the project is unlikely to result in a long-term decrease in the size of a population of the Long-nosed Potoroo.

Is the action likely to reduce the area of occupancy of an important population?

The area of occupancy of the Long-nosed Potoroo extends from Queensland to eastern Victoria and Tasmania. Within New South Wales, there is a gap in records between Gosford and Kiama of almost 150 kilometres (NSW Government 2009). While the study area does not lie at or near the limit of the overall area of occupancy of the Long-nosed Potoroo, it does occur close to the southern edge of the record gap in New South Wales (NSW Government 2009).

The study area lies south of a greater concentration of records of the species (eg Barren Grounds Nature Reserve and Cambewarra Range Nature Reserve). As only one record of the species occurs south of the study area (recorded in 1992), it is unlikely that impacts to the Long-nosed Potoroo occurring within the study area and surrounds would result in a reduction of the species' extent in these nature reserves. Given this, and that the study area does not occur at or near the limit of the overall area of occupancy of the Long-nosed Potoroo, the project is unlikely to reduce the area of occupancy of an important population.

Is the action likely to fragment an existing population into two or more populations?

Given the distribution of records both north and south of the study area it is considered possible that the Long-nosed Potoroo occurs within and passes through the study area from time to time. The fact that only one record occurs south of the study area (from 1992) may indicate the species is unlikely to cross the study area frequently or may be the result of insufficient survey in the area. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. This may result in the fragmentation of a population of Long-nosed Potoroo into two or more populations.

However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is the action likely to adversely affect habitat critical to the survival of a species?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. A Register of Critical Habitat is maintained by the Minister under the EPBC Act. To date, no critical habitat has been declared for the Long-nosed Potoroo (DEWHA 2009d).

Critical habitat can also refer to areas that are necessary for activities such as foraging, breeding or dispersal; for the long-term maintenance of the species; to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species (DEWHA 2009d). There is no consistent pattern to the habitat of the Long-nosed Potoroo (SE Mainland); it can be found in wet eucalypt forests (Seebeck 1995), coastal heaths and scrubs (Mason 1997). The main factors would appear to be access to some form of dense vegetation for shelter (Bennett 1987) and the presence of an abundant supply of fungi for food (Claridge et al. 1992). The potential habitat within the study area is considered only marginal due to the disturbed nature of the habitat (ie roadside), and the lack of a nearby mosaic of micro-habitats (eg from dense, floristically simple sites for nesting, to open floristically diverse sites for obtaining food (Claridge *et al.* 2007)). Given the above, the project is considered unlikely to affect critical foraging or breeding habitat of the Long-nosed Potoroo. However, habitat critical to the dispersal of an important population may be affected by the creation of a movement barrier (ie the highway).

The proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is the action likely to disrupt the breeding cycle of an important population?

The Long-nosed Potoroo requires a dense understorey in heaths or forest for breeding (DEC 2005y). No heaths occur in the study area. Limited potential breeding habitat occurs within the eucalypt forest patches (the riparian forest is considered unlikely to provide potential breeding resources). The potential habitat is considered only marginal due to the disturbed nature of the habitat (ie roadside), and the lack of a nearby mosaic of micro-habitats (eg from dense, floristically simple sites for nesting, to open floristically diverse sites for obtaining food (Claridge *et al.* 2007)). Within the study area, site 15 provides the most opportunities given its reasonable size and connectivity to other areas of habitat. The project would result in the removal of only roadside vegetation from site 15, leaving the remainder of the patch intact.

The project is unlikely to impact high quality potential breeding resources for the Long-nosed Potoroo within the study area, however, the impacts to the local wildlife corridors could affect dispersal of the species. This could result in reduced breeding success of a local population. However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for the Long-nosed Potoroo.

Is the action likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would directly impact up to 27.8 hectares of limited potential foraging and breeding habitat (eucalypt and riparian forest) for the Long-nosed Potoroo. Within the area of OEH vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.8 per cent of potential habitat within the locality (3628.0 hectares). A further 26.05 hectares of eucalypt and riparian forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.5 per cent of the potential habitat occurring in the locality would be impacted by the project.

Although the Long-nosed Potoroo has the potential to occur in the study area, the habitat to be modified, destroyed and/or removed is predominantly disturbed roadside and disturbed riparian vegetation. The project is considered unlikely to decrease the availability or quality of habitat to the extent that the species may decline. Regardless, this disturbed habitat forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore considered to be of high importance for the long-term survival of the Long-nosed Potoroo occurring within the study area and surrounds. It is considered possible that the project would isolate areas of habitat (through the creation of a movement barrier; ie the highway) to the extent that the Long-nosed Potoroo may decline

However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is the action likely to result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat;

DSEWPaC does not identify any threats to the Long-nosed Potoroo (DEWHA 2009c).

Is the action likely to introduce disease that may cause the species to decline?

DSEWPaC does not list disease as a threat to the Long-nosed Potoroo (DEWHA 2009c).

Is the action likely to interfere substantially with the recovery of the species?

There is currently no recovery plan for the Long-nosed Potoroo.

DSEWPaC identify the red fox as a threat to the recovery of the Long-nosed Potoroo within the threat abatement plan for predation by the European red fox (DEWHA 2008d). Dedicated fauna underpasses, whilst serving to maintain connectivity either side of the highway for native fauna, may encourage exotic pest species such as foxes to cross the highway also. Maintaining habitat connectivity for the Long-nosed Potoroo provides the opportunity for dispersal and to maintain and/or strengthen genetic continuity and an effective population size, thus giving the species a fighting chance against existing pest species.

Targeted surveys were conducted for the Long-nosed Potoroo. The project would result in the removal of limited potential habitat. However, as discussed above, the areas to be removed are already disturbed. Similar habitat resources occur and would remain adjacent to the cleared areas. A vegetation management plan (including weed control) is proposed to help minimise impacts on fauna and fauna habitats (Chapter 5).

The project has the potential to impact on the ability of the Long-nosed Potoroo to cross the highway. However, the mitigation measures described in Chapter 5 including fauna underpasses, riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings would help compensate for the loss of habitat connectivity in the event the species does on occasion use habitat to the south and east of the upgrade.

Conclusion

Based on the above assessment, the Long-nosed Potoroo is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for this species.

Pteropus poliocephalus Grey-headed Flying-fox

The Grey-headed Flying-fox is listed as Vulnerable under the EPBC Act. The species is also listed as Vulnerable on the TSC Act.

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

The Grey-headed Flying-fox is found in a variety of habitats, including rainforest, mangroves, paperbark swamps, wet and dry sclerophyll forests and cultivated areas (Churchill 1998). The species is a canopy-feeding frugivore and nectarivore. Their major food source is Myrtaceae blossom (mostly eucalypt) and fruits such as native figs (*Ficus* spp.) and cultivated fruit orchards (Churchill 1998). Bats commute daily to foraging areas, usually within 15 kilometres of the day roost (Strahan 1995), although some individuals may travel up to 70 kilometres. Grey-headed flying-foxes seasonally congregate in large camps of up to 200,000 individuals (Churchill 1998). The availability of blossom in the surrounding area influences the number of bats in a camp (Churchill 1998).

The Grey-headed Flying-fox was recorded foraging at site 15 during the field surveys. The species has also been previously recorded six times within the locality, predominantly to the south but also to the north-east and west. These records occurred between 1994 and 2008 (DECCW 2011).

The study area provides known and potential foraging habitat for the Grey-headed Flying-fox within the eucalypt and riparian forests and woodlands. No evidence of a camp site (breeding habitat) was found within the study area. Known camp sites occur within Coomonderry Swamp approximately 5.5 kilometres southeast of Berry, and at Bomaderry Creek approximately 13 kilometres southwest of the study area.

The project would impact potential foraging habitat for the Grey-headed Flying-fox through the removal of eucalypt and riparian forest and woodland. About 27.8 hectares of eucalypt and riparian forest (known and/or potential foraging habitat) would be removed from the study area with a further 26.05 hectares affected by indirect impacts (eg edge effects). This equates to only 1.4 per cent of the potential habitat (eg eucalypt and riparian forest, rainforest, mangroves and paperbark swamps) available within the locality (3792.6 hectares; which also fits the description of 'critical foraging habitat' (DECCW 2009b). Given the availability of known and potential habitat within the locality (including protected habitat within Seven Mile Beach National Park), that no breeding habitat would be impacted and the high mobility of this species, it is considered unlikely that the project would lead to a long-term decrease in the size of an important population of the Grey-headed Flying-fox.

Is the action likely to reduce the area of occupancy of an important population?

The study area does not lie at or near the limit of the area of occupancy of the Grey-headed Flying-fox, which extends from Bundaberg in Queensland to Melbourne in Victoria (DEC 2005t).
The Grey-headed Flying-fox is known to forage in the study area. Given the distribution of records of the species within 10 kilometres, individuals from the Bomaderry Creek and Comerong Island camps are likely to utilise resources within the study area. However, given the high mobility of the Grey-headed Flying-fox (able to travel up to 70 kilometres from a camp site) and the availability of known and potential habitat in the locality (including protected habitat within Seven Mile Beach National Park), the loss of 27.8 hectares eucalypt and riparian forest considered to be 'critical foraging habitat' (predominantly disturbed roadside and disturbed riparian habitat) is unlikely to reduce the area of occupancy of an important population of the species.

Is the action likely to fragment an existing population into two or more populations?

Grey-headed flying-foxes commute daily to foraging areas, usually within 15 kilometres of the day roost (Strathan 1995), although some individuals may travel up to 70 kilometres. The project would involve removal of known and potential foraging habitat from the study area. The areas to be removed (predominantly roadside and riparian areas) are contiguous with intact forest that would remain. Given the availability of surrounding eucalypt and riparian forests, the small areas of proposed vegetation removal (the 27.8 hectares to be removed is made up of smaller areas spread along the 11.6 kilometres route including proposed ancillary sites) and the high mobility of the Grey-headed Flying-fox, it is considered unlikely that the project would fragment an existing population into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. A Register of Critical Habitat is maintained by the Minister under the EPBC Act. To date, no critical habitat has been declared for the Grey-headed Flying-fox (DEWHA 2009d).

Critical habitat can also refer to areas that are necessary for activities such as foraging, breeding or dispersal; for the long-term maintenance of the species; to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species (DEWHA 2009d). The *Draft National Recovery Plan for the Grey-headed Flying-fox* Pteropus poliocephalus (DECCW 2009b) describes foraging habitat that is considered critical to the survival of the species. The vegetation to be removed by the project is consistent with criteria number three listed in the recovery plan: natural foraging habitat that is productive during the final weeks of gestation, and during the weeks of birth, lactation and conception (September to May). Therefore, the project would adversely affect habitat critical to the survival of the Grey-headed Flying-fox, according to the draft recovery plan (DECCW 2009b). However, the foraging habitat to be directly impacted is predominantly disturbed roadside and disturbed riparian vegetation (ie in poor condition); and constitutes only 1.4 per cent of that available in the locality.

Is the action likely to disrupt the breeding cycle of an important population?

Pregnant Grey-headed Flying-foxes congregate in maternity camps, giving birth to a single young a couple of weeks later (Churchill 1998). No Grey-headed Flying-fox colonies have been mapped within the locality; although the Bomaderry Creek camp is located approximately 10.5 kilometres southwest of Berry, and at Comerong Island approximately 12.2 kilometres south of the study area (DECCW 2008). Breeding is unlikely to occur within the study area.

Given the impacts to potential foraging habitat are unlikely to lead to a long-term decrease in the size of an important population of the Grey-headed Flying-fox (described above) and that no breeding habitat would be impacted, it is considered unlikely that the project would disrupt the breeding cycle of an important population of the Grey-headed Flying-fox.

Is the action likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would directly impact up to 27.8 hectares of known and potential foraging habitat (eucalypt and riparian forest) for the Grey-headed Flying-fox. Within the area of OEH vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.7 per cent of potential habitat within the locality (3792.6 hectares; which also fits the description of 'critical foraging habitat' (DECCW 2009b). A further 26.05 hectares of eucalypt and riparian forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.4 per cent of the potential habitat occurring in the locality would be impacted by the project.

Although the Grey-headed Flying-fox is known to forage in the study area, and that the habitat fits the description of 'critical foraging habitat' (DECCW 2009b), the habitat to be directly impacted is predominantly disturbed roadside and disturbed riparian vegetation and is considered to be of low to moderate importance for the long-term survival of the Grey-headed Flying-fox. Given this, the large (and diverse) extent of potential habitat available in the locality (3792.6 hectares; which also fits the description of 'critical foraging habitat' (DECCW 2009b) and the species' high mobility, the loss and/or disturbance of 1.4 per cent of potential habitat within the locality is considered unlikely to modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the Grey-headed Flying-fox is likely to decline.

Is the action likely to result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat;

DSEWPaC identifies competition with the black flying-fox (*Pteropus alecto*) as a threat to the Grey-headed Flying-fox due to shared roosting and foraging resources (DEWHA 2009b). However, the study area occurs well south of the southern limit of the black flying-fox's distribution with sporadic records for the species in Sydney, Taree and Port Macquarie (DEC 2005c); and the project is unlikely to result in this species becoming established in the study area or locality.

Is the action likely to introduce disease that may cause the species to decline?

The Grey-headed Flying-fox may be susceptible to pathogens such as the Australian bat Lyssavirus and pollutants such as lead (DEWHA 2009b). The project is unlikely to introduce the Australian bat Lyssavirus to the study area. Although the project would result in the increased capacity for traffic movement, and therefore possibly increased exhaust gases in the environment, it is unlikely to increase the incidence of lead to the point that the Grey-headed Flying-fox would decline.

Is the action likely to interfere substantially with the recovery of the species?

OEH (on behalf of DSEWPaC) has developed a draft national recovery plan for the Grey-headed Flying-fox (DEWHA 2009b). The following recovery objectives outlined in this plan relevant to the project include:

1. Identify and protect foraging habitat critical to the survival of Grey-headed Flying-foxes throughout their range.
2. Identify, protect and enhance roosting habitat critical to the survival of Grey-headed Flying-foxes.

The Grey-headed Flying-fox is known to forage within the study area and the foraging habitat is considered to be critical to the species' survival (DECCW 2009b). However, the foraging habitat to be directly impacted (0.7 per cent of that occurring in the locality) is predominantly disturbed roadside and disturbed riparian vegetation (ie in poor condition). Whilst adjoining areas of foraging habitat would be subject to indirect impacts such as weed invasion and increased light penetration (also 0.7 per cent of that occurring in the locality), the habitat would not be removed. Further, the majority of potential habitat occurring in the locality also likely meets the criteria for identification as 'critical foraging habitat' (DECCW 2009b).

No evidence of a camp site (roosting/breeding habitat) was found within the study area. No Grey-headed Flying-fox colonies have been mapped within the locality; although the Bomaderry Creek camp is located approximately 10.5 kilometres southwest of Berry, and at Comerong Island approximately 12.2 kilometres south of the study area (DECCW 2008)., These camps would not be impacted by the project.

Given that evidence of a camp site was not found within the study area, and that a total of only 1.4 per cent of potential habitat within the locality would be impacted (directly and indirectly), it is unlikely that the project would interfere with these recovery objectives.

Conclusion

Based on the above assessment the Grey-headed Flying-fox is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for this species.

Phascolarctos cinereus Koala

The Koala is listed as Vulnerable under the EPBC Act. The species is also listed as Vulnerable under the TSC Act.

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

Koalas live in breeding aggregations comprised of a dominant male, a small number of mature females, and juveniles (DECC 2008). The home range of Koalas varies depending on the quality of the habitat and the number of available food trees. Home ranges can vary from less than one hectare to 500 hectares (DECC 2008). Home ranges in the Pilliga State Forest overlapped for both sexes and were about 12 hectares for males and nine hectares for females. Koalas were found to continue to occupy all or part of their previous home-ranges after selective logging, and home-range sizes remained similar between logged and unlogged areas (Kavanagh *et al.* 2007).

The Koala was not recorded during the field surveys. There have been three records of the species within the locality (DECCW 2011); one record to the north and two records to the south of the study area (recorded between 2004 and 2005). Two additional records occur outside the locality but within 10 kilometres; one to the north-east (2004) and one to the south (1940).

The study area provides limited potential foraging habitat for the Koala within the eucalypt forests and woodlands. Although some preferred feed tree species were recorded during the field surveys (eg *Eucalyptus microcorys*, *E. racemosa*, *E. robusta* and *E. tereticornis*), none were dominant within the forest/woodland patches of the study area. Based on the low density of preferred feed trees and the absence of records of this well-recognised species within the study area, it is considered unlikely that the study area supports (or could support) a population of Koala. However, it is possible that the species moves through the study area on occasion between areas of potential habitat.

About 22.2 hectares of eucalypt forest (limited potential habitat) would be removed from the study area with a further 17.5 hectares affected by indirect impacts (eg edge effects). This equates to only 1.6 per cent of the potential habitat available within the locality (2425.7 hectares). The impacts of the loss of potential habitat are amplified by the fragmentation of fauna movement corridors through the study area (see below). The project would not only result in the loss of potential habitat, it could also limit the ability of the Koala to access other areas of habitat within the locality.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). Given the availability of known and potential habitat within the locality, the reasonable mobility of this species and provided the mitigation measures in Chapter 5 are implemented, the project is unlikely to result in a long-term decrease in the size of an important population of the Koala.

Is the action likely to reduce the area of occupancy of an important population?

The Koala has a fragmented distribution throughout eastern Australia extending from north-east Queensland to the Eyre Peninsula in South Australia (DEC 2005v). The study area is not at, or near, the limit of distribution for this species.

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Koala (some of which contains preferred feed tree species). Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.9 per cent of potential habitat within the locality (2425.7 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.6 per cent of the potential habitat occurring in the locality would be impacted by the project.

Given the lack of records of this conspicuous species in the locality; that a total of only 1.6 per cent potential habitat would be impacted by the project (either directly or indirectly); that the study area is not at, or near, the limit of distribution for this species; and, provided the mitigation measures in Chapter 5 are implemented (to reduce impacts to wildlife corridors), the project is unlikely to reduce the area of occupancy of an important population of Koala.

Is the action likely to fragment an existing population into two or more populations?

The Koala has been recorded within the locality to the north of the project near Foxground, and to the south near Foys Swamp and Back Forest. The Toolijooa Ridge – Harley Hill wildlife corridor may provide connectivity for this species. The project crosses the Toolijooa Ridge – Harley Hill and Broughton Creek corridors, as well as a number of smaller riparian and roadside corridors. By crossing these wildlife corridors, the project creates (or increases) a barrier to fauna movement between areas of potential habitat.

In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). The proposed riparian corridor enhancement and fauna underpasses may help mitigate impacts on habitat connectivity for this species.

Given the availability of known and potential habitat within the locality, the reasonable mobility of this species and provided the mitigation measures in Chapter 5 are implemented, it is considered unlikely that the project would result in the fragmentation of a population of Koala into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. A Register of Critical Habitat is maintained by the Minister under the EPBC Act. To date, no critical habitat has been declared for the Koala (DEWHA 2009d).

Critical habitat can also refer to areas that are necessary for activities such as foraging, breeding or dispersal; for the long-term maintenance of the species; to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species (DEWHA 2009d).

In addition to the general criteria by DEWHA (2009) to define critical habitat the *Interim koala referral advice for proponents* (DSEWPaC, 2012) provide a more detailed set of criteria to define habitat critical to the survival of the Koala focusing on primary and secondary food tree species cited in the NSW Recovery Plan for the species (DECC, 2008). The DSEWPaC (2012) critical habitat criteria are assessed below and with reference to the Koala food tree species inventory for the NSW south coast from DECC (2008).

Habitat critical to the survival of the koala is currently considered to be areas of forest or woodland where:

- *Primary koala food tree species comprise at least 30 per cent of the overstorey trees*.

  Primary koala food tree species recorded in the current surveys are *Eucalyptus amplifolia* ssp. *amplifolia* and *Eucalyptus tereticornis*. In combination these two tree species comprise less than 30% of the overstorey trees.

- *Primary koala food tree species comprise less than 30 per cent of the overstorey trees, but together with secondary food tree species comprise at least 50 per cent of the overstorey trees.*

  The primary koala food tree species *Eucalyptus amplifolia* ssp*. amplifolia* and *Eucalyptus tereticornis* in combination comprise less than 30 per cent of the overstorey trees. The secondary koala food tree species *Eucalyptus scias* ssp. *scias* is recorded in the current surveys. In combination the two primary and one secondary food tree species comprise less than 30 per cent of the overstorey trees.

- *Primary food tree species are absent but secondary food tree species alone comprise at least 50 per cent of the overstorey trees.*

  In combination the two primary and one secondary food tree species comprise less than 30 per cent of the overstorey trees.

- *The above qualities may be absent in a forest or woodland but other essential habitat features are present and adjacent to areas exhibiting the above qualities.*

  DECC (2008) suggest that habitat for koalas is influenced by a range of factors such as species and size of trees present, structural diversity of the vegetation, soil nutrients, climate and rainfall, size and disturbance history of the habitat patch. Finer scale habitat features for these factors include the diversity of other non feed tree species, the presence of suitable shelter trees, some groundcover vegetation and other features such as hollow logs, leaf chemistry and its relationship to soil nutrient status, soil moisture and proximity to waterways, edge effects on patches of habitat and presence of predators (DECC, 2008). In summary other essential habitat features mentioned are affected by the long history of rural land use and the associated impacts. The study area is unlikely to support a matrix of high quality additional essential habitat features critical to the survival of the species in the region.

- *A relatively high density of koalas is supported, regardless of the presence of food tree species. Koala population densities vary across their range and regional data should be used to judge relative density.*

  There have been three records of the species within the locality (DECCW 2011) including one record to the north and two records to the south of the study area (recorded between 2004 and 2005). Two additional records occur outside the locality but within 10 kilometres; one to the north-east (2004) and one to the south (1940). These records are not considered to represent a relatively high density of koalas.

- *Habitat critical to the survival of the koala is also considered to be any form of landscape corridor which is essential to the dispersal of koalas between forest or woodland habitats.*

  Corridors at local and regional scale are discussed in Section 3.8 of the report and mapped in mapped in Figure 3.4. In summary the project creates (or increases) a barrier to fauna movement between areas of potential habitat. In order to mitigate impacts of corridor fragmentation, riparian corridor enhancement (through rehabilitation and revegetation) and fauna crossing structures are proposed (Chapter 5). The proposed riparian corridor enhancement and fauna underpasses may help mitigate impacts on habitat connectivity for this species.

It is considered possible that the Koala occurs within and passes through the study area from time to time. By crossing the Toolijooa Ridge – Harley Hill and Broughton Creek wildlife corridors, as well as a number of smaller riparian and roadside corridors, the project creates (or increases) a barrier to fauna movement between areas of habitat. This may result in the fragmentation of a population of Koala into two or more populations, which could limit the genetic diversity of the populations. However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species.

Is the action likely to disrupt the breeding cycle of an important population?

The Koala inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall (Reed and Lunney 1990, DECC 2008). Koalas live in breeding aggregations comprised of a dominant male, a small number of mature females, and juveniles, with adult Koalas generally exhibiting long-term fidelity to their individual home range areas (DECC 2008). Based on the low density of preferred feed trees and the absence of records of this conspicuous species within the study area, it is considered unlikely that the study area supports (or could support) a breeding population of Koala. However, it is possible that the species moves through the study area on occasion between areas of potential habitat.

Potential habitat in the study area forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore important for the long-term survival of the Koala within the locality. Impacts to the wildlife corridors could affect dispersal of the species which could result in reduced breeding success of a local population.

Provided the mitigation measures described in Chapter 5 are implemented (to minimise potential impacts to wildlife movement corridors), it is considered unlikely that the project would disrupt the breeding cycle of an important population of Koala.

Is the action likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

The project would directly impact up to 22.2 hectares of potential foraging habitat (eucalypt forest) for the Koala (some of which contains preferred feed tree species). Within the area of DEC vegetation mapping (as amended following the field surveys), the habitat to be directly impacted represents 0.9 per cent of potential habitat within the locality (2425.7 hectares). A further 17.5 hectares of eucalypt forest would be indirectly affected (eg edge effects) by the project. This equates to about 0.7 per cent of potential habitat within the locality. In total, 1.6 per cent of the potential habitat occurring in the locality would be impacted by the project.

Although the Koala has the potential to occur in the study area, the habitat to be modified, destroyed and/or removed is predominantly disturbed roadside and disturbed riparian vegetation. The project is considered unlikely to decrease the availability or quality of habitat to the extent that the species may decline. Regardless, this disturbed habitat forms part of a discontinuous wildlife corridor between Seven Mile Beach National Park and Barren Grounds Nature Reserve and is therefore important for the long-term survival of the Koala occurring within the study area and surrounds. It is considered possible that the project may isolate areas of habitat (through the creation of a movement barrier; ie the highway).

However, the proposed dedicated fauna underpasses (and associated fauna fencing), riparian corridor enhancement (through rehabilitation and revegetation), and bridges over creek crossings will help mitigate impacts on habitat connectivity for this species. Therefore, the project is considered unlikely to result in the decline of the Koala.

Is the action likely to result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?

DSEWPaC identifies predation by dogs as a threat to the Koala (DSEWPaC 2012). However, dogs are already present in the study area and the project is unlikely to increase their prevalence. Refuge poles (timber poles) erected within and/or at the entrances to fauna underpasses are recommended (Chapter 5) to allow arboreal mammals (such as the Koala) a place to seek refuge should they encounter a terrestrial predator (eg dog) whilst attempting to make a crossing.

Is the action likely to introduce disease that may cause the species to decline?

The two primary known diseases that threaten the Koala are Chlamydia and Koala Retrovirus. Chlamydia can be transmitted between Koalas sexually, to young in the birth canal, and possibly through fighting. The Koala Retrovirus is transmitted genetically (ie by inheritance) from parents to offspring and possibly by close contact, including from infected mothers to their joeys via the milk (DSEWPaC 2012). The project is considered unlikely to result in the introduction of these diseases into the study area.

It is possible that individual Koalas in the study area already carry these diseases. Chlamydiosis may contribute to local declines or extinctions in small, isolated populations, where recruitment rates between populations are low and mortalities from other threats are high. There is some evidence that Chlamydiosis may be exacerbated by the Koala Retrovirus (DSEWPaC 2012). Given this, maintaining habitat connectivity to avoid population isolation, encourage high recruitment rates and to reduce mortality, is of high importance to assisting Koalas battle such diseases. The dedicated fauna underpasses described in Chapter 5 are proposed to help maintain habitat connectivity.

Is the action likely to interfere substantially with the recovery of the species?

There is currently no published national recovery plan for the Koala.

DSEWPaC identify loss and fragmentation of habitat, vehicle strike, disease, and predation by the dog as a threat to the recovery of the Koala (DSEWPaC 2012). Dedicated fauna underpasses, whilst serving to maintain connectivity either side of the highway for native fauna, may encourage exotic pest species such as dogs to cross the highway also. Maintaining habitat connectivity for the Koala provides the opportunity for dispersal and to maintain and/or strengthen genetic continuity and an effective population size, thus giving the species improved odds against existing pest species and diseases. The recommended fauna exclusion fencing and refuge poles would also help to minimise the impacts of vehicle strike and terrestrial predator attack (during a crossing attempt), respectively.

The project is considered unlikely to interfere substantially with the recovery of the Koala.

Conclusion

Based on the above assessment, the Koala is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for this species.

Litoria aurea **Green and Golden Bell Frog**

The Green and Golden Bell Frog is listed as Vulnerable under the EPBC Act. The species is also listed as Endangered under the TSC Act.

The Draft Recovery Plan for the Green and Golden Bell Frog (DEC 2005) refers to 11 Key Populations within the Shoalhaven LGA, one of which occurs in the locality of the study area. Coomonderry Swamp, located approximately four kilometres east of the study area is listed as a Key Population. No Green and Golden Bell Frog have been recorded in the study area however, given that the size of Green and Golden Bell Frog populations can rapidly expand during seasons of high breeding success, individuals are known to disperse across the landscape from core populations during these conditions and that the species has been known to disperse up to three kilometres in a night, farm dams and areas of low lying floodplain are considered to provide connective habitat for the Coomonderry Swamp population (including the associated farm dams and Foys Swamp to the north) to the study area.

Therefore it is considered that an 'important population' of the Green and Golden Bell Frog may occur within the study area for dispersal purposes on occasion, particularly following seasons of high reproductively. As there is potential for the works to result in a "break in continuity of vegetation (of) vegetated corridors linking habitat" an Assessment of significance has been undertaken based on non-limiting dispersal habitat according to the significant impact thresholds outlined in DEWHA (2009b).

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

The Town Creek diversion will intersect the low-lying closed grassland habitat throughout the study area. It is considered that this flood prone land, as well as the current established aquatic environments of the Study Area such as Town Creek, Broughton Mill Creek, Bundewallah Creek may provide dispersal habitat for the Green and Golden Bell Frog on occasion. A number of mitigation measures have been recommended including bridges (underpasses) at each crossing of Broughton Creek and the retention and protection of existing riparian vegetation to allow for continued dispersal routes and refuge.

Given that Green and Golden Bell Frog are considered to be rare visitors to the study area and that impacts to dispersal habitat in the study area will be temporary in nature, the project is not considered likely action likely to lead to a long-term decrease in the size of an important population of the Green and Golden Bell Frog.

Is the action likely to reduce the area of occupancy of an important population?

The current known area of occupancy of the Green and Golden Bell Frog is centralised around the Coomonderry Swamp Key Population. It is possible that individuals disperse from this area to aquatic habitats of the study area in seasons of high reproductive success. The Town Creek diversion will intersect the low-lying closed grassland habitat throughout the study area. It is considered that this flood prone land, as well as the current established aquatic environments of the Study Area such as Town Creek, Broughton Mill Creek, Bundewallah Creek may provide dispersal habitat for the Green and Golden Bell Frog on occasion.

It is unlikely that the project will impact the existing area of occupancy of an important population located at Coomonderry Swamp or their dispersal requirements.

Is the action likely to fragment an existing population into two or more populations?

The Green and Golden Bell Frog have been recorded within the locality to the south at Coomonderry Swamp and to the east in farm dams and Foys Swamp. There are currently no records west of the study area and it is considered unlikely that the project would result in the fragmentation of a population of Green and Golden Bell Frog into two or more populations.

Is the action likely to adversely affect habitat critical to the survival of a species?

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations or ecological communities. A Register of Critical Habitat is maintained by the Minister under the EPBC Act. Critical habitat can also refer to areas that are necessary for activities such as foraging, breeding or dispersal; for the long-term maintenance of the species; to maintain genetic diversity and long-term evolutionary development; or for the reintroduction of populations or recovery of the species (DEWHA 2009d).

To date, no critical habitat has been declared for the Green and Golden Bell Frog and the proposed action would not impact any other critical habitat, such as that located at Coomonderry Swamp.

Is the action likely to disrupt the breeding cycle of an important population?

The subject site does not provide breeding habitat, and no impacts to breeding habitat are likely to occur. It is possible that individuals disperse from this core population to aquatic habitats of the study area in seasons of high reproductive success, although given the current disturbance regimes within the study area, breeding unlikely to be successful. Therefore, the project is not considered likely to impact the breeding cycle of an important population.

Is the action likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

As detailed above, limited breeding and foraging habitat is present within the study area and sheltering and dispersal habitat is present in the subject site and study area. There is potential for the GGBF to disperse through the subject site and study area on occasion, particularly in seasons of high reproductive success at the nearby (3-5 km) Coomonderry Swamp population.

The Town Creek diversion will intersect potential dispersal habitat, and although this may result in local changes to hydrology and disturbance of 0.2 hectares of constructed wetland forming part of the existing creek, the species is unlikely to regularly utilise this habitat for breeding, foraging, sheltering or over-wintering purposes due to the current disturbance regimes. Furthermore, impacts will be temporary in nature and are unlikely to permanently affect the current state of habitat. An additional 0.2 hectares of constructed habitat will be permanently removed as a result of the roadway.

Given that impacts to dispersal habitat in the subject site will be temporary in nature, the flow along the current Town Creek alignment will be maintained to an ecologically sustainable level and the species is only considered to occur within the study area on rare occasions for dispersal purposes, the project is not considered likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.

Is the action likely to result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?

Gambusia was recorded in all waterbodies across the study area. Gambusia are capable of preying on hatchlings and tadpoles of the Green and Golden Bell Frog and, in 1999 the NSW Science Committee determined that predation by Gambusia poses a serious threat to the survival of threatened species. It is now listed as a key threatening process under Schedule 3 of the TSC Act 1995 (NSW NPWS 2003).

Given that this invasive species is already present in all potential habitats of the study area, it is unlikely that the project will result in the further establishment of this invasive species.

Is the action likely to introduce disease that may cause the species to decline?

Green and Golden Bell Frogs are known to be highly susceptible to the effects of Chytrid fungus. Chytrid is consider to be present in nearby Green and Golden Bell Frog populations (F.Lemckert pers. comm,). It is also likely that individuals dispersing through the study area on occasion may already contain the disease.

The project is unlikely to significantly introduce or exacerbate the spread of disease that places the species at further risk of decline.

Is the action likely to interfere substantially with the recovery of the species?

The project is considered unlikely to interfere substantially with the recovery of the Green and Golden Bell Frog given the already limited nature of suitable habitat available within the study area, the distance to know suitable breeding habitat and that impacts associated with the project are likely to be temporary in nature.

Conclusion

According to DEWHA (2009a), there is a possibility of a significant impact on the Green and Golden Bell Frog, and a referral under the EPBC Act should be considered, if the action proposed results in:

- *The removal or degradation of aquatic or ephemeral habitat either where the Green and Golden Bell Frog has been recorded since 1995 or habitat that has been assessed as being suitable according to these guidelines. This can include impacts from chytrid, Gambusia originating offsite*

  Given that the species is not considered to be a permanent resident of the study area, removal or degradation of aquatic or ephemeral habitats in the study area will be temporary in nature and the flow along the current Town Creek alignment will be maintained to an ecologically sustainable level, it is considered unlikely that the project will result in the removal or degradation of habitat as listed above.

- *The removal or degradation of terrestrial habitat within 200 metres of habitat identified in threshold 1*

  See above.

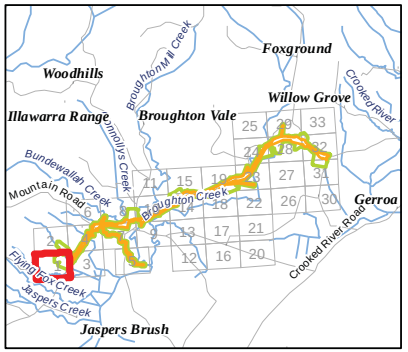
- *Breaking the continuity of vegetation fringing ephemeral or permanent waterways or other vegetated corridors linking habitats meeting the criteria in threshold 1*

  The project will be undertaken in accordance with the guidelines set out in the recovery plan for this species as connectivity will be maintained through the measures listed above. This will ensure that the project would not interfere with the recovery of the species. Given that impacts to dispersal habitat in the study area will be temporary in nature, the flow along the current Town Creek alignment will be maintained to an ecologically sustainable level and provided that the management and mitigation measures in Section 5 of this report are adhered to, the project is not considered likely to affect habitat connectivity for the Green and Golden Bell Frog population at Coomonderry Swamp. Given the temporary and limited nature of the works, and the implementation of the mitigation measures listed above to maintain connectivity, it is considered unlikely that the project will result in a break in the continuity of vegetation fringing waterways or corridors linking habitat listed above.

Based on the above assessment and key thresholds, the Green and Golden Bell Frog is unlikely to be significantly impacted by the project, and as such, a Referral under the provisions of the EPBC Act is not recommended for this species.

Appendix J

Figure mapbooks



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

Biosis Research Pty. Ltd.
18-20 Mandible Street
Alexandria
NEW SOUTH WALES
2015

Figure 2.1.1: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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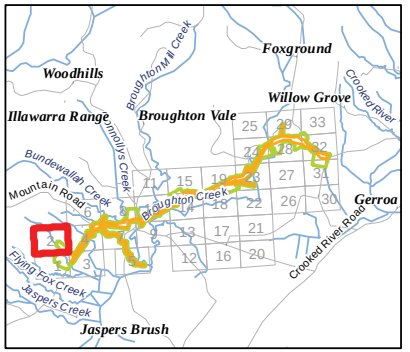
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.2: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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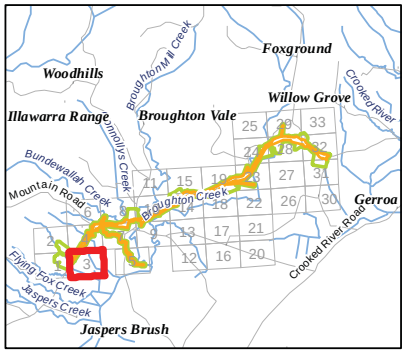
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.3: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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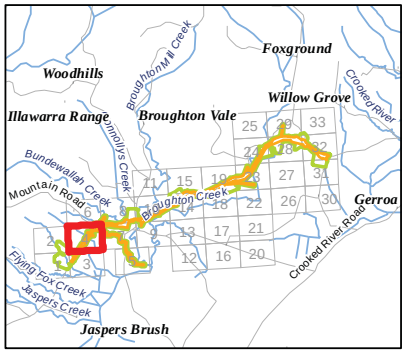
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.4: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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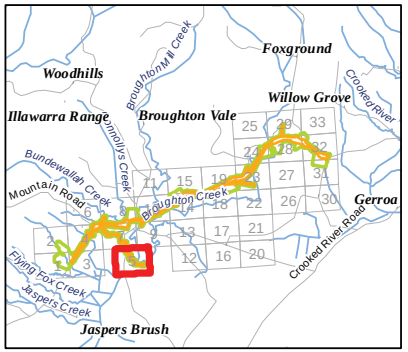
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.5: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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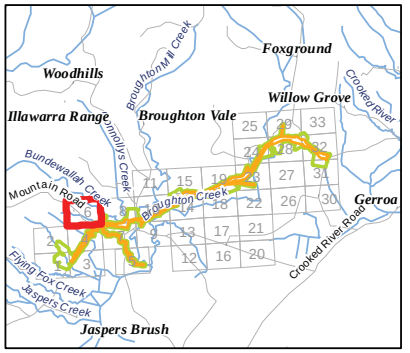
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.6: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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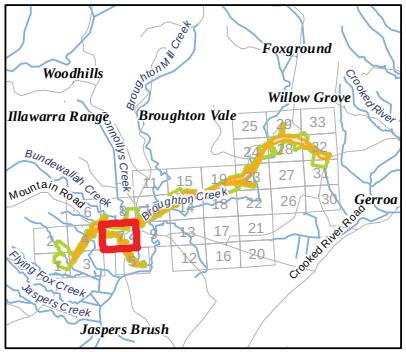
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.7: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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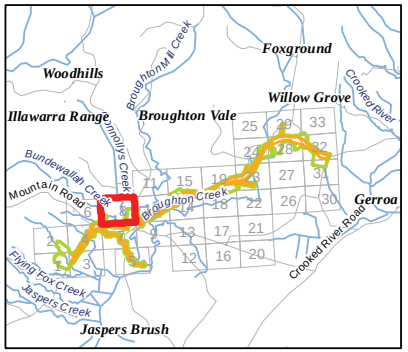
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.8: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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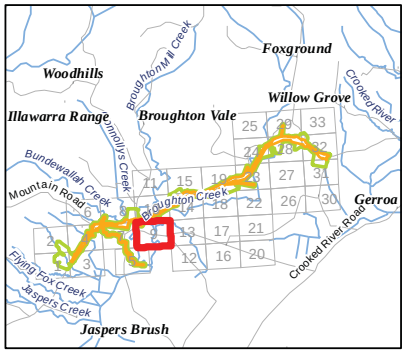
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.9: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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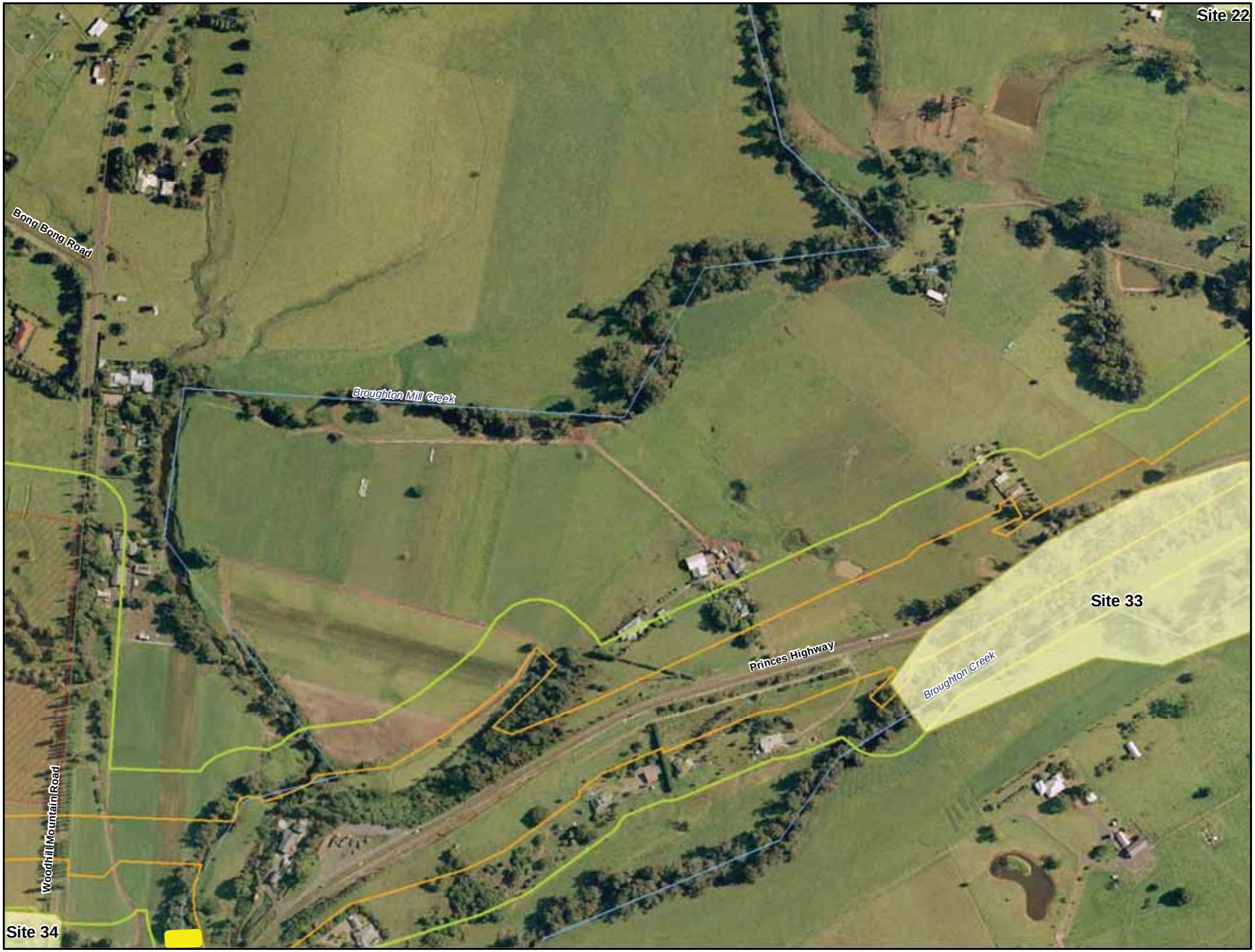
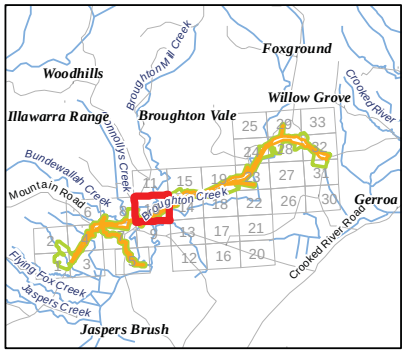
Figure 2.1





Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.10: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
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Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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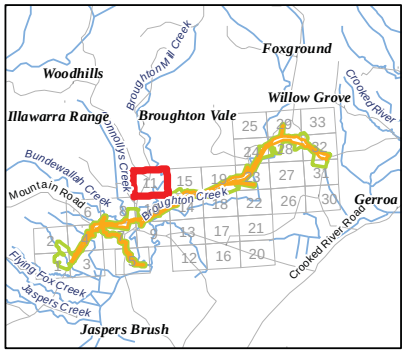
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.11: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
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Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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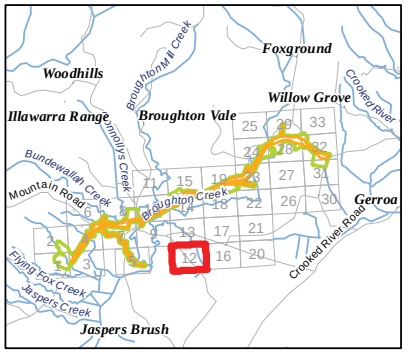
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.12: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
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Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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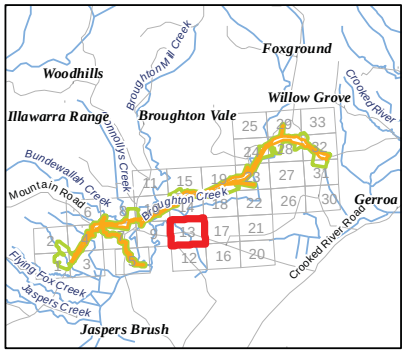
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.13: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
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Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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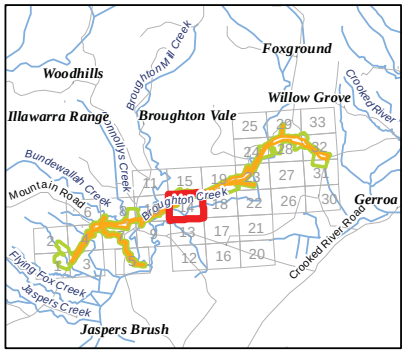
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.14: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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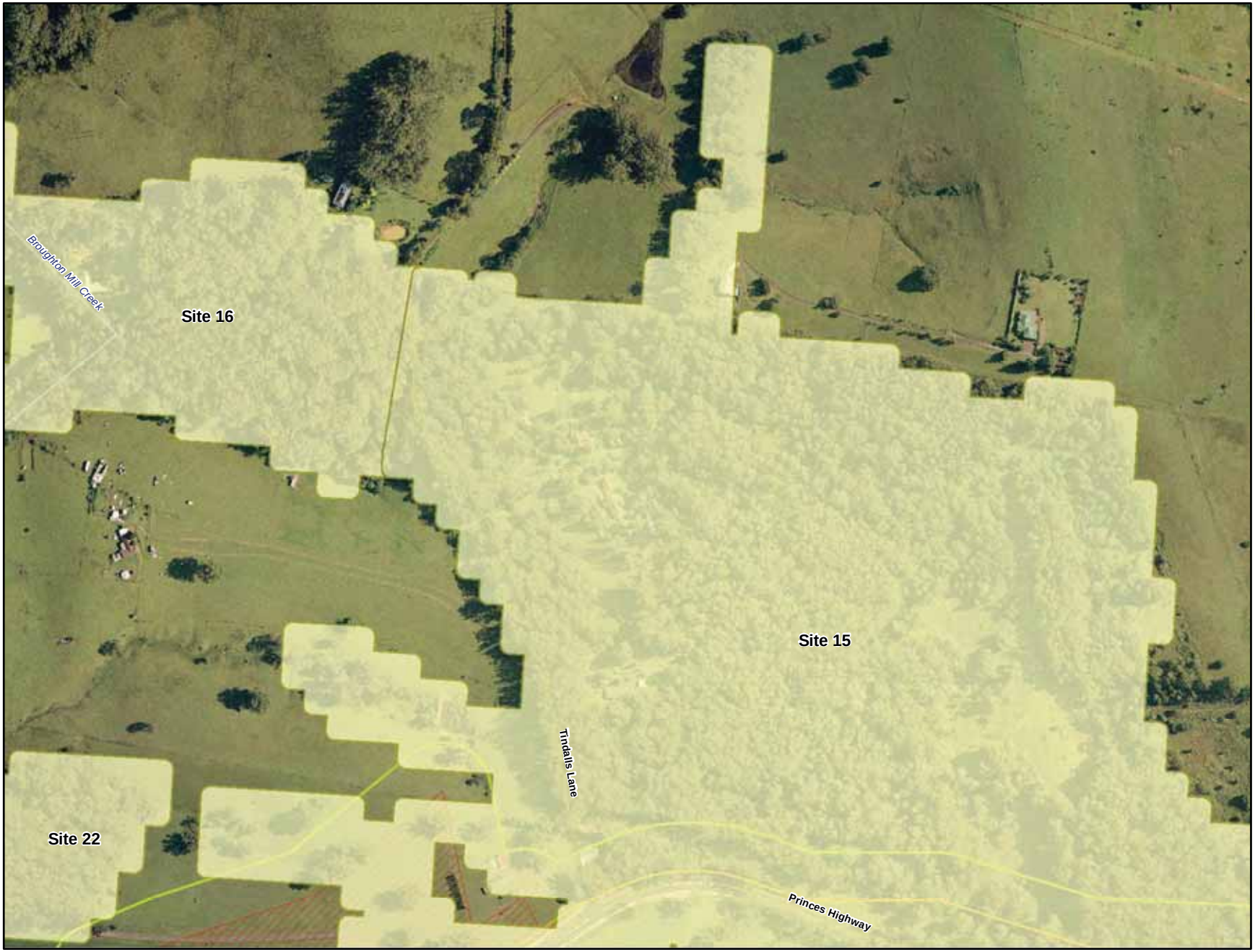
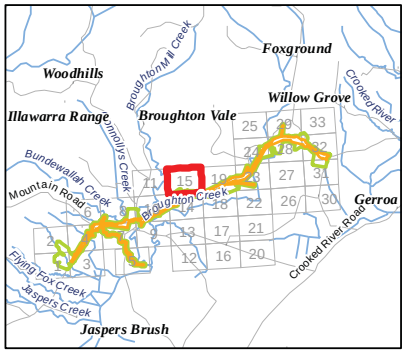
Figure 2.1





Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.15: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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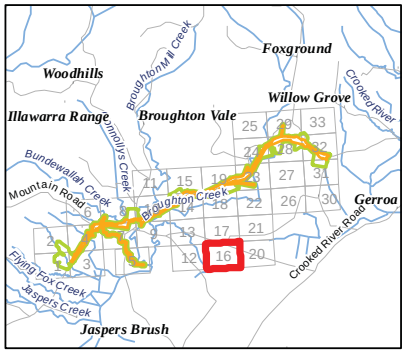
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.16: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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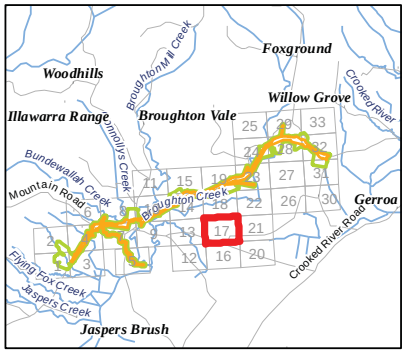
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.17: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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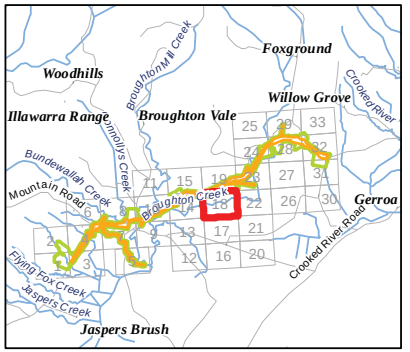
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.18: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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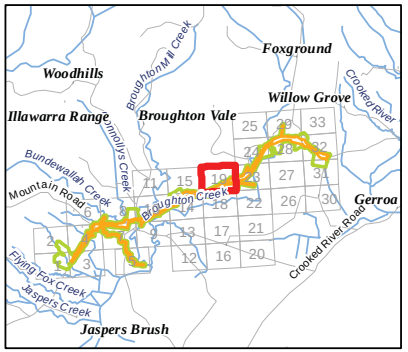
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.19: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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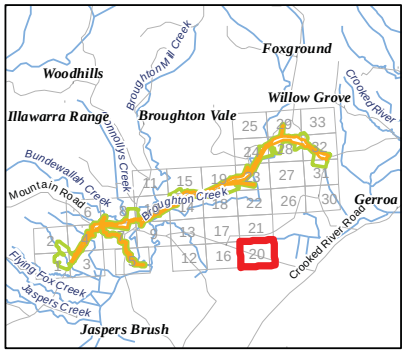
Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.20: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

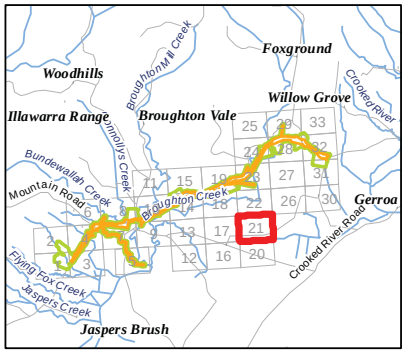
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.21: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

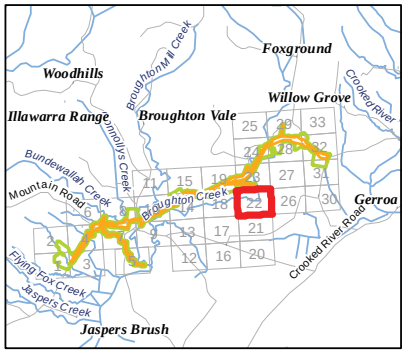
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.22: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

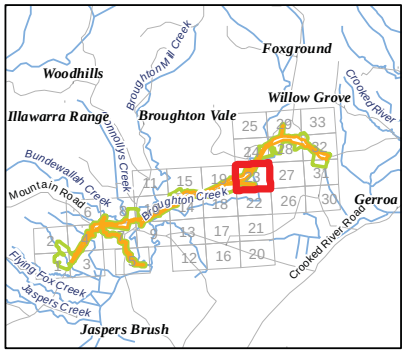
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.23: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

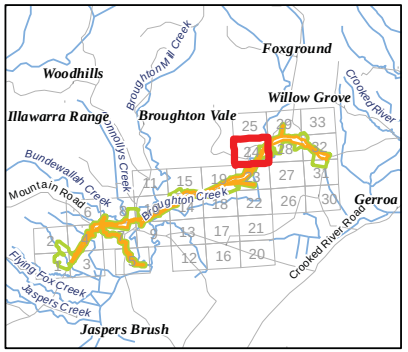
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.24: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

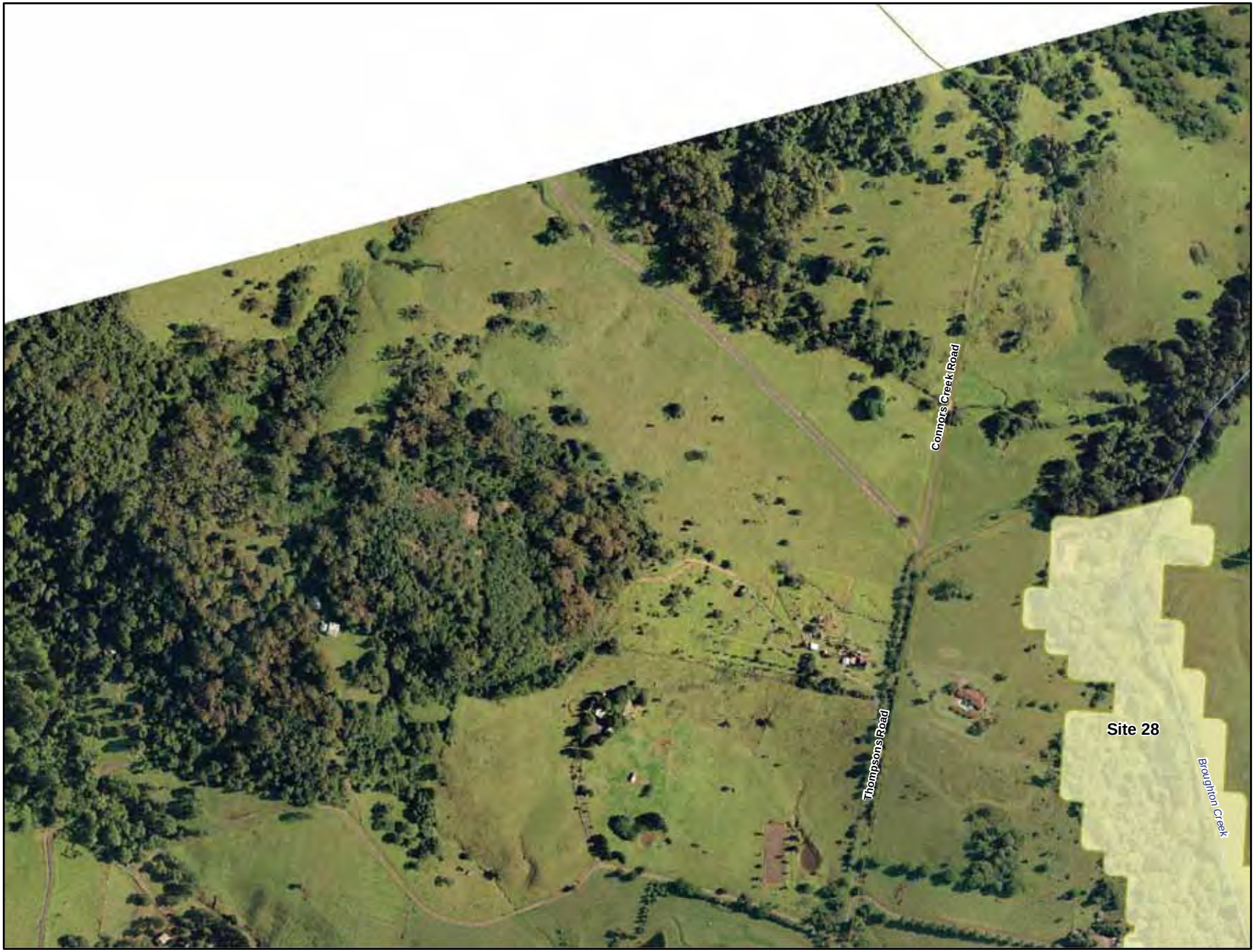
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

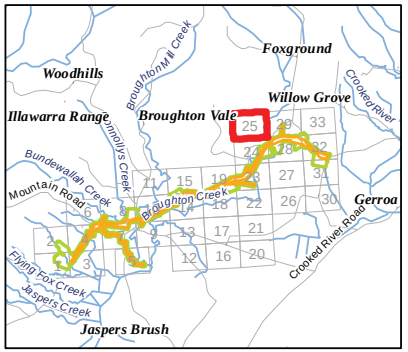
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1





Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.25: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

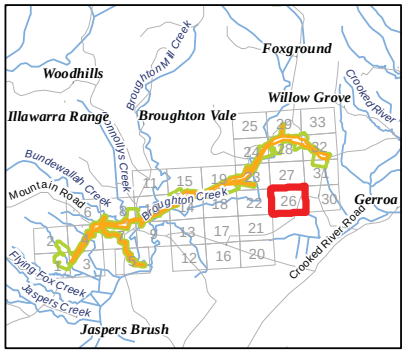
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.26: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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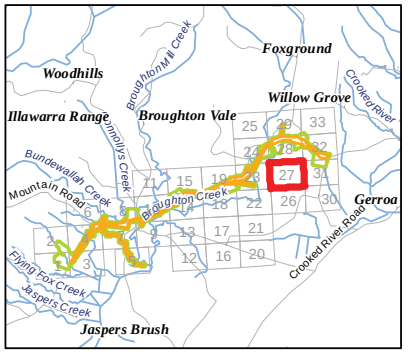
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.27: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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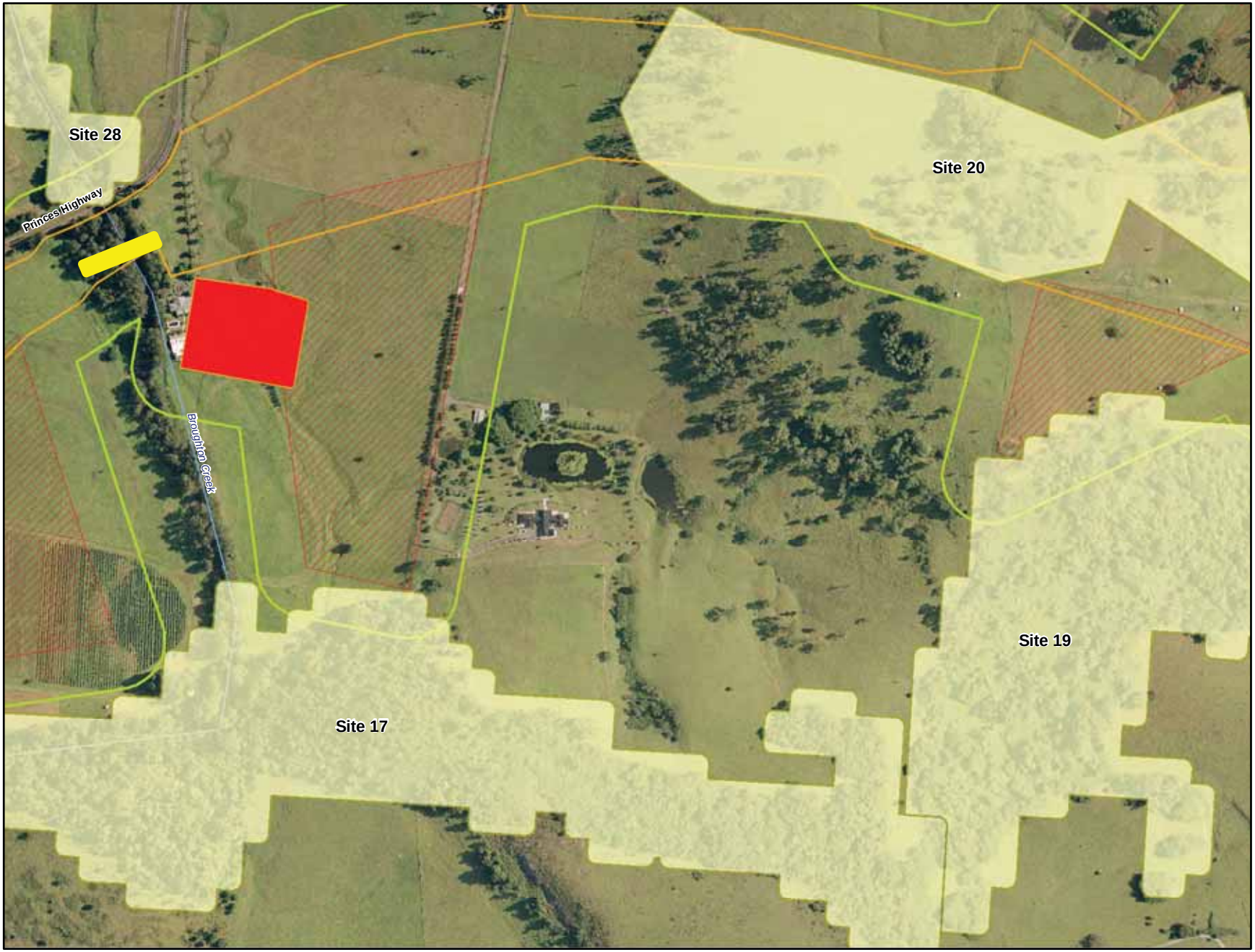
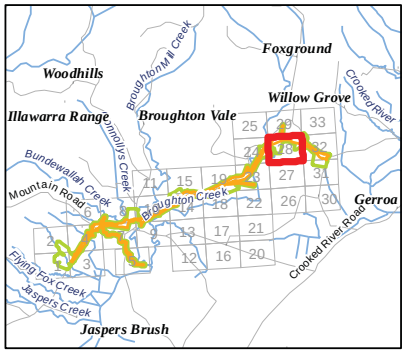
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1





Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.28: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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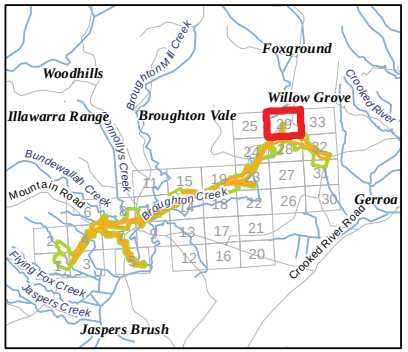
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.29: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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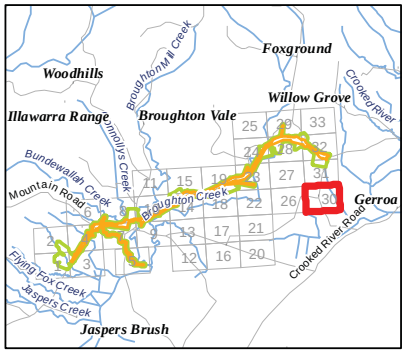
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.30: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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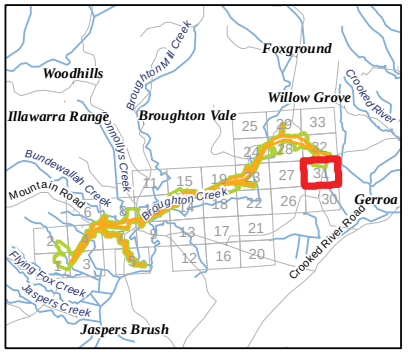
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.31: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

Acknowledgements:
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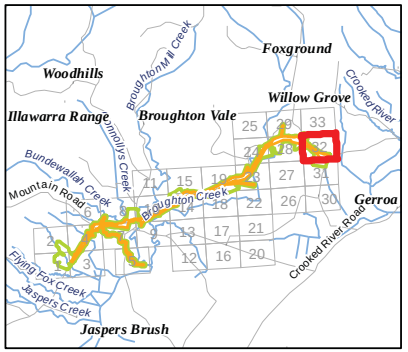
0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.32: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

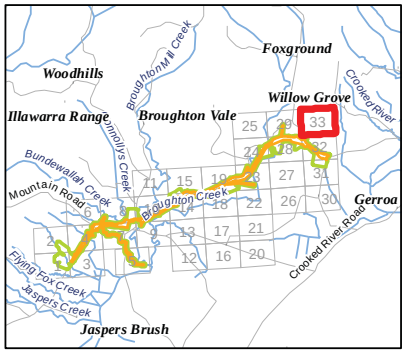
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

- Survey sites
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.1.33: Survey sites

Date: 13 July 2012	Drawn by: RS/JS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F2-1_Sites_130712.mxd	

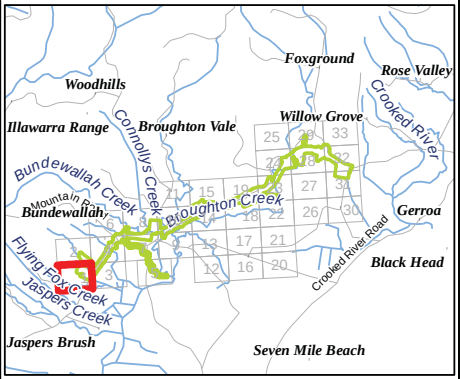
Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

Ü

Figure 2.1



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.1: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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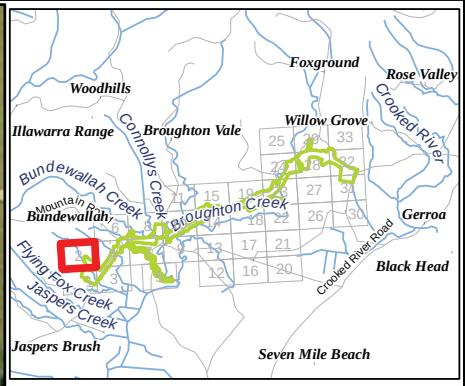
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- (Summer 2007 - Habitat condition assessment
-) Summer 2007 - Quadrat
-) Spring 2008 - Quadrat
- (Autumn 2009 - Habitat condition assessment
-) Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.2: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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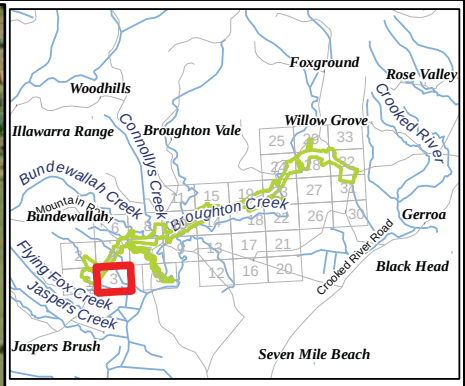
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.3: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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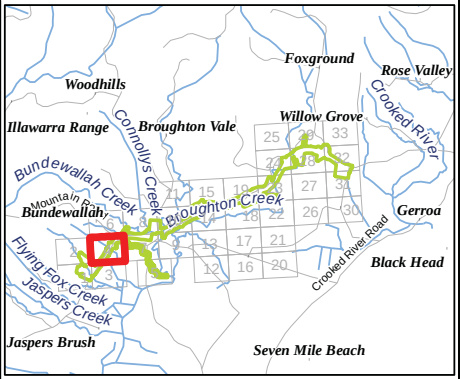
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.4: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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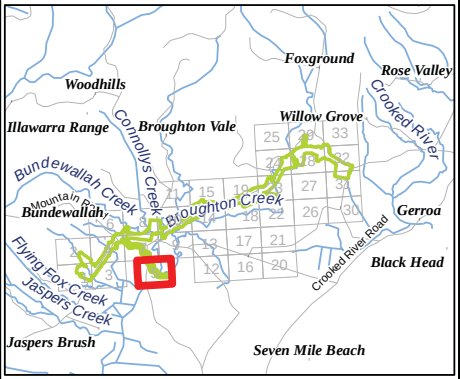
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.5: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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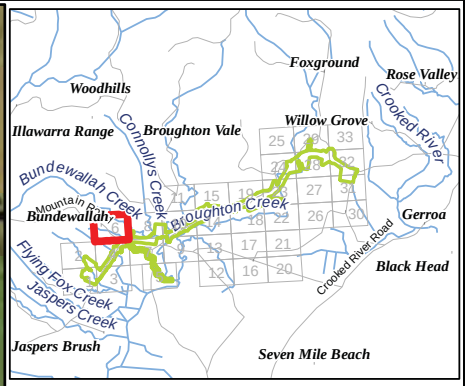
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.6: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
This product incorporates Data which is copyright to the Commonwealth of Australia (c.2003)

0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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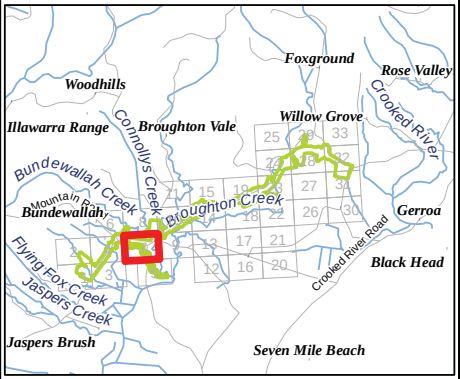
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- (Summer 2007 - Habitat condition assessment
-) Summer 2007 - Quadrat
-) Spring 2008 - Quadrat
- (Autumn 2009 - Habitat condition assessment
-) Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.7: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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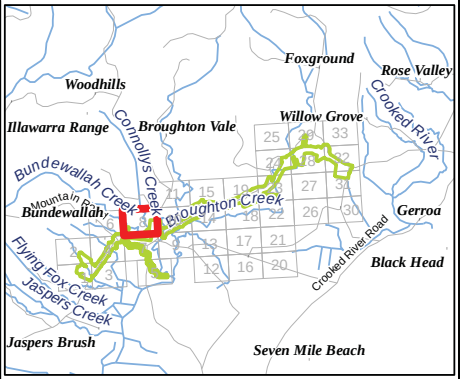
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.8: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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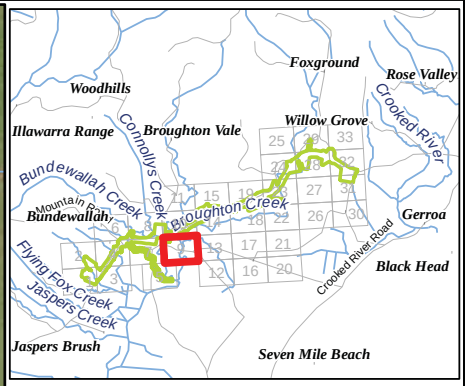
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.9: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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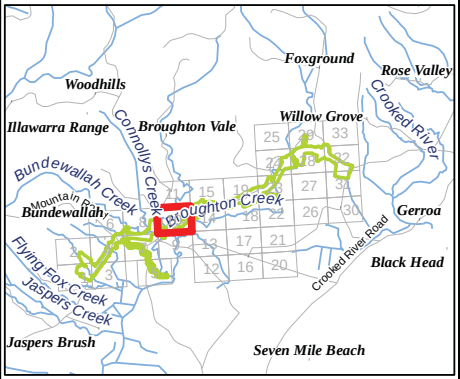
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- (Summer 2007 - Habitat condition assessment
-) Summer 2007 - Quadrat
-) Spring 2008 - Quadrat
- (Autumn 2009 - Habitat condition assessment
-) Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.10: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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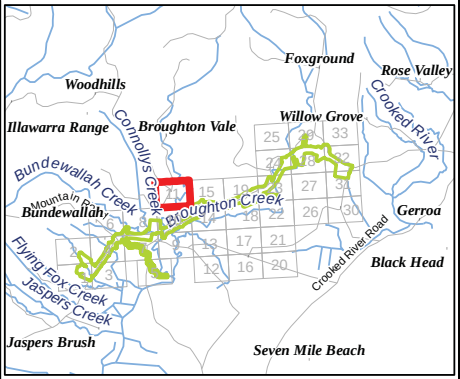
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.11: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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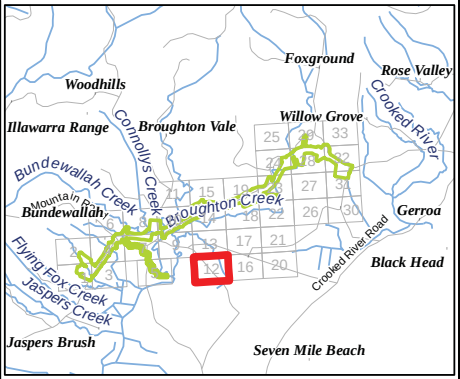
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.12: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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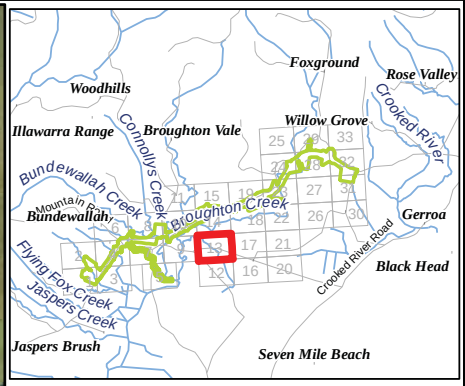
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.13: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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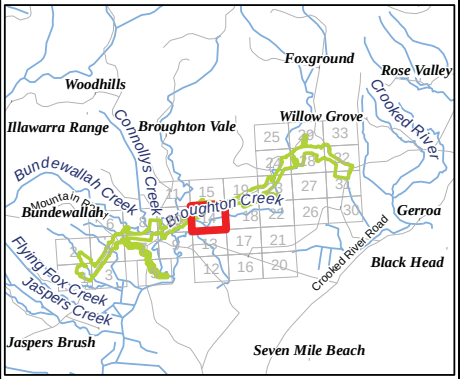
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.14: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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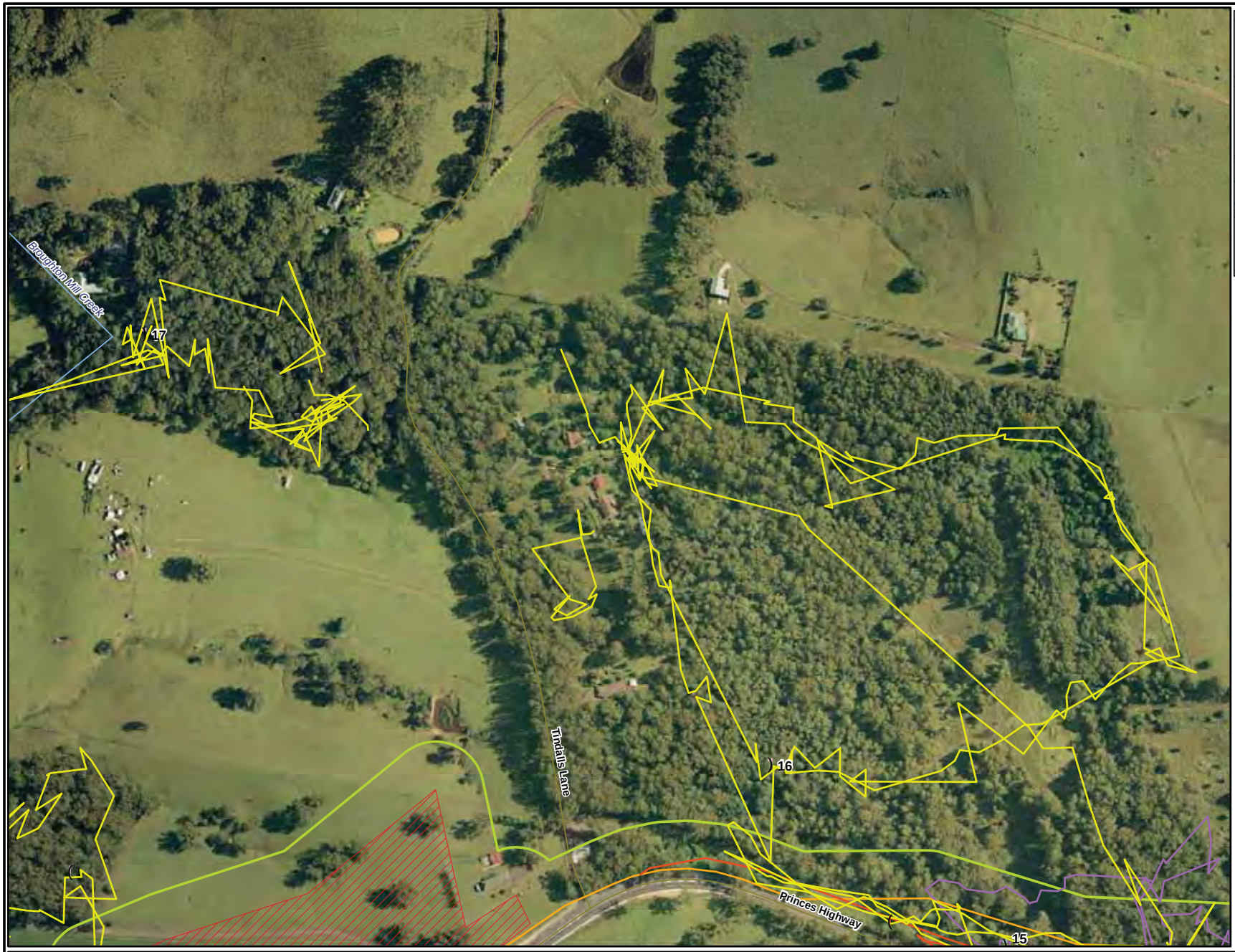
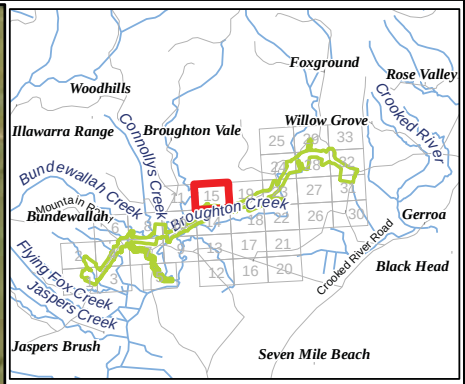
Figure 2.2





Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.15: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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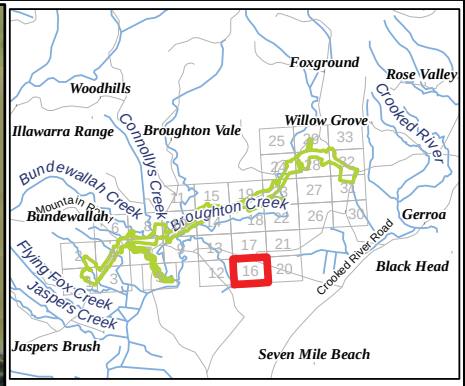
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.16: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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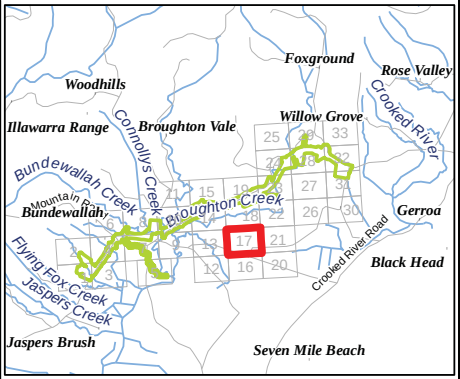
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.17: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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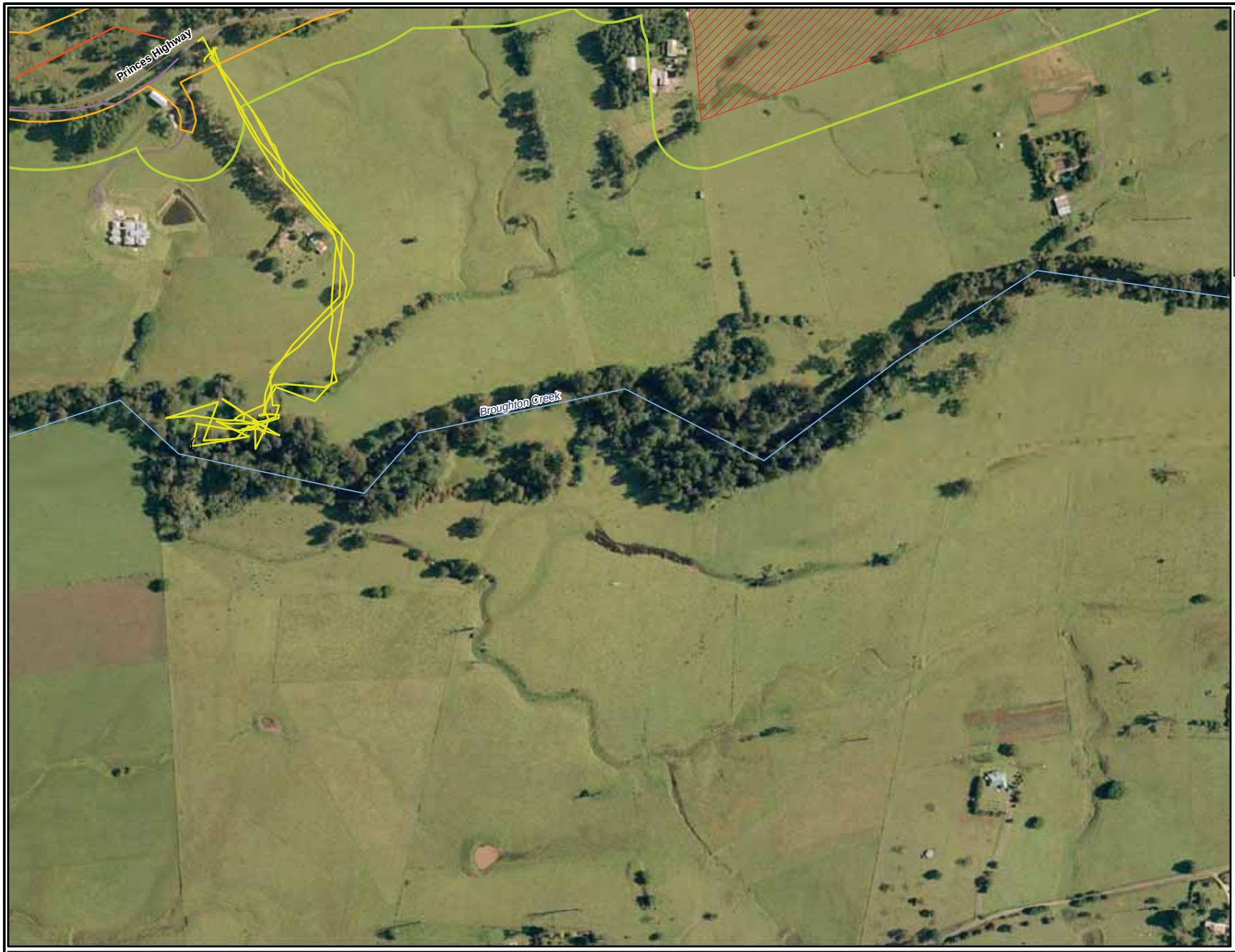
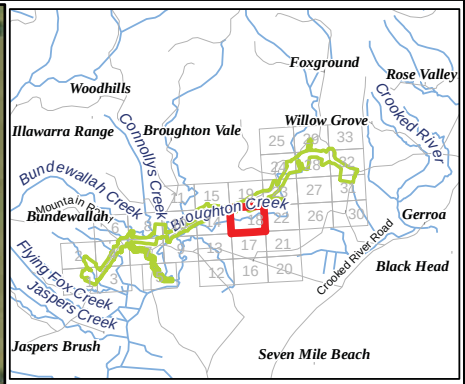
Figure 2.2





Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.18: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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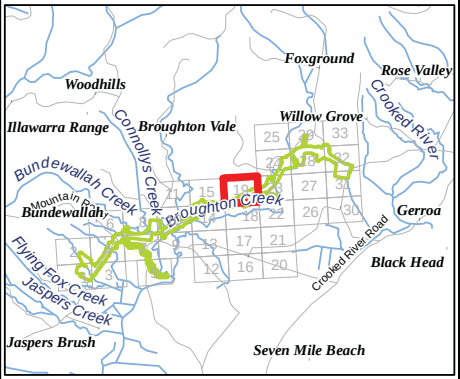
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- (Summer 2007 - Habitat condition assessment
-) Summer 2007 - Quadrat
-) Spring 2008 - Quadrat
- (Autumn 2009 - Habitat condition assessment
-) Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.19: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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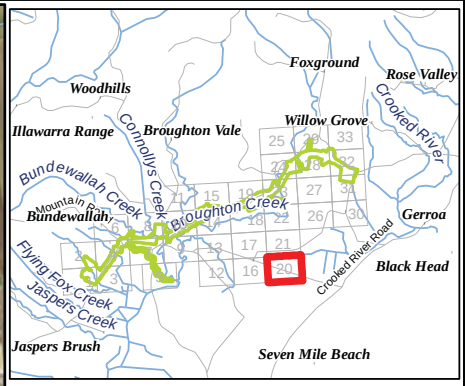
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- (Summer 2007 - Habitat condition assessment
-) Summer 2007 - Quadrat
-) Spring 2008 - Quadrat
- (Autumn 2009 - Habitat condition assessment
-) Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.20: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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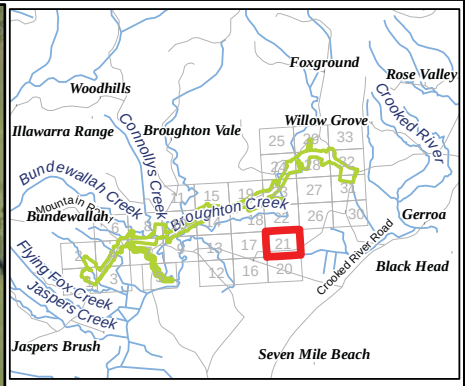
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.21: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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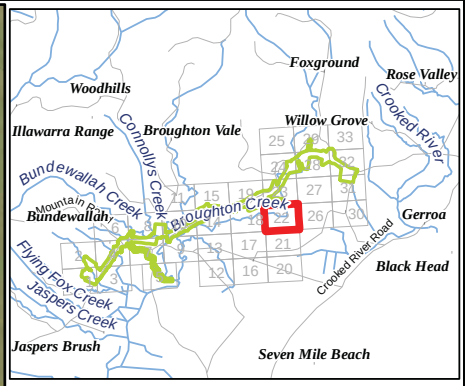
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.22: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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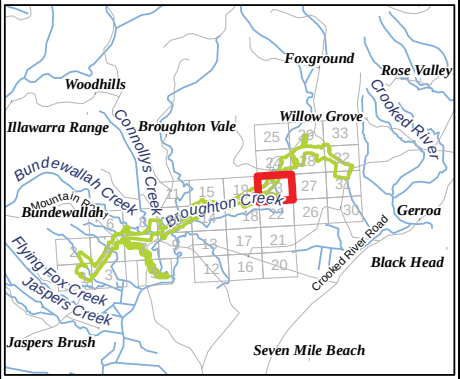
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.23: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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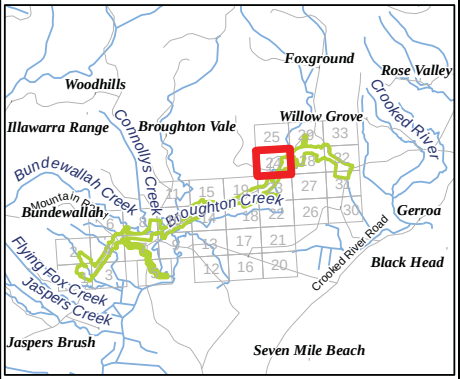
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.24: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
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Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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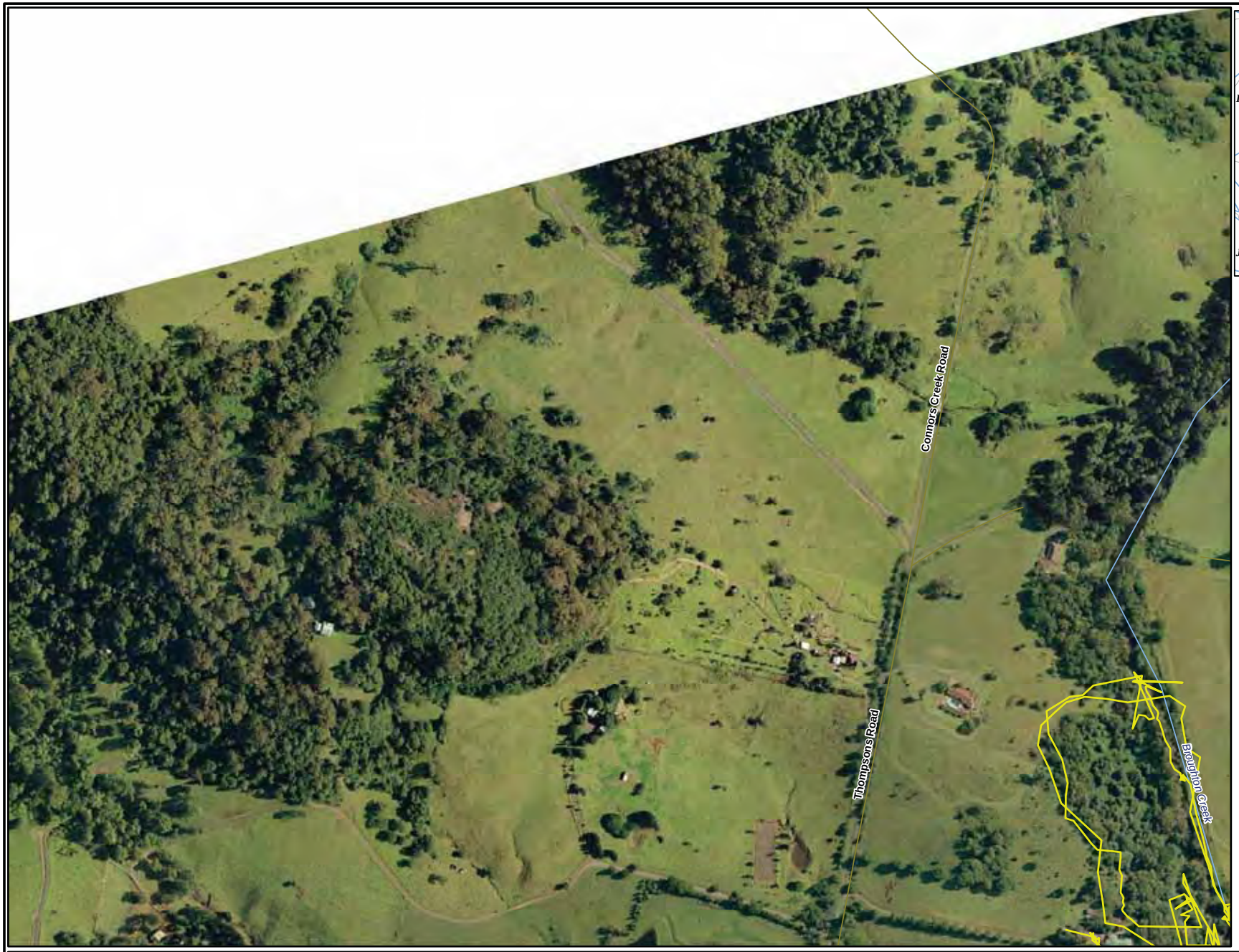
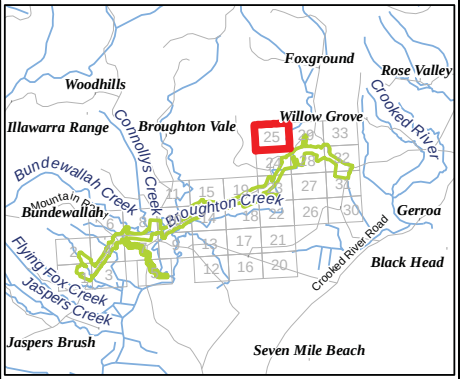
Figure 2.2





Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.25: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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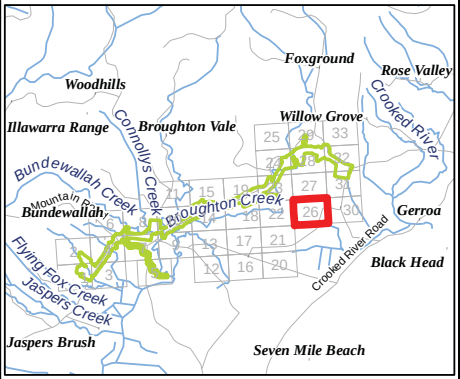
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
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Figure 2.2.26: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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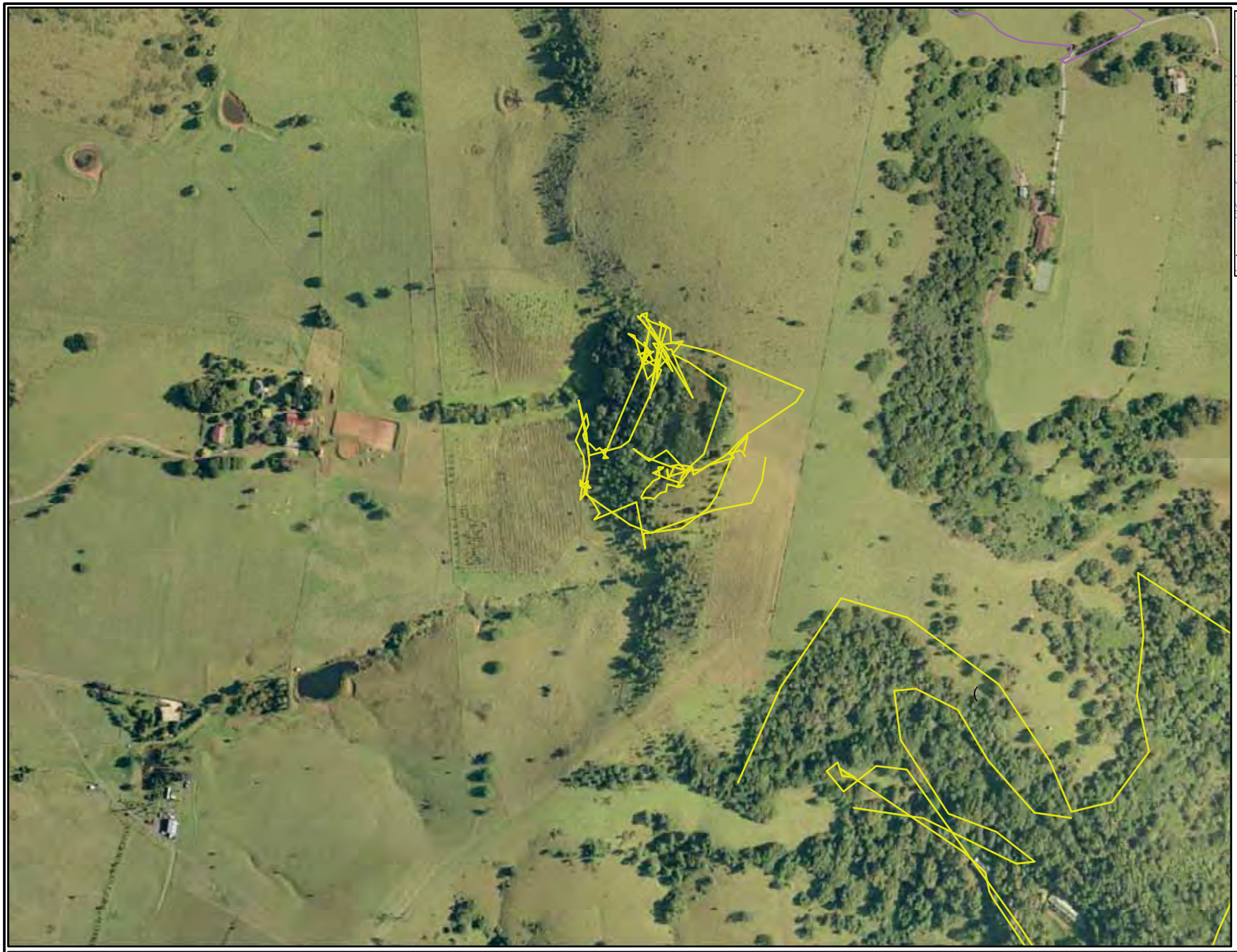
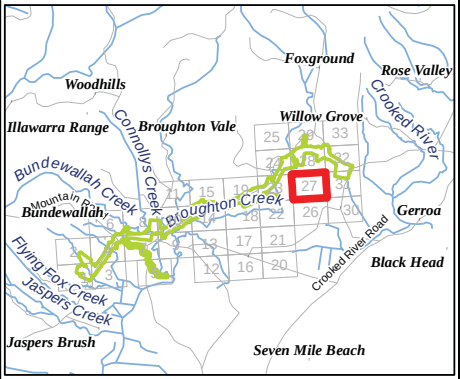
Figure 2.2





Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
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Figure 2.2.27: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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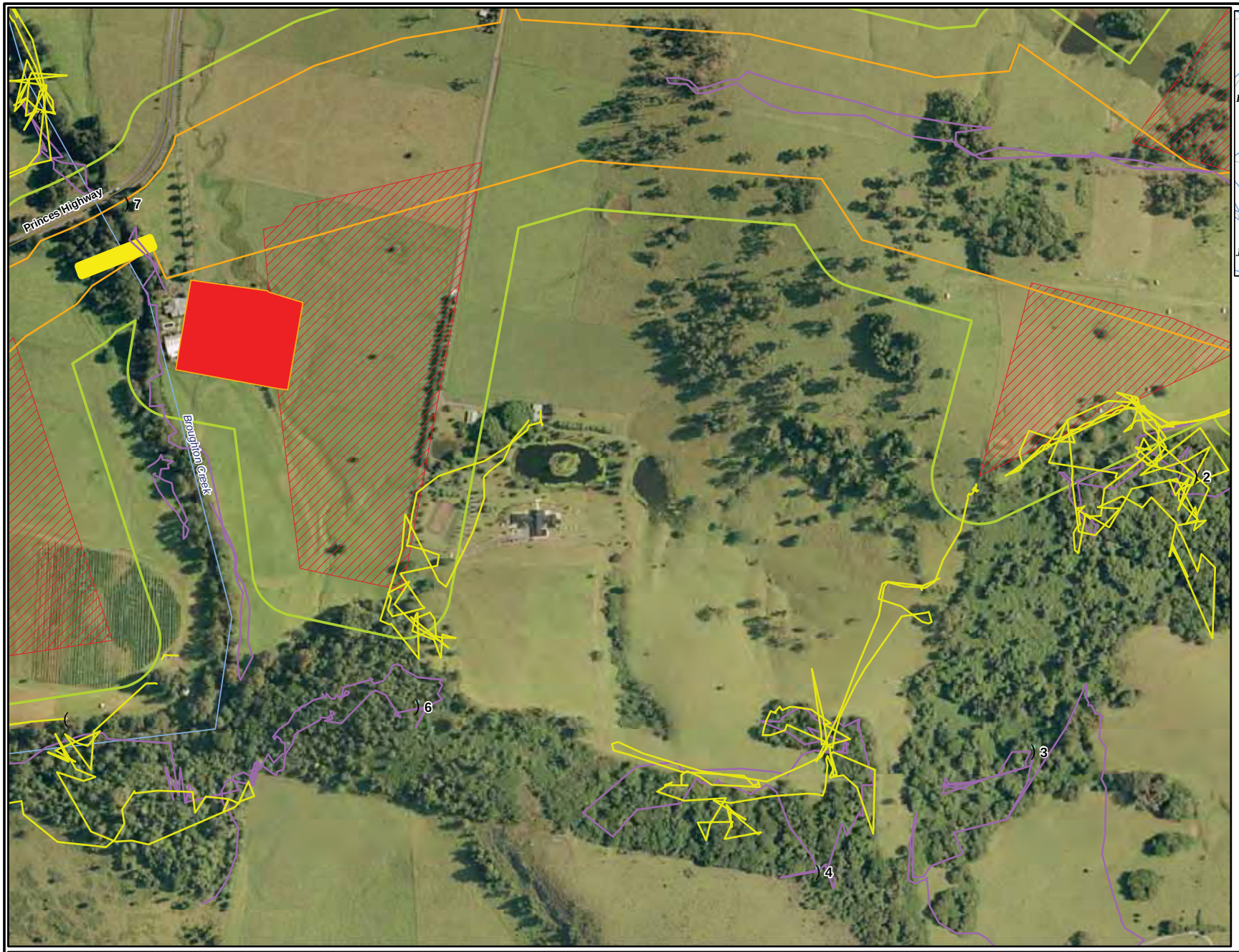
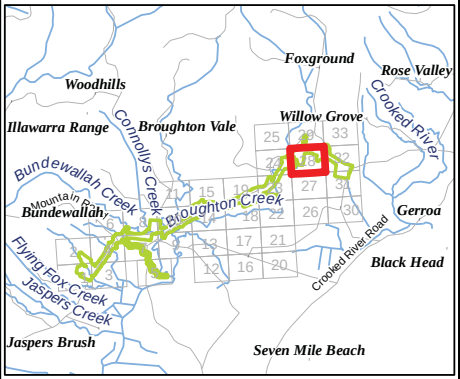
Figure 2.2





Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.28: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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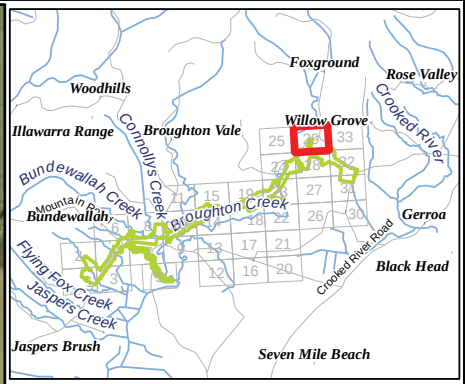
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.29: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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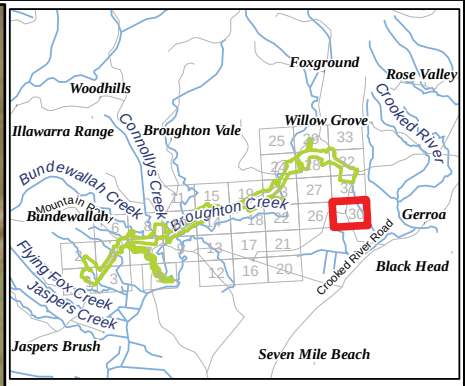
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.30: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

Acknowledgements:
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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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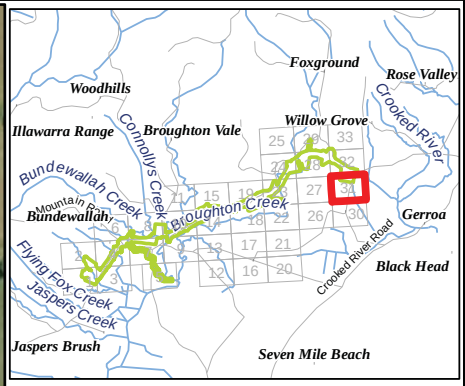
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.31: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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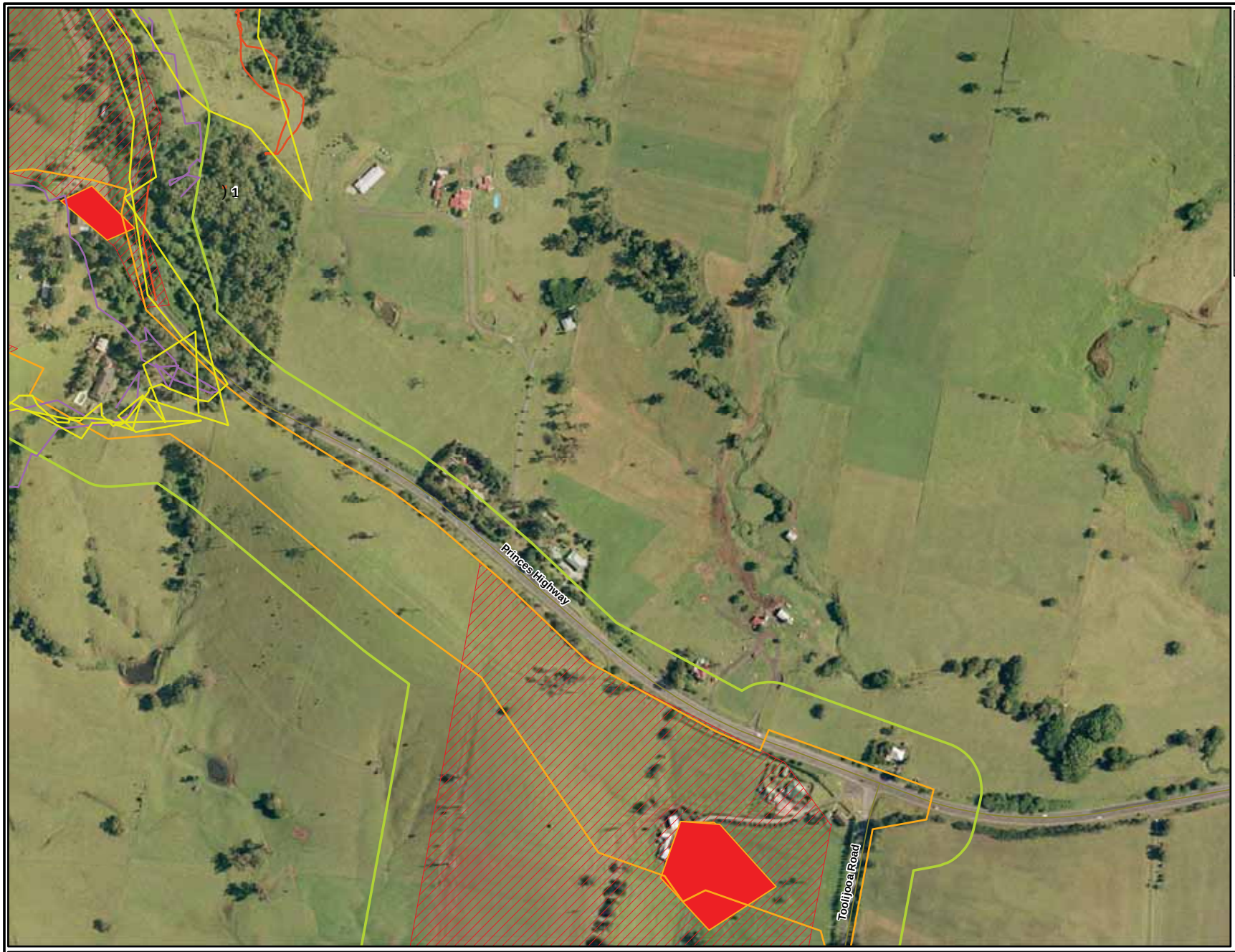
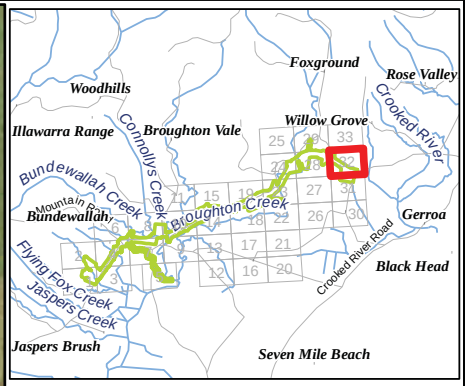
Figure 2.2





Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.32: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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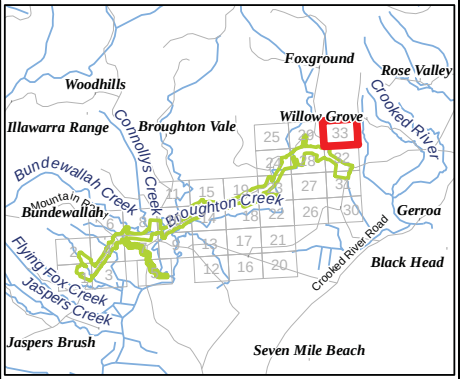
Figure 2.2



Legend

(No. Refers to Quadrats listed in Appendix A)

- Summer 2007 - Habitat condition assessment
- Summer 2007 - Quadrat
- Spring 2008 - Quadrat
- Autumn 2009 - Habitat condition assessment
- Autumn 2009 - Quadrat
- Summer 2007 - Random meander transect
- Spring 2008 - Random meander transect
- Autumn 2009 - Random meander transect
- Spring 2011 - Town Creek Random meander transect
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 2.2.33: Location of flora survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location:P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-2_SurveyFlora_130712.mxd	

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0 50 100 150 200
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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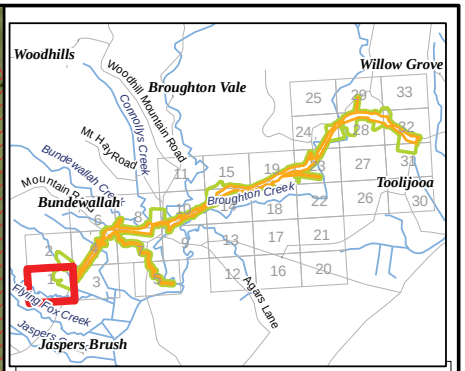
Figure 2.2



Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
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- Autumn 2009 - Spotlighting
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.1: Location of fauna survey effort

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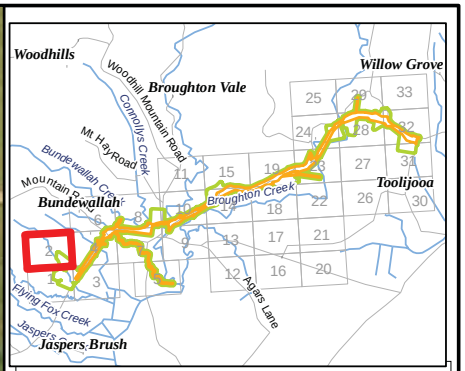
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
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- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
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- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
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- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
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- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
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Figure 2.3.2: Location of fauna survey effort

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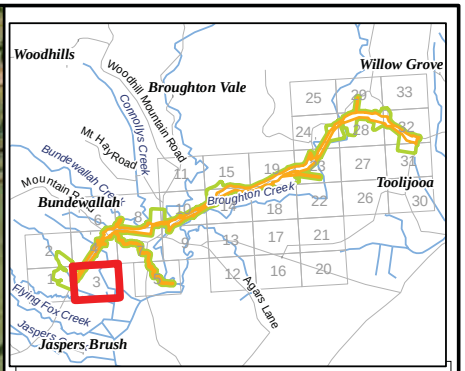

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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
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Figure 2.3.3: Location of fauna survey effort

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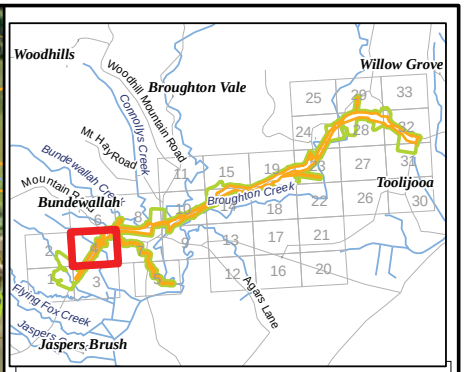

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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
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Ancillary Sites
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- Subject Site - Stockpile
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Figure 2.3.4: Location of fauna survey effort

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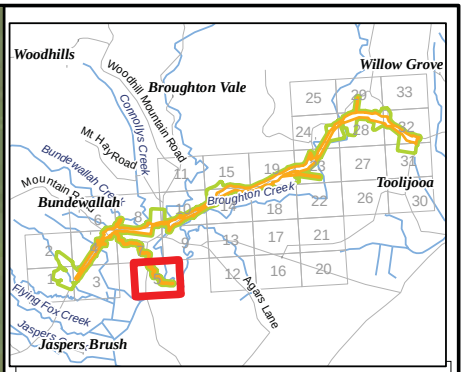

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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
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- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
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Figure 2.3.5: Location of fauna survey effort

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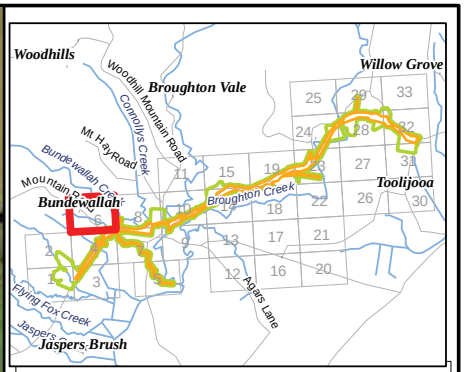

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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
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Ancillary Sites

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Figure 2.3.6: Location of fauna survey effort

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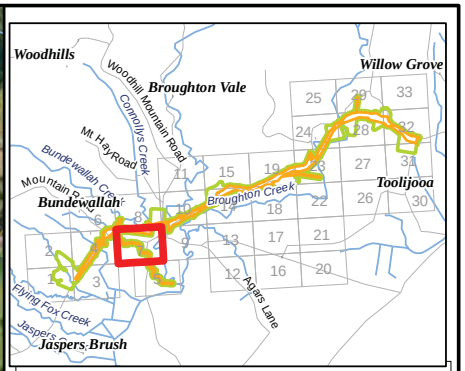

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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
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Ancillary Sites

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Figure 2.3.7: Location of fauna survey effort

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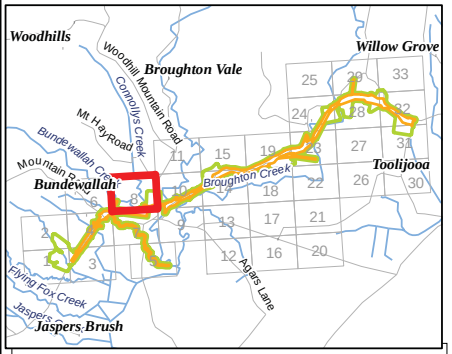

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Survey points
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- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
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- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
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- Summer 2007 - Spotlighting
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Figure 2.3.8: Location of fauna survey effort

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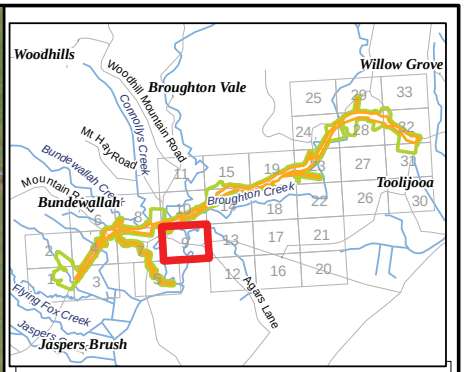

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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
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Survey transects
- Summer 2007 - Bird Survey
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- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
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Figure 2.3.9: Location of fauna survey effort

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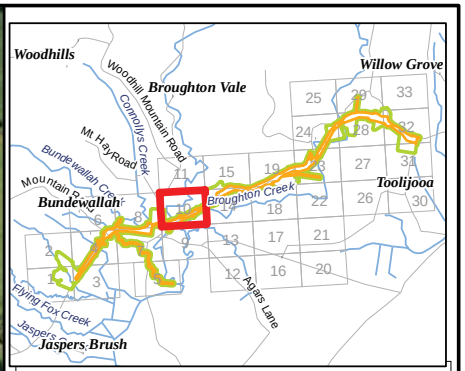

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Survey points
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- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
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- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
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- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
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Figure 2.3.10: Location of fauna survey effort

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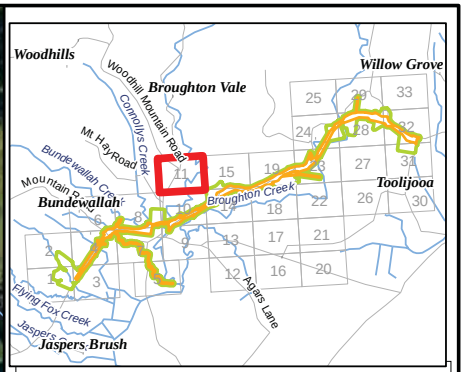

Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.11: Location of fauna survey effort

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Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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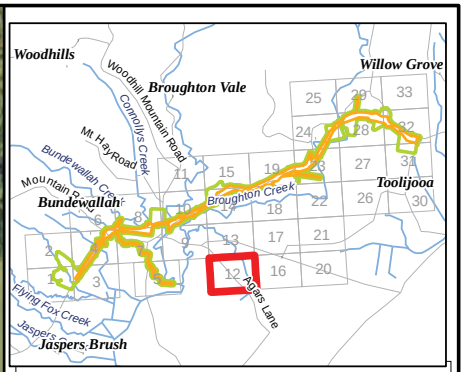
Figure 2.3



Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.12: Location of fauna survey effort

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Grid: Map Grid of Australia, Zone 56

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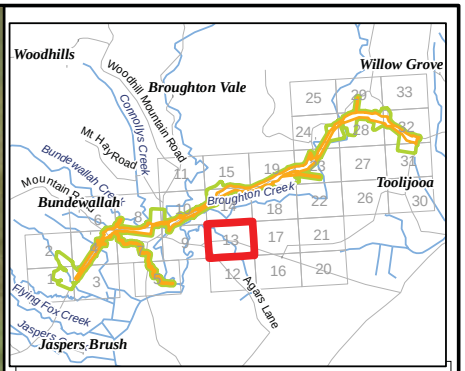
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
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Figure 2.3.13: Location of fauna survey effort

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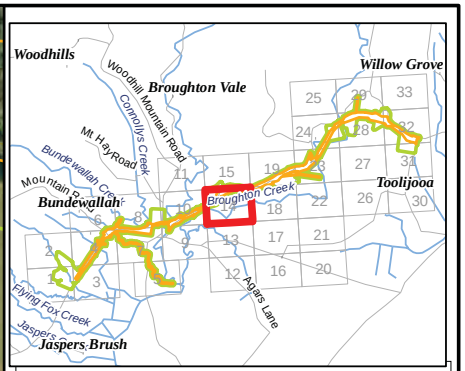

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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
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Figure 2.3.14: Location of fauna survey effort

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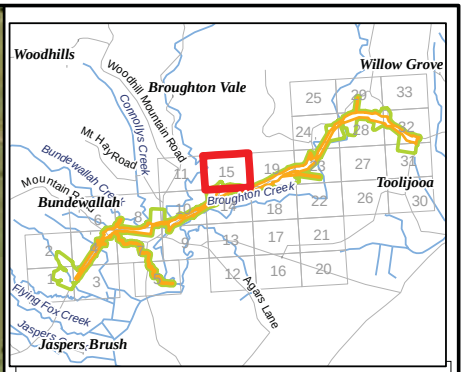

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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
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- Autumn 2009 - Spotlighting
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Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
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Figure 2.3.15: Location of fauna survey effort

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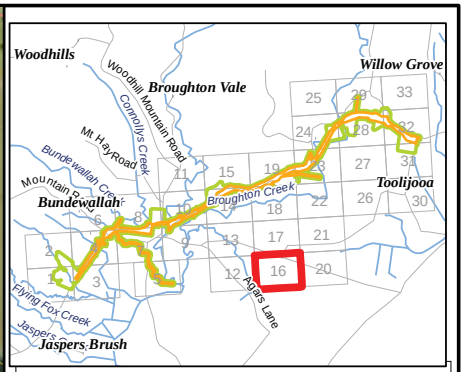

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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
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- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
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Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
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Figure 2.3.16: Location of fauna survey effort

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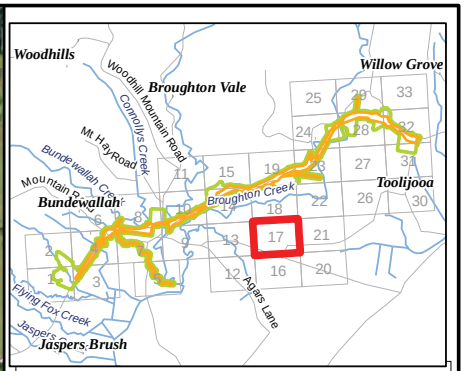

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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
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- Subject Site - Temporary Creek Crossings
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Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
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Figure 2.3.17: Location of fauna survey effort

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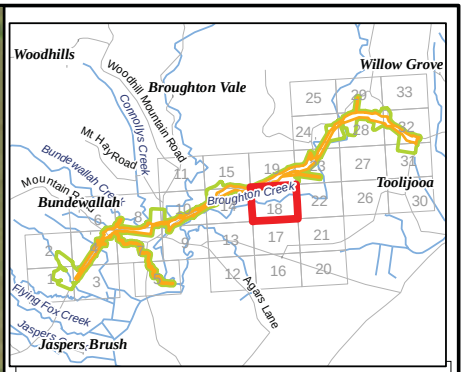
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
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Ancillary Sites
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Figure 2.3.18: Location of fauna survey effort

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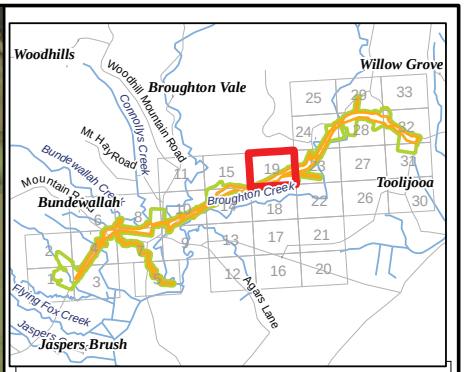

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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
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Ancillary Sites
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Figure 2.3.19: Location of fauna survey effort

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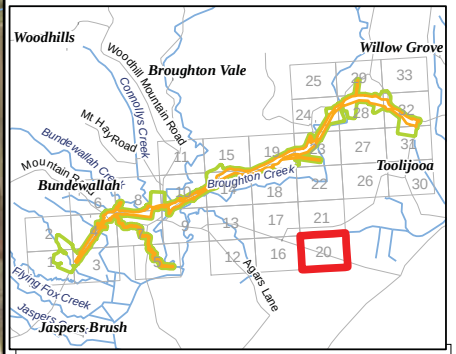

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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
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Ancillary Sites
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Figure 2.3.20: Location of fauna survey effort

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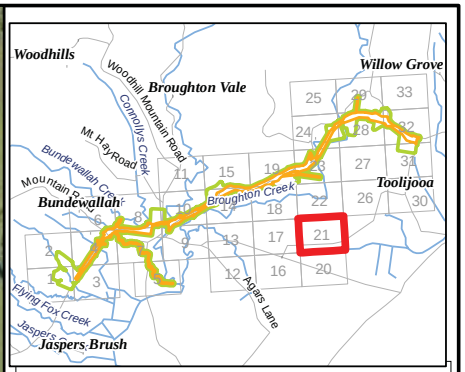
Figure 2.3



Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.21: Location of fauna survey effort

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0 40 80 120 160 200
Metres

Scale: 1: 4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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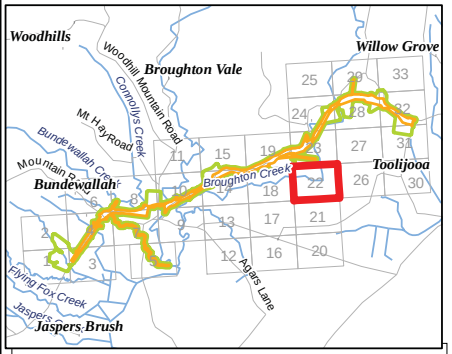
Figure 2.3



Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.22: Location of fauna survey effort

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Metres

Scale: 1: 4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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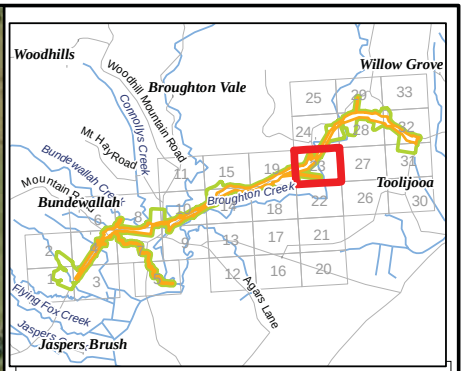
Figure 2.3



Legend

Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.23: Location of fauna survey effort

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Metres

Scale: 1: 4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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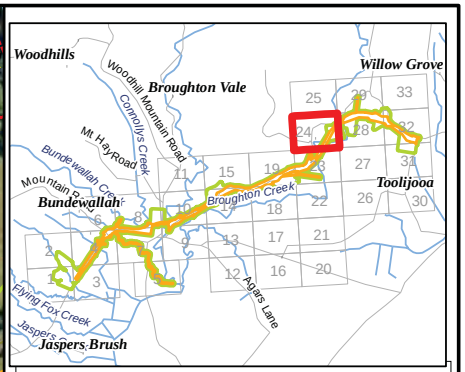
Figure 2.3



Legend

Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
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Figure 2.3.24: Location of fauna survey effort

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Scale: 1: 4,000 at A3
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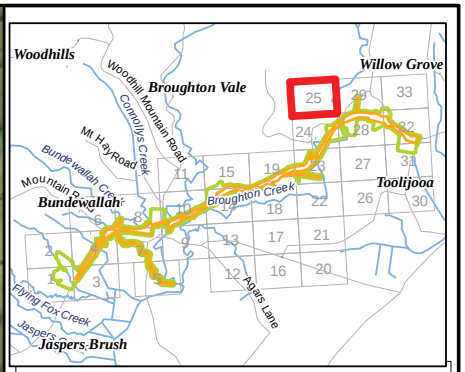
Figure 2.3



Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
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- Subject Site - Temporary Creek Crossings
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Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.25: Location of fauna survey effort

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Scale: 1: 4,000 at A3
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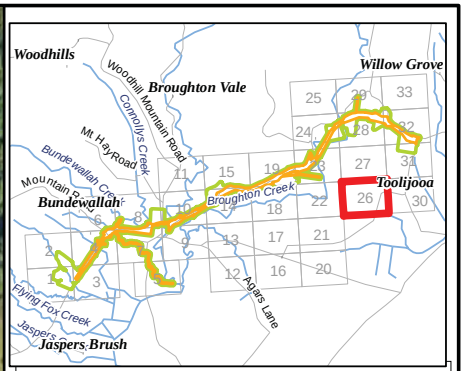
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.26: Location of fauna survey effort

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Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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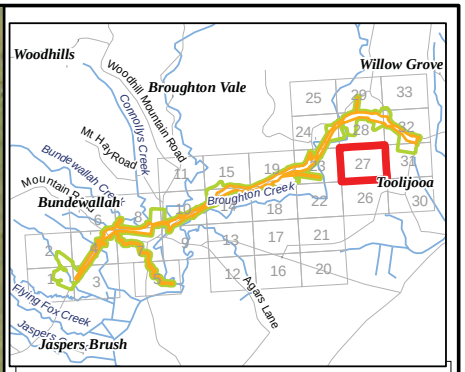
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
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- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.27: Location of fauna survey effort

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Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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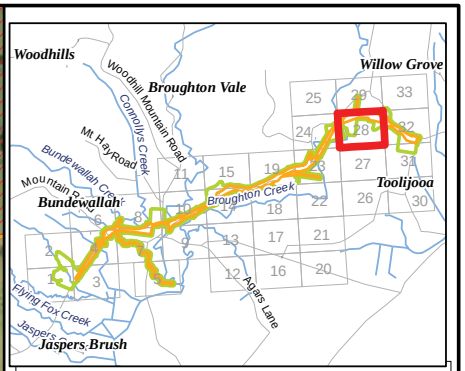
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
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Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
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- RoadNameExtent

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Figure 2.3.28: Location of fauna survey effort

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Metres

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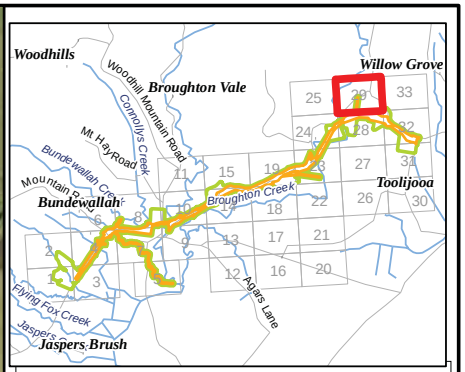
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
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Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
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- RoadNameExtent

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Figure 2.3.29: Location of fauna survey effort

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Metres

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Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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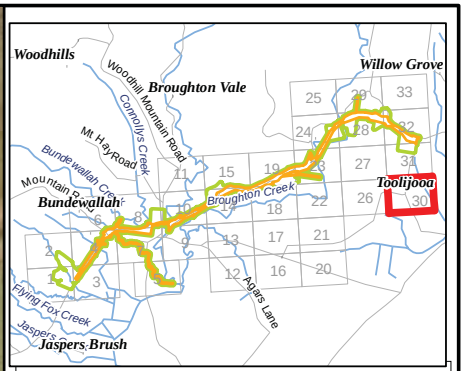
Figure 2.3



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Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
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- RoadNameExtent

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Figure 2.3.30: Location of fauna survey effort

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Metres

Scale: 1: 4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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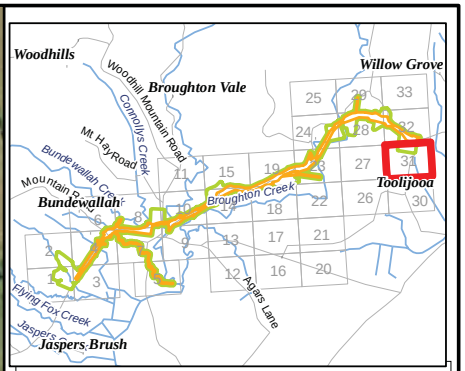
Figure 2.3



Legend

Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.31: Location of fauna survey effort

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Location: P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-3_survey_fauna_010812.mxd	

Acknowledgements:
Aerial imagery provided by ARUP
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0 40 80 120 160 200
Metres

Scale: 1: 4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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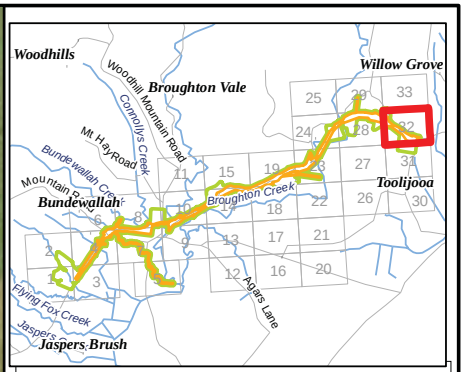
Figure 2.3



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Survey points
- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects
- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites
- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.32: Location of fauna survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
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Acknowledgements:
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Metres

Scale: 1: 4,000 at A3
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Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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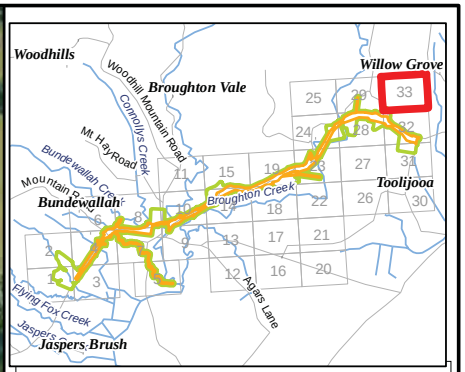
Figure 2.3



Legend

Survey points

- Summer 2007, Anabat
- Summer 2007, Anabat/Harp Trap
- Summer 2007, Anabat/Owl Call Playback
- Summer 2007, Bird Survey
- Summer 2007, Habitat Assessment
- Summer 2007, Harp Trap
- Summer 2007, Owl Call Playback
- Summer 2007, Spotlighting
- Spring 2008, Anabat
- Spring 2008, Bird Survey
- Spring 2008, Frog Spotlight
- Spring 2008, Habitat Assessment
- Spring 2008, Owl Call Playback
- Autumn 2009, Bird Survey
- Autumn 2009, Call Playback
- Autumn 2009, Frog Spotlight
- Autumn 2009, Habitat Assessment
- Autumn 2009, Spotlighting

Survey transects

- Summer 2007 - Bird Survey
- Summer 2007 - Elliot Trap
- Summer 2007 - Cage Trap
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey
- Summer 2007 - Elliot Trap/Cage Trap/Bird Survey/Spotlighting
- Summer 2007 - Spotlighting
- Summer 2007 - Spotlighting/Nocturnal Bird Survey
- Spring 2008 - Bird survey
- Spring 2008 - Elliot Trap/Cage Trap
- Spring 2008 - Elliot Trap/Cage Trap/Hair Tube
- Spring 2008 - Spotlighting
- Spring 2008 - Spotlighting/Nocturnal Bird Survey
- Autumn 2009 - Bird survey
- Autumn 2009 - Cage Trap
- Autumn 2009 - Spotlighting
- Spring 2011 - Town Creek general survey and habitat assessments
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area
- RoadNameExtent

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Figure 2.3.33: Location of fauna survey effort

Date: 1 August 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variation 2\Variation 2 figures\15039_S2_F2-3_survey_fauna_010812.mxd	

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Scale: 1: 4,000 at A3
Map Projection: Transverse Mercator
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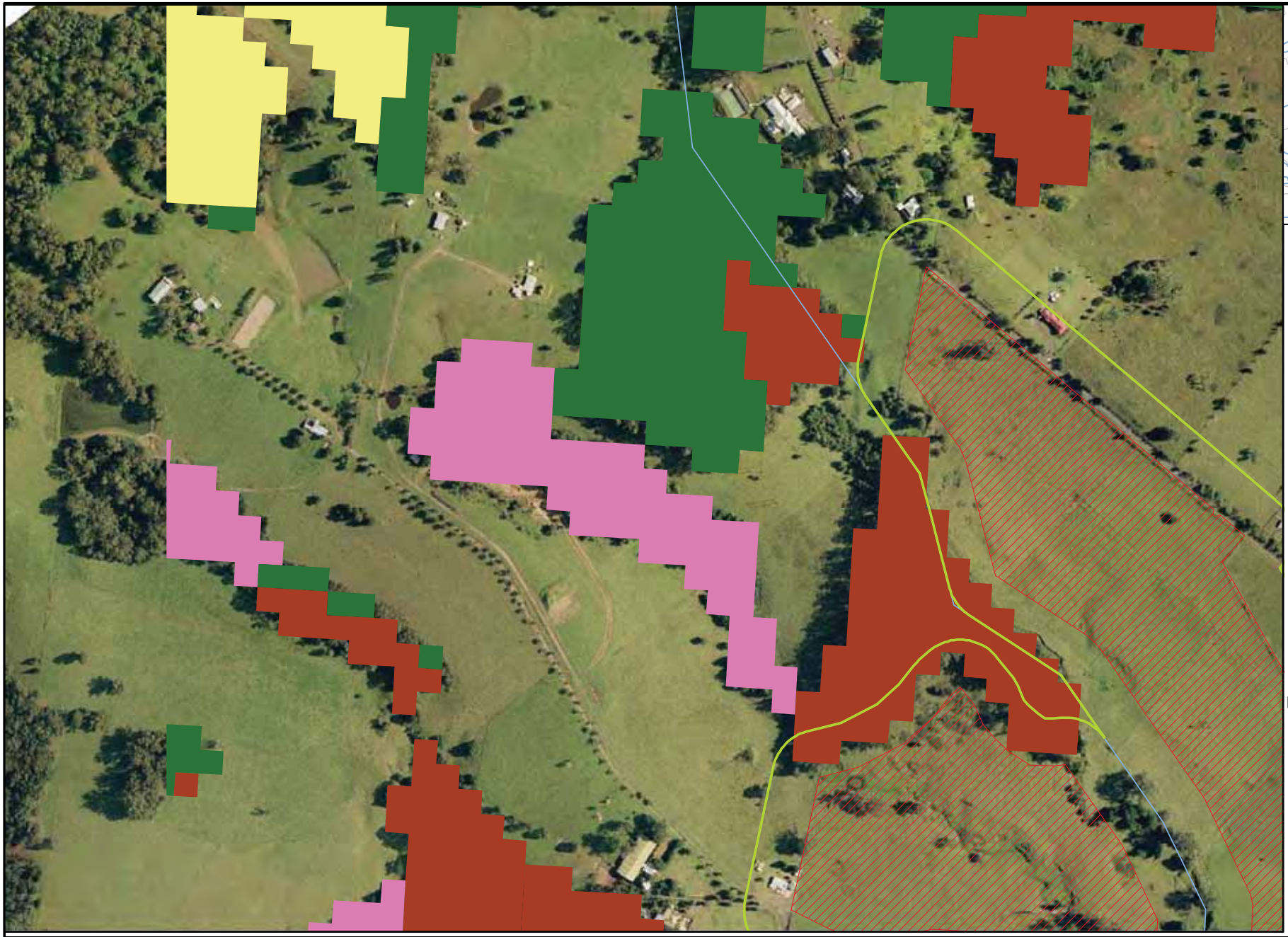
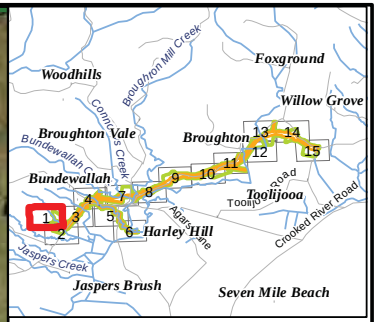
Figure 2.3





Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest

- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile

- Study Area

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Figure 3.1.1: Vegetation mapping of the study area (modified from DECCW, 2005)

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File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

Acknowledgements:
Vegetation mapping from DECCW
Aerial imagery provided by ARUP

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Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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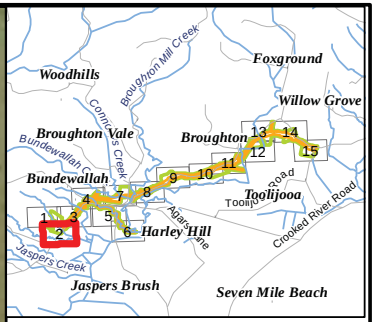
Figure 3.1



Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.2: Vegetation mapping of the study area (modified from DECCW, 2005)

Date: 16 July 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

Acknowledgements:
Vegetation mapping from DECCW
Aerial imagery provided by ARUP
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Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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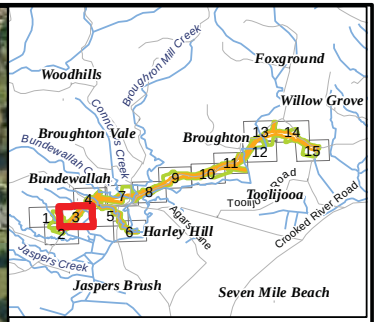
Figure 3.1



Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.3: Vegetation mapping of the study area (modified from DECCW, 2005)

Date: 16 July 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

Acknowledgements:
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Aerial imagery provided by ARUP
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0 60 120 180 240

Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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Figure 3.1

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Figure 3.1.4: Vegetation mapping of the study area (modified from DECCW, 2005)

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Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

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Aerial imagery provided by ARUP
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0 60 120 180 240
Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
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Grid: Map Grid of Australia, Zone 56

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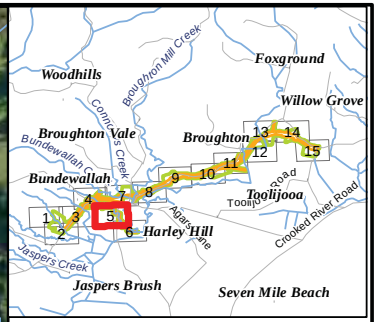
Figure 3.1



Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.5: Vegetation mapping of the study area (modified from DECCW, 2005)

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File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

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Aerial imagery provided by ARUP
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Metres

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Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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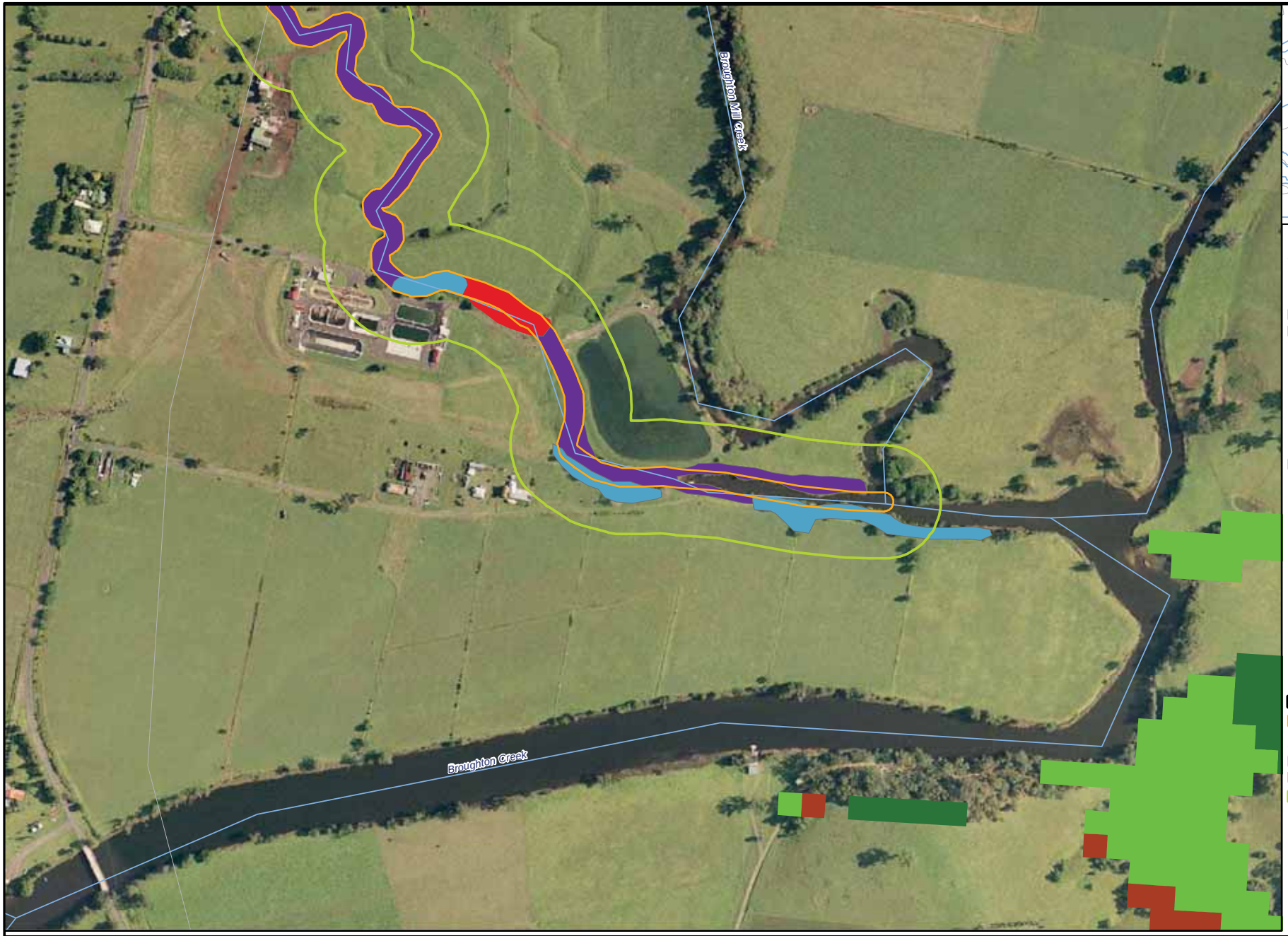
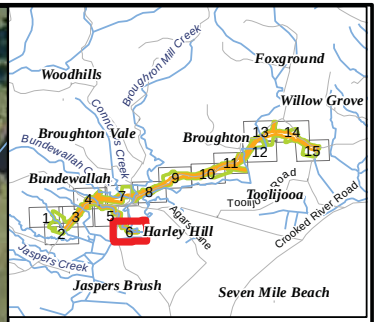
Figure 3.1





Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.6: Vegetation mapping of the study area (modified from DECCW, 2005)

Date: 16 July 2012	Drawn by: RS/JMS/ANP
File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

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0 60 120 180 240

Metres

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Map Projection: Transverse Mercator
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Grid: Map Grid of Australia, Zone 56

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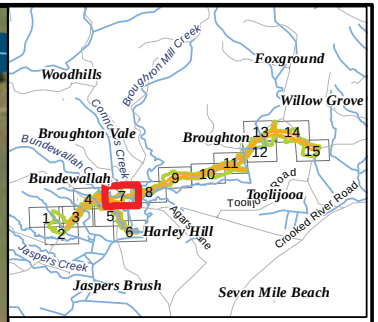
Figure 3.1



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Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.7: Vegetation mapping of the study area (modified from DECCW, 2005)

Date: 16 July 2012	Drawn by: RS/JMS/ANP
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Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

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Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
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Grid: Map Grid of Australia, Zone 56

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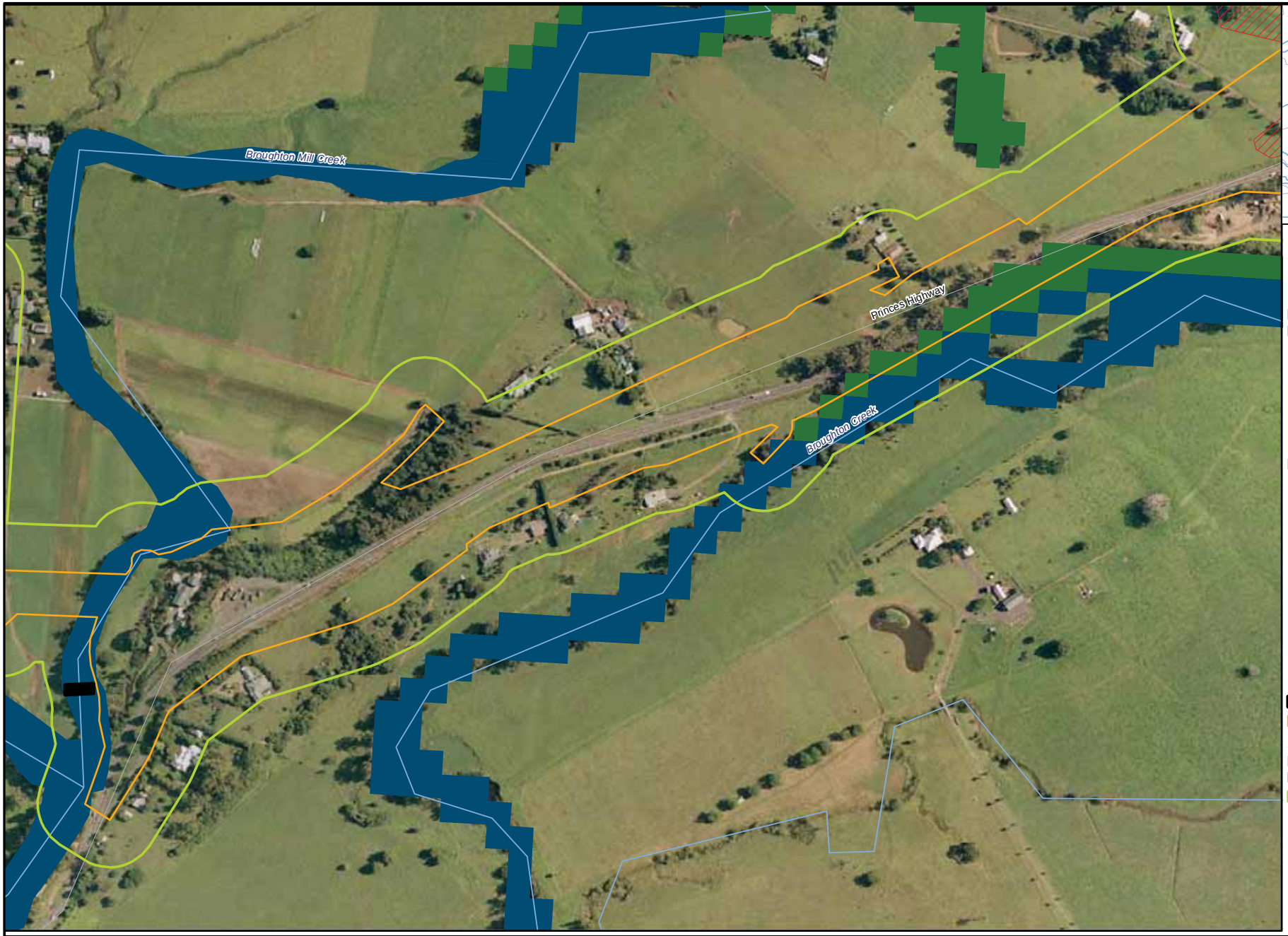
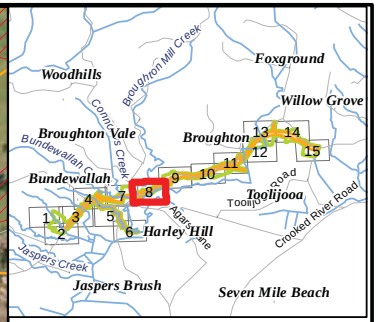
Figure 3.1





Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
- Estuarine Mangrove Forest
- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
- Illawarra Lowland Swamp Woodland
- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.8: Vegetation mapping of the study area (modified from DECCW, 2005)

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File: 13194	Checked by: JC
Location: P:\15000s\15039\Mapping\Variaition 1\Variation 1 Figures\13194_S2_F3-1_Veg_StripIndex_160712.mxd	

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Vegetation mapping from DECCW
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0 60 120 180 240

Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia, Zone 56

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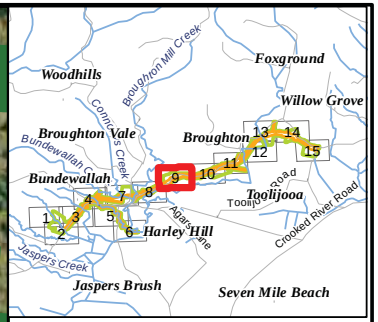
Figure 3.1



Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
- Coastal Sand Swamp Forest
- Coastal Warm Temperate Rainforest
- Constructed Wetland
- Currambene-Batemans Lowlands Forest
- Disturbed Riparian Open Woodland
- Escarpment Foothills Wet Forest
- Estuarine Creekflat Scrub
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- Floodplain Swamp Forest
- Illawarra Gully Wet Forest
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- Intermediate Temperate Rainforest
- Riverbank Forest
- South Coast Grassy Woodland
- Subtropical Complex Rainforest
- Subtropical Dry Rainforest
- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.9: Vegetation mapping of the study area (modified from DECCW, 2005)

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Acknowledgements:
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0 60 120 180 240

Metres

Scale: 1:4,000 at A3
Map Projection: Transverse Mercator
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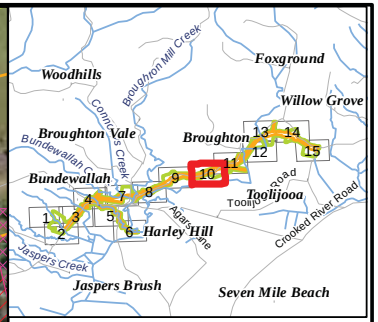

Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
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- Subject Site - Temporary Creek Crossings
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Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.10: Vegetation mapping of the study area (modified from DECCW, 2005)

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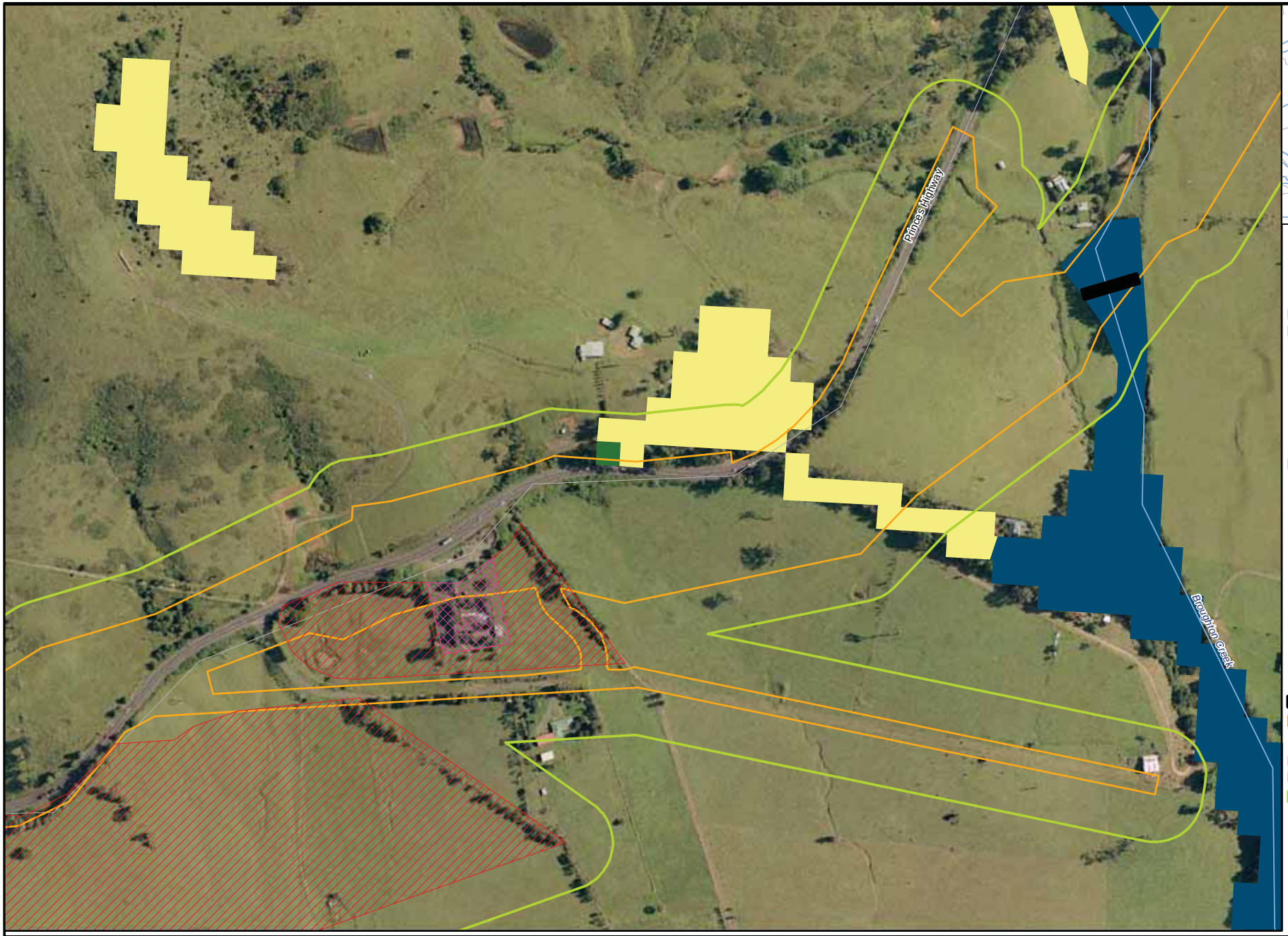

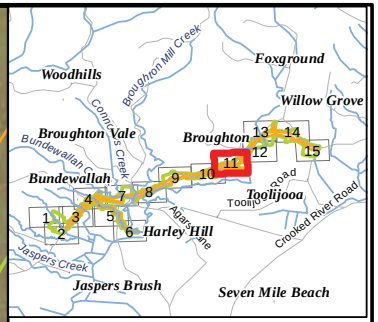

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Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.11: Vegetation mapping of the study area (modified from DECCW, 2005)

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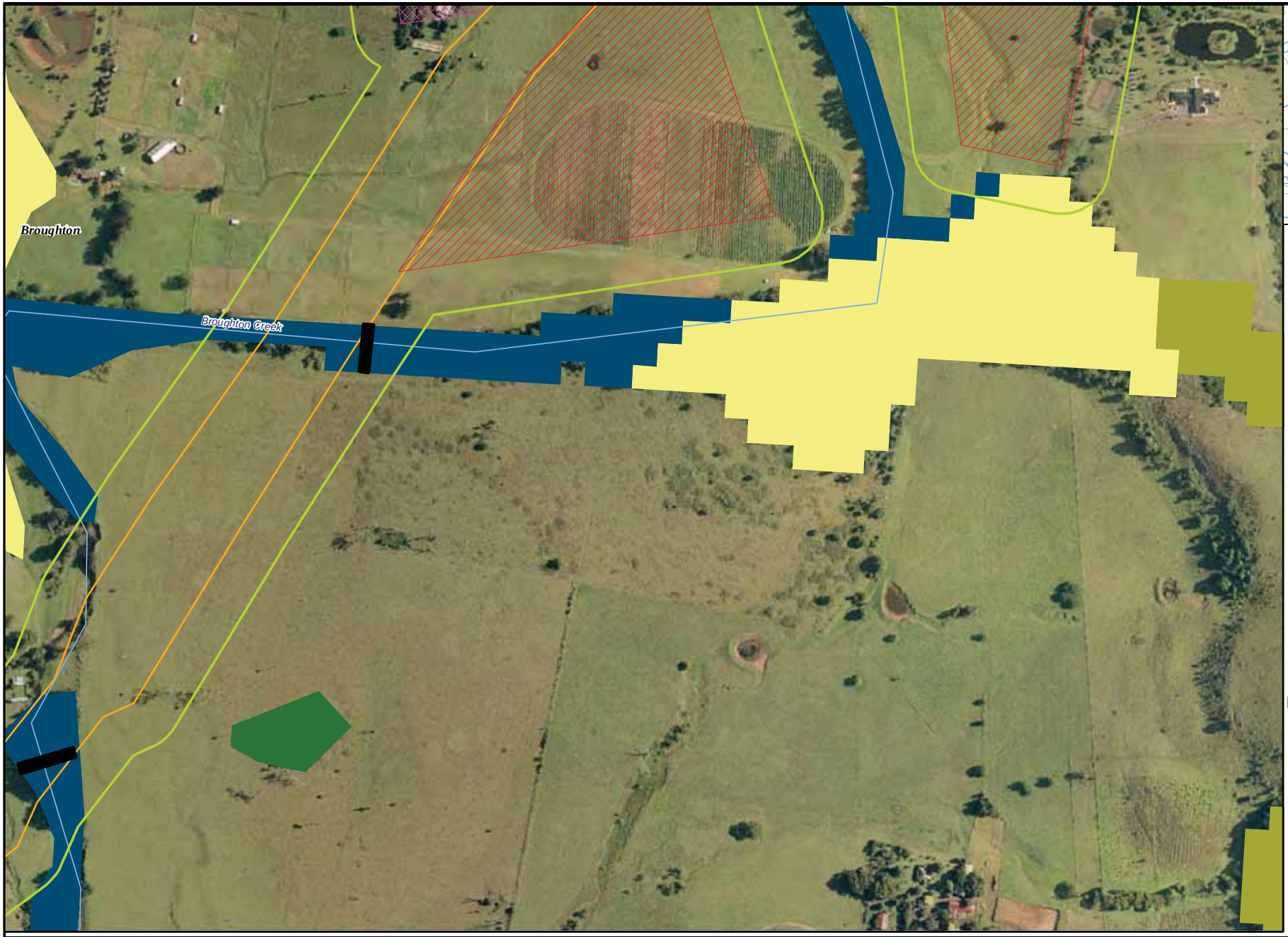

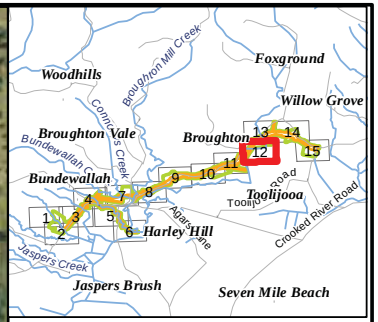

Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.12: Vegetation mapping of the study area (modified from DECCW, 2005)

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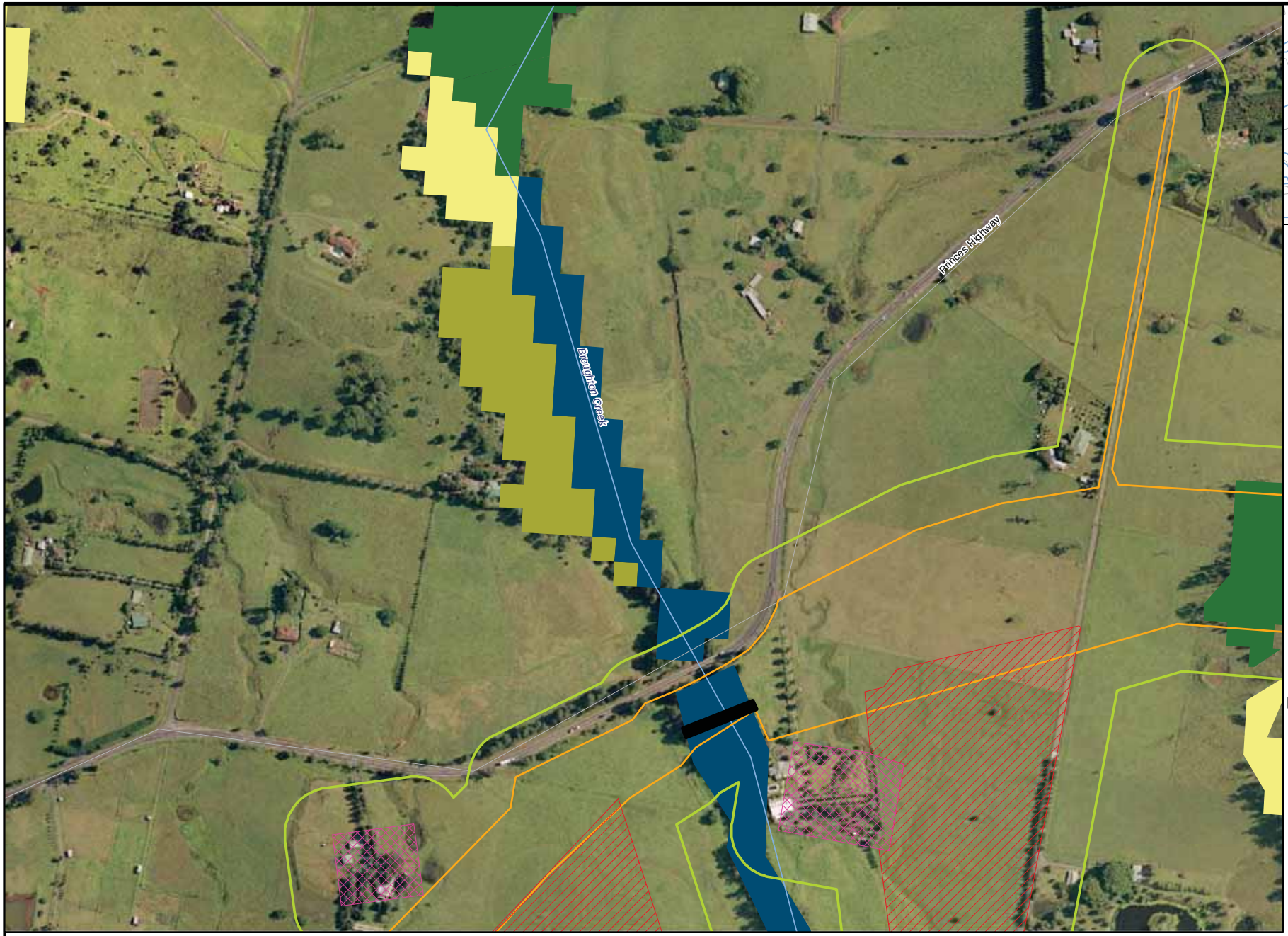

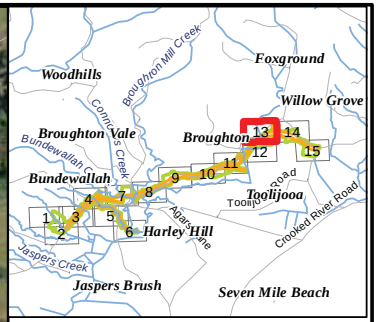

Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.13: Vegetation mapping of the study area (modified from DECCW, 2005)

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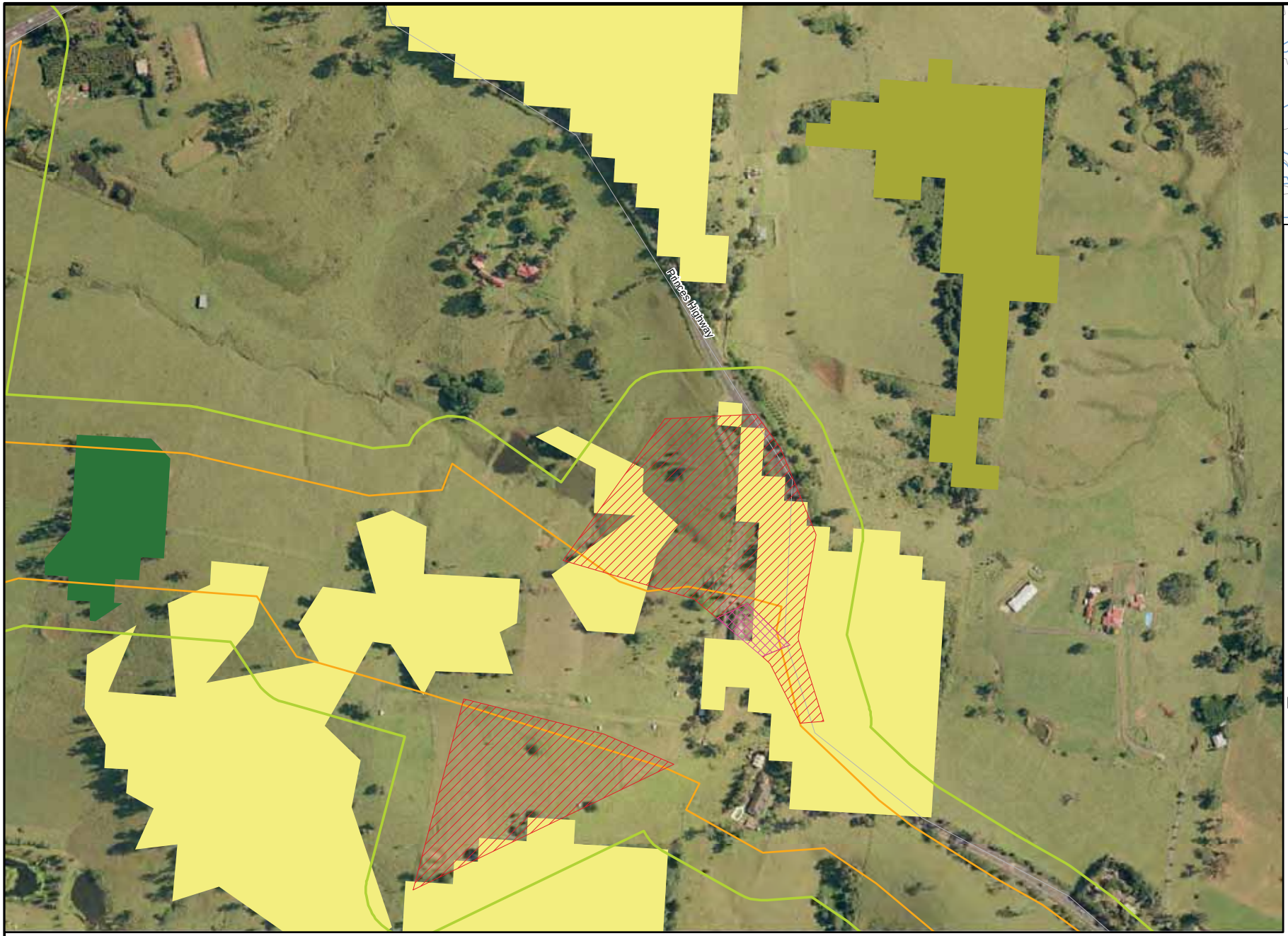

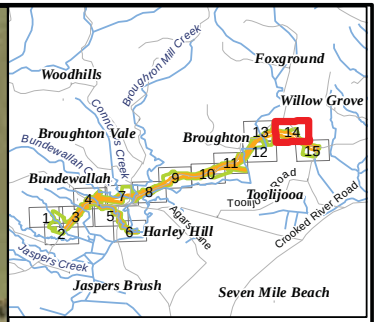

Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
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- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.14: Vegetation mapping of the study area (modified from DECCW, 2005)

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Metres

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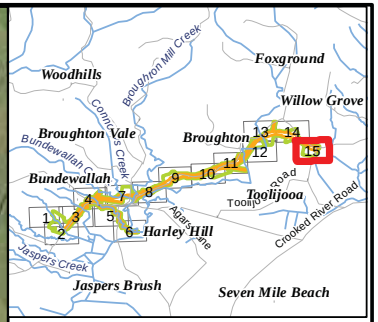

Legend

Vegatation communities

- Budderoo Temperate Rainforest
- Budderoo-Morton Plateau Forest
- Closed Grassland
- Closed Grassland/Sedgeland
- Coastal Foredune Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Forest
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- Warm Temperate Layered Forest
- Yarrawarra Temperate Rainforest
- Subject Site - Temporary Creek Crossings
- Subject Site - Footprint

Ancillary Sites

- Subject Site - Compound
- Subject Site - Stockpile
- Study Area

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Figure 3.1.15: Vegetation mapping of the study area (modified from DECCW, 2005)

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Metres

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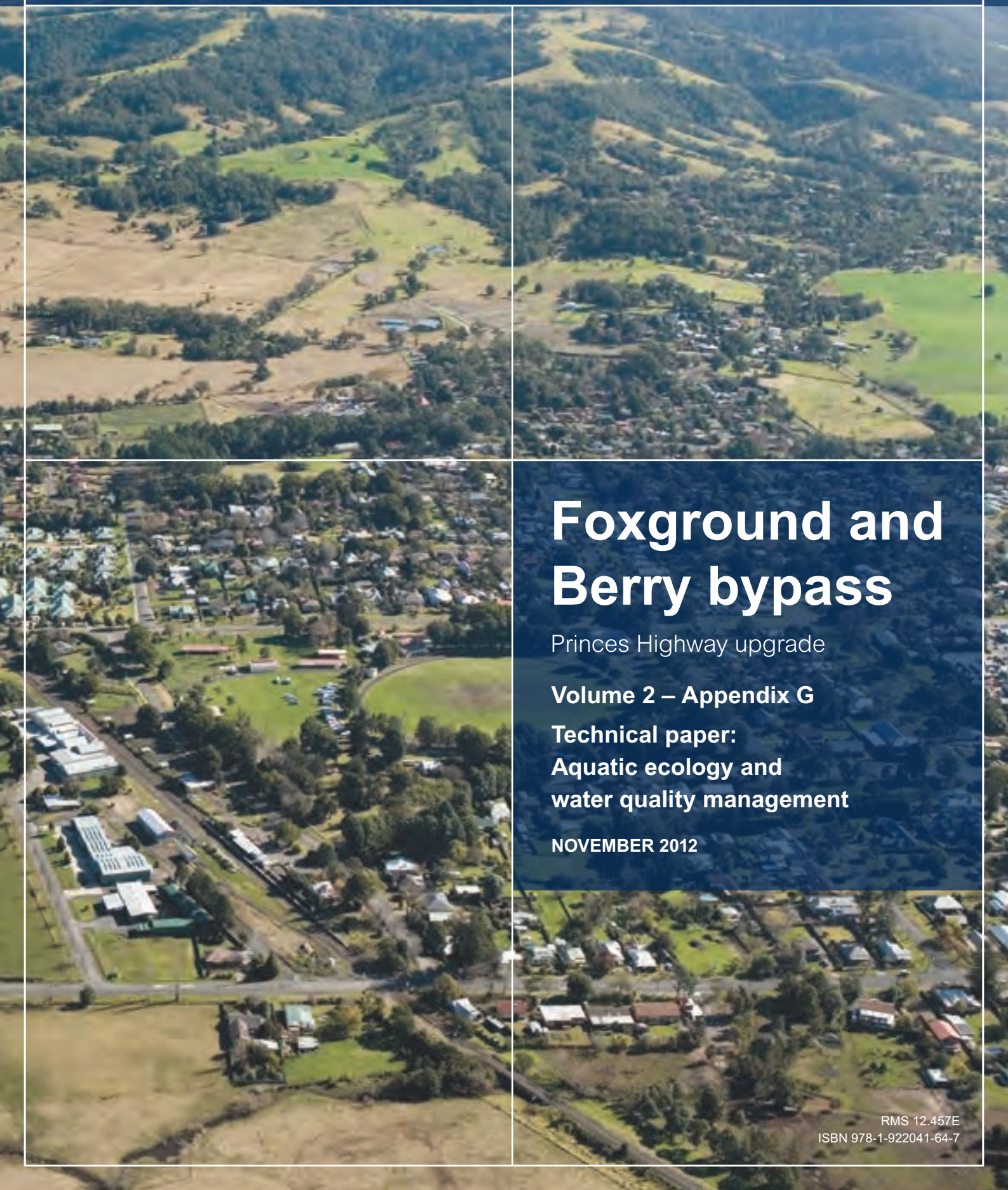

Transport
Roads & Maritime
Services

NSW GOVERNMENT

Foxground and Berry bypass

Princes Highway upgrade

Volume 2 – Appendix G

Technical paper:
Aquatic ecology and water quality management

NOVEMBER 2012

RMS 12.457E
ISBN 978-1-922041-64-7

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Foxground and Berry bypass

Prepared for

Roads and Maritime Services

Prepared by

Cardno Ecology Lab
Level 9, 203 Pacific Highway, St Leonards NSW 2065

In association with

AECOM Australia Pty Ltd
Level 21, 420 George Street, Sydney NSW 2000, Australia

November 2012

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Executive summary

Cardno Ecology Lab Pty Ltd was commissioned by AECOM on behalf of the Roads and Maritime Services of NSW (RMS) to carry out an aquatic ecology and water quality management assessment for the Foxground and Berry bypass project (the project).

RMS is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway, to achieve a four lane divided highway (two lanes in each direction) with median separation between Toolijooa Road north of Foxground and Schofields Lane, south of Berry (the project). The project would include bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The aim of the assessment is to identify issues of conservation significance associated with the project. The specific objectives are to:

- Update existing information on aquatic habitat, biota and water quality within the region of the project (study area), including threatened species, populations, ecological communities and key threatening processes.
- Describe the nature, extent and condition of aquatic habitats and biotic communities and associated waterways within the study area based on field assessments.
- Assess the potential impacts of the project on aquatic ecology and water quality in the study area.
- Make recommendations to mitigate or offset potential impacts.

Aquatic ecology and water quality

The majority of the project is contained within the Broughton Creek catchment. Broughton Creek is the dominant watercourse within this catchment and originates in the Cambewarra Range. South of the Princes Highway alignment the creek flows in a south-westerly direction towards Berry. To the north and north-west of Berry are the smaller Broughton Mill Creek and Bundewallah Creek catchments. A smaller section of the project is located in the Crooked River catchment. This section of the project does not cross any significant waterways.

Freshwater habitat within the study area ranged from relatively healthy to significantly degraded. Riparian vegetation was generally absent on the smaller waterways, banks were unconsolidated, eroded and channels often colonised by pasture grasses and/or annual weeds. The larger waterways, particularly Broughton Creek, Broughton Mill Creek and Bundewallah Creek retain large sections of relatively complete riparian vegetation, support frequent alternation of riffles and pools sequences and considerable instream habitat (eg macrophytes, submerged woody debris, rocks and deep holes). Water quality in the catchment is typical of aquatic ecosystems that have been disturbed by agricultural practices. Downstream of the study area, in the low-lying floodplain, the tributaries of Broughton Creek have been highly modified by flood mitigation works.

AusRivAS (Australian River Assessment System) assessments found the aquatic macroinvertebrate assemblages within the Broughton Creek were generally moderately impaired, reflecting the effects of diffuse agricultural pollution and/or local habitat degradation, although the assemblages from pool edge habitat at Broughton Mill Creek and Bundewallah Creek were equivalent to reference condition. Macroinvertebrate assemblages were often dominated by pollution-tolerant taxa and usually had a greater proportion of pollution-tolerant taxa than at equivalent reference sites.

Assessment of impacts and recommendations

The potential environmental issues relating to the proposed highway upgrade primarily included:

- Mobilisation of sediment into waterways.
- Mobilisation of pollutants into aquatic habitat.
- Disturbance of acid sulfate soils.
- Establishment of invasive species within the study area.
- Degradation of riparian vegetation.
- Removal of large woody debris.
- Changes to the natural flow regime.
- Obstructions to fish passage.
- Presence of threatened and protected populations, species and endangered ecological communities.

An inventory of freshwater fish identified a total of 36 species as potentially being present within the region. Of these, three are introduced and two are listed as threatened. Macquarie Perch (*Macquaria australasica*) is listed as Vulnerable under the *Fisheries Management Act 1994* (FM Act) and Endangered under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). Australian Grayling is listed as Vulnerable under the EPBC Act. No listed threatened or protected species were observed in freshwater habitat within the study area.

Eight species of freshwater fish were recorded during the field surveys with the greatest diversity occurring in Broughton Creek. Broughton Creek was assessed as providing 'major' fish habitat (Class 1 Waterway) and Bundewallah and Broughton Mill Creek as providing 'moderate' fish habitat (Class 2 Waterway) (Fairfull and Witheridge 2003). The remaining watercourses in the study area are ephemeral and degraded and were assessed as providing 'minimal' to 'unlikely' fish habitat (Class 3 – 4 Waterways).

Provided the recommended mitigation measures are implemented it is unlikely that the works and structures associated with the construction and operation of the project would have long-term impacts on other threatened or protected species or the wider aquatic ecology of the area. The majority of potential impacts on aquatic ecology and water quality associated with the construction and design of the project could be avoided, minimised or mitigated.

Potential impacts from mobilised sediment would be minimised by an erosion and sediment control plan that implements standard sediment control measures. Similarly, potential contamination of waterways with polluted runoff from the highway or accidental spills would be mitigated by channelling and treating runoff in a system of sediment basins and/or vegetated swales.

Specific guidelines for the design and construction of waterway crossings to maintain fish passage have been developed by the NSW Government. An assessment of minimum recommended crossing requirements for each waterway that would be crossed by the project has been provided as input to the concept design.

Mitigation

It is recommended that several measures be implemented to avoid, minimise or mitigate potential issues arising from the project in regard to both its design and operation.

Design

It is recommended that the project design aim to minimise stormwater and disturbed surface runoff entering adjacent waterways by diverting and/or containing it in sediment basins/vegetated swales. Earthworks are recommended to be designed to minimise the risk of mobilising acid sulfate soils.

The project design would require the removal of 10 hectares of riparian habitat (within the project corridor, ancillary infrastructure and temporary crossing footprint) which would be compensated for within an offset.

Impacts on the natural surface and groundwater flow regime of the study area would be minimised through the redirection of groundwater seepage into aquatic habitats via longitudinal drainage systems. It is recommended that bridge structures be designed to have minimal impact on the natural flow regime and to provide immunity from 100 and 50 year ARI flood events respectively. It is recommended that no bridge piers or abutments be positioned within the section of waterway channel (wetted width) that carries median flows. Therefore, bridges are the recommended structures for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. It is recommended that bridge piers be placed outside the main channel where possible to avoid formation of turbulence and bed erosion, and abutments placed away from the bank. Due to their size and classification as fish habitat, culverts are considered adequate crossings for the remaining waterways.

It is recommended that the design of the channel created to divert flows from Town Creek into Bundewallah Creek aim to mimic a natural creek line, mimicking as far a practical natural (non-linear) alignment, creek beds and bank form. Bank design should be optimised to allow planting and maintenance of native riparian floral communities.

Construction

Erosion and sediment controls, such as bunding, silt fences/curtains, sediment basins and vegetated swales are recommended to mitigate potential impacts to aquatic ecology during the construction phase of the project.

It is recommended that runoff from disturbed areas, stockpiles and dust suppression/washdown facilities be diverted into sediment basins and erosion controls, and that clean water be diverted around disturbed areas. Areas of exposed earthworks are recommended to be re-vegetated and remediated as soon as possible with erosion controls and sediment traps remaining in place until vegetation cover has been established. It is recommended that project works and ancillary infrastructure not take place within 50 metres of Category 1 (Environmental Corridor) riparian habitat.

The outline of a surface water quality monitoring program consistent with (Australian and New Zealand Environment Conservation Council (ANZECC) guidelines has been prepared (Appendix F) and its incorporation into the erosion and sediment control plan is recommended. The measures that are recommended to mitigate erosion and sedimentation would also address potential contamination and pollution issues. It is additionally recommended that any hazardous substances be properly handled, stored, transported and disposed of.

To avoid spreading the invasive aquatic Alligator Weed observed within the study area it is recommended that large woody debris displaced during construction be relocated within the same reach.

Residual impacts on aquatic ecology and water quality that cannot be adequately mitigated and fail to 'maintain or improve' biodiversity include:

- Loss of 10 hectares of riparian habitat within the project corridor, comprised of 2.9 hectares Riverbank forest directly impacted and 7.1 hectares indirectly impacted, including ancillary sites and temporary creek crossing footprints. The area directly impacted includes a small area of riparian habitat that would be degraded as a result of the diversion of flow from Town Creek north of the upgrade, across pasture land and directed into Bundewallah Creek via a constructed creek channel.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Slight changes to hydrology due to placement of a pier structures within the waterway at Bundewallah Creek.
- Potential reduced longitudinal connectivity at temporary creek crossings and temporary construction pads during low flows.
- Changes to hydrology at Town Creek, Bundewallah Creek and Broughton Creek from the diversion of Town Creek and installation of transverse road drainage structures.

The Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) have a policy of 2:1 environmental compensation for direct loss of aquatic or riparian habitat (Smith and Pollard 1999). Compensation for the unavoidable loss of riparian habitat for the project is addressed in a Biodiversity Offset Strategy detailed in the *Foxground and Berry bypass Terrestrial Flora and Fauna Technical Paper* (Biosis 2012) which was prepared for this environmental assessment and is provided at Appendix F of the environmental assessment.

Due to the potential lag in the response of aquatic macroinvertebrates to disturbances it is recommended that aquatic ecological monitoring be carried out in conjunction with surface water quality monitoring to assess the effectiveness of the construction erosion and sediment control plan and potential operational impacts on aquatic macroinvertebrates. Outlines for surface water quality monitoring and ecological monitoring programs are presented in Appendices F and G of this report.

Should the recommended mitigation measures and Biodiversity Offset Strategy be implemented as outlined, then the project should result in no net/residual/long-term impacts on aquatic ecology and water quality.

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1 Introduction

1.1 Background and objectives

The Roads and Maritime Services (RMS) is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway, to achieve a four lane divided highway (two lanes in each direction) highway with median separation between Toolijooa Road north of Foxground and Schofields Lane, south of Berry (the project). The project would include bypasses of Foxground and Berry.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

The general features of the project are:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.

- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.
- Eight underpasses including roads, drainage structures and fauna underpasses:
  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Gembrook Road, Tindalls Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent stockpiling site for general road maintenance.

The project and the key features of the project are shown **Figure 1.1**.

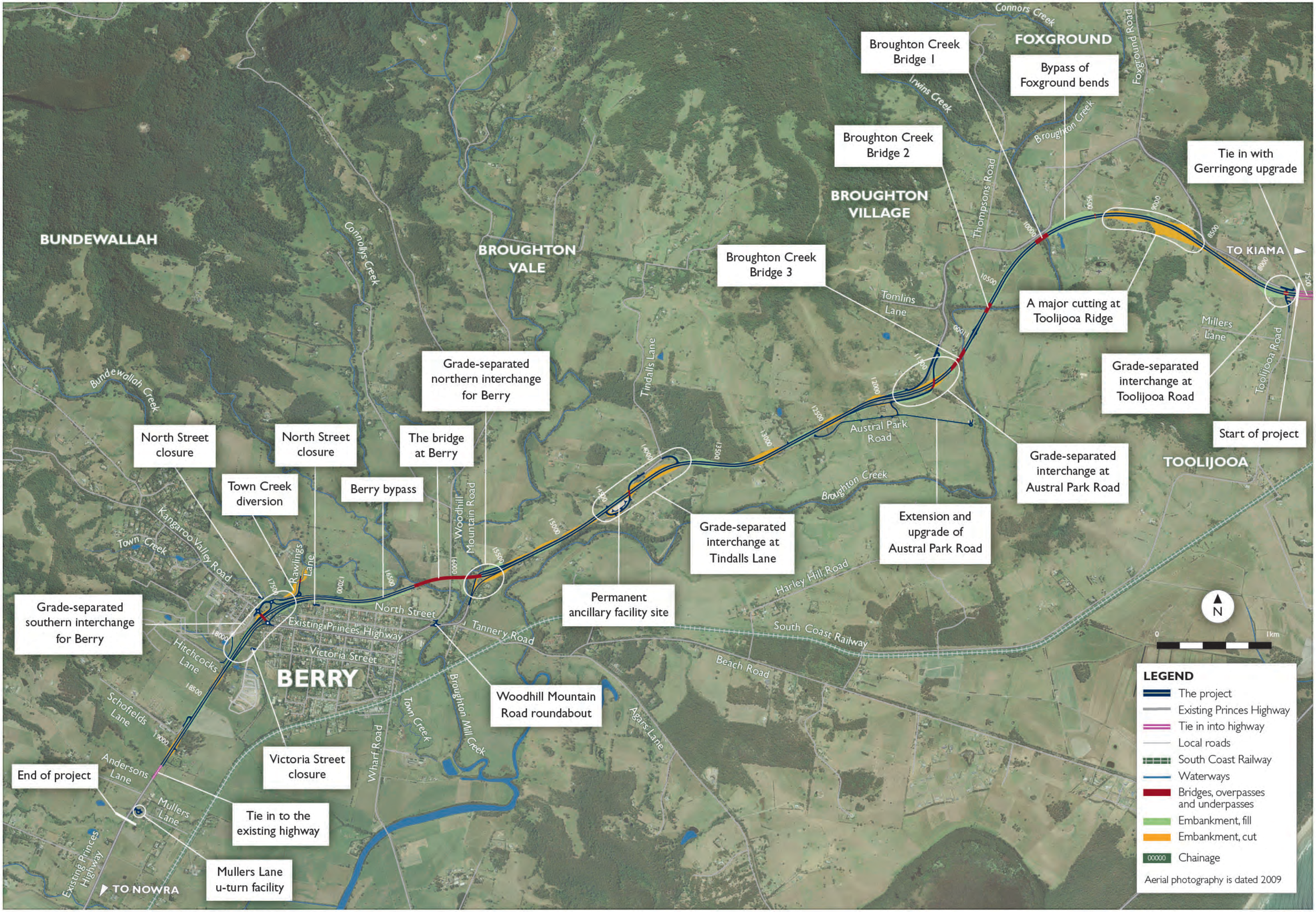

Figure 1-1: Foxground and Berry bypass project area

This technical paper presents an assessment of the potential environmental impacts of the project on aquatic ecology and water quality in the context of an environmental assessment as required under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.1.1 Objectives of the aquatic ecology and water quality assessment

The objectives of this assessment are to provide a description of the aquatic habitats, biota and water quality within the study area (the footprint of the project and 50 metre buffer), with the aim of assessing constraints and opportunities associated with the project. This report provides information that would assist the selection of the most appropriate design structures and construction methodology. The specific objectives of this assessment study are:

- Update existing information on aquatic habitat, biota and water quality within the study area, including threatened species, populations, ecological communities and listed key threatening processes.
- Describe the nature, extent and condition of aquatic habitats and biotic communities and associated waterways within the study area based on field assessments.
- Assess the potential impacts of the project on aquatic ecology and water quality in the study area.
- Make recommendations to mitigate or offset potential impacts.

1.2 Agency consultation

In relation to aquatic ecology and water quality, this document addresses the relevant Director-General's requirements (DGRs) as indicated in **Table 1.1** below.

Table 1.1: DGRs for aquatic ecology and water quality

Director-General's requirements	Relevant section in this document
An **assessment of the key issues,** including an assessment of the worst case and representative impact for each issue for all aspects of the project (including the proposed locations of and/or options for the ancillary facilities) with the following aspects addressed for each key issue (where relevant):	Summarised in Executive Summary Section 4
• Describe the existing environment.	Section 3
• Assess the potential impacts of the proposal at both construction and operation stages, in accordance with relevant policies and guidelines. Both direct and indirect impacts must be considered including potential interactions with the existing Princes Highway (as relevant).	Section 4
• Identify how relevant planning, land use and development matters, (including relevant strategic and statutory matters), have been considered in the impact assessment and/or in developing management/mitigation measures.	Section 1.4 Section 3.3 Section 4.3 Section 4.3 Section 5.1
• Describe measures to be implemented to avoid, minimise, manage, mitigate, offset and/or monitor the impacts of the project and the residual impacts.	Section 5.1

Director-General's requirements	Relevant section in this document
Flora and fauna – including but not limited to:	
• An assessment of all project components on flora and fauna and their habitat (both terrestrial and aquatic as relevant) consistent with the Draft Guidelines for Threatened Species Assessment (DEC 2005).	Section 4
• Specific consideration of impacts to threatened species, populations, ecological communities and/or critical habitat listed under both State and Commonwealth legislation that have been recorded on the site and surrounding land.	Section 3.3 Section 4.2 Section 4.3
• Details on the existing site conditions (both terrestrial and aquatic) and quantity and likelihood of disturbance (including quantifying the worst case extent of impact on the basis of vegetation type and total native vegetation disturbed).	Section 4
• As relevant, consideration of weed infestation and edge effects; habitat fragmentation, impacts to wildlife and riparian corridors; impacts to groundwater-dependent communities, riparian and aquatic habitat (including impacts on SEPP 14 wetlands and fish passage).	Section 4
• Provide details of how flora and fauna impacts would be managed during construction and operation for all project components, including adaptive management and maintenance protocols and monitoring programs.	Section 5.1 Appendix F Appendix G
• Demonstrate actions to be undertaken to avoid, mitigate or offset impacts associated with the project (all components) consistent with the principles of "improve or maintain". Sufficient details must be provided to demonstrate the availability of viable and achievable options to offset the impacts of the project, where offset measures are proposed to address residual impacts.	Section 5 Appendix F
Surface and ground water - including but not limited to:	
• Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. The assessment must describe measures to control erosion and sedimentation during construction activities and measures to capture and treat runoff from the site during the operational phase.	Section 5 Appendix F
• Identify potential risks of the project on groundwater resources including: impacts to groundwater quality and implications for groundwater-dependent ecological communities.	Section 4.1.4
• Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better.	Section 5 Appendix G

1.3 Project description

1.3.1 The study area

The project is located west of Gerringong, and extends from the junction of Toolijooa Road and the Princes Highway for around 11.6 kilometres to the junction of Schofields Lane and the Princes Highway, south of Berry. The project lies partly within the Kiama local government area (LGA) and partly within the Shoalhaven LGA.

The project largely follows the existing Princes Highway corridor, deviating away in two locations, once across Toolijooa Ridge and the Broughton Creek floodplain and a second deviation with a northern bypass of Berry.

In addition to crossings of minor waterways and ephemeral drainage lines along its length, the project crosses Broughton Creek three times as it traverses the floodplain, with the northern-most crossing occurring adjacent to the existing Princes Highway bridge crossing. The project also includes a substantial crossing of Broughton Mill Creek and Bundewallah Creek as part of the bypass around Berry via a bridge around 600 metres long. The bridge at Berry would extend over Broughton Mill Creek and Woodhill Mountain Road, and then run along the north side of Bundewallah Creek for around 300 metres before crossing the creek (downstream of the confluence of Bundewallah and Connollys creeks).

Potential environmental impacts associated with the project can extend to areas beyond the immediate footprint of the project corridor. The area considered in the aquatic ecology and water quality management assessment therefore includes aquatic habitat and biota upstream and downstream of the project (**Figure 1.1**). The project crosses sections of both the Crooked River and Broughton Creek catchments. The Crooked River catchment includes the estuarine Crooked River Lagoon. The upper Broughton Creek catchment includes the smaller sub-catchments of Bundewallah Creek and Broughton Mill Creek. The estuarine reach of Broughton Creek and the Shoalhaven/Crookhaven estuary are located downstream of the project.

1.3.2 Concept design

Project design and engineering considerations relevant to aquatic ecology and water quality include:

- Bridge structures over three crossings of Broughton Creek and one substantial bridge structure (around 600 metres long) spanning Broughton Mill Creek, Woodhill Mountain Road and Bundewallah Creek (the bridge at Berry).
- Five temporary creek crossings and possible temporary construction pads in the vicinity of the proposed bridge structures (above) during the construction phase.
- Placement of bridge pier structures within the waterway at Bundewallah Creek.
- Provision of drainage structures (such as culverts and bridges) within the road embankment for flood mitigation during flow events. Transverse drainage structures would be sized to control flow and manage downstream flooding in some instances.
- The diversion of Town Creek to the north of the upgrade into Bundewallah Creek upstream of its confluence with Connollys Creek.
- Drainage and retention basin/swale systems to control and discharge drainage from cuttings and embankments.
- Widening of the existing highway corridor.
- Earthworks include cuttings at various locations along the project, the largest of which would be 900 metres long and up to 26 metres deep as the project traverses Toolijooa Ridge.

- Construction of an embankment linking two bridge structures crossing Broughton Creek (Crossing L and Crossing M).
- Appropriate batter slopes and engineering treatment to mitigate potential instability on steep side slopes of ridges with deep colluvial soils.
- Possible ground conditioning using preloading or replacement with engineered fill in areas where settlement has been assessed as a geotechnical issue, eg alluvial soils of floodplain areas.
- Ancillary infrastructure constructed near or over existing waterways such as stockpiles, drilling/blasting compound and crushing plant, temporary traffic facilities (temporary creek crossings) and diversion networks, site compounds and offices, vehicle washdown facilities and vehicle/plant storage. Examples include:
  - RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane.
  - Bridge compound and stockpile associated with the proposed Broughton Creek Bridge 1 (Crossing K).
  - Bridge satellite compound near Town Creek.
  - Permanent ancillary facility at the site of the existing quarry/stockpile adjacent to the Princes Highway two kilometres north-east of Berry.
  - Temporary creek crossings near each proposed bridge structure.
- Clearing of limited riparian vegetation to provide temporary creek crossings.

1.3.3 Limitations of assessment

Field surveys of aquatic habitat, biota and water quality were undertaken by Cardno Ecology Lab from 15 April 2009 to 17 April 2009, with subsequent inspection of potential sites for temporary creek crossings on 28 June 2011. Water quality parameters recorded, species sampled or observed are likely to be representative of the range of conditions and species that could be recorded using the methodology employed, but should be considered "snapshot" in nature rather than representing seasonal changes in aquatic assemblage that may occur. Surveys were undertaken following a period of locally significant rainfall which was not considered to have significantly affected the number or type of species recorded.

1.4 Policy context and legislative framework

With reference to aquatic flora and fauna and aquatic habitat, the following statutory requirements and policy are relevant to the project.

1.4.1 *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

Under the EPBC Act, administered by the Commonwealth via the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), actions that are likely to have a significant impact on a matter of national environmental significance (MNES) are subject to a referral, assessment and approval process. MNES relevant to the project include threatened aquatic species, populations and ecological communities listed under the EPBC Act. Listed migratory species; cetaceans; marine species and Ramsar areas of national significance are protected under this Act.

1.4.2 *Environmental Planning and Assessment Act 1979* (EP&A Act)

The EP&A Act and the Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) provide the statutory planning framework for environmental assessment of the project. The Minister for Planning has declared by Order that the project is "*major infrastructure*" and as such will be assessed under Part 3A of the EP&A Act. The provisions of Part 3A detail the approval process for major infrastructure and other significant projects, with the Minister for Planning as the approval authority for the project.

Aquatic threatened species assessment was carried out according to NSW Office of Environment and Heritage (OEH) and Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) (DEC/DPI 2005). The guidelines identify important factors and/or heads of consideration that must be considered by proponents when assessing impacts on threatened species, populations, or ecological communities for projects assessed under Part 3A of the EP&A Act.

Section 75R (2) of the EP&A Act states that State Environmental Planning Policies (SEPPs) apply to:

(a) The declaration of a project as a project to which this Part applies or as a critical infrastructure project; and

(b) The carrying out of a project, but (in the case of a critical infrastructure project) only to the extent that provisions of such a policy expressly provide that they apply to and in respect of the particular project.

The following SEPPs are relevant to the project:

- ***State Environmental Planning Policy No. 14 – coastal wetlands***

  SEPP 14 provides protection for wetlands identified as significant coastal wetlands and gazetted for protection.

- ***State Environmental Planning Policy No. 71 – coastal protection***

  SEPP 71 applies to land defined as the coastal zone by maps held by local council and identifies a number of issues to be considered by a consent authority before issuing development consent.

Section 75R (3) of the EP&A Act states that:

> *"environmental planning instruments (other than State environmental planning policies) do not apply to or in respect of an approved project".*

As the project has been declared to be a project to which Part 3A applies, local environmental plans do not apply to the project. The Minister may, but need not, consider these plans in the determination of the project. The following Local Environmental Plans *(*LEPs) apply to the land in the project location;

- *Shoalhaven LEP 1985.*
- *Kiama LEP 1996.*
- *Draft Kiama LEP 2010.*

As discussed above the Director-General of the NSW Department of Planning and Infrastructure (DP&I) has issued DGRs for the project. The points relevant to the aquatic ecology and water quality assessment are detailed in **Table 1.1**.

1.4.3 *Water Management Act 2000* (WM Act)

Works within 40 metres of a lake, river or estuary require a controlled activity approval under this Act. However as '*major infrastructure'* under Part 3A of the EP&A Act, controlled activity approval is not required. Requirements under the WM Act are addressed by DP&I in the issuing of DGRs.

1.4.4 *Protection of the Environment Operations Act 1997* and *Protection of the Environment Operations Amendment Act 2005*

It is offence to pollute the environment under the *Protection of the Environment Operations Act 1997*. An environmental protection licence is required for scheduled activities.

1.4.5 *Threatened Species Conservation Act 1995* (TSC Act)

The TSC Act lists threatened species, populations and endangered ecological communities (EECs) under Schedules 1 and 2 of the TSC Act, that are priorities for conservation within NSW. Schedule 3 of the TSC Act lists key threatening processes for species, populations and ecological communities within NSW. The TSC Act is predominantly concerned with terrestrial biota but does include some aquatic groups; such as aquatic plants, aquatic reptiles, aquatic mammals and aquatic EECs.

This aquatic ecology and water quality management assessment considered potential impacts to aquatic biota listed under the TSC Act that are known or considered likely to occur within the study area. A licence under Section 91 is required if it is determined that a threatened species, population or ecological community is likely to be harmed.

NSW OEH (formerly DECCW), a division of the NSW Department of Premier and Cabinet (DPC), is responsible for administering the TSC Act. In 2010, the then DECCW released the South Coast Regional Conservation Plan (RCP) (DECCW 2010) to guide natural heritage conservation on lands on the south coast excluding national parks and State forests. The RCP identifies areas of high conservation value and provides strategic direction to planning so that future development can occur without jeopardising regional goals of 'improving or maintaining' biodiversity. The project has been assessed to ensure it is consistent with the objectives of the South Coast RCP.

Riparian habitat of each waterway within the study area was classified according to criteria developed by the then NSW Department of Infrastructure, Planning and Natural Resources *Riparian Corridor Management Study* in the Wollongong LGA (DIPNR 2004). DIPNR has subsequently become part of DP&I and OEH.

1.4.6 *Fisheries Management Act 1994* (FM Act) and *Fisheries Management Amendment Act 1997* (FMA Act)

The FM Act and its regulations are administered by the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS; formerly Industry and Investment NSW and also referred to in this document as DPI) and are relevant to aquatic habitat and fauna that have the potential to be affected by the project. The FM Act lists threatened species, populations and ecological communities under Schedules 4, 4A and 5. Schedule 6 lists key threatening processes (KTPs) for species, populations and ecological communities in NSW Waters. This aquatic ecology and water quality management assessment considers potential impacts to all species, populations and EECs listed under the FM Act that are known or considered likely to occur within the study area.

The following sections of the FM Act have relevance but are exempt under a Part 3A approval:

- Section 199 – permit required for any dredging or reclamation works.
- Section 219 – permit required for any obstructions to fish passage.

Other relevant sections include:

- Section 37 (Miscellaneous collection) – permit required to harm more fish or invertebrates than is currently allowed by restrictions on daily limits.

The classification of waterways in the study area was carried out according to 'NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation' (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003). The assessment of impacts assumed that any waterway crossing would be designed and built to comply with these guidelines and policies.

2 Methods

2.1 Review of existing information

Existing information on aquatic habitats and their associated biota within the study area was obtained by searching Cardno Ecology Lab's extensive specialist library and undertaking searches for relevant literature using the internet.

Relevant threatened species, populations and EECs that do, or may, occur within the study area were identified by reviewing published distributions and current listings on databases maintained by DSEWPaC, DTIRIS and OEH. Results from a previous search of NSW Government database BioNet made on 7 September 2007 during the aquatic ecology and water quality management assessment stage were also used (note: BioNet database is no longer operational). DSEWPaC, DTIRIS and OEH database searches were current as at 22 June 2011. The following search tools were used:

- The *DSEWPaC Protected Matters Search Tool*: used to determine relevant MNES, listed Marine Species and Migratory Marine Species under the schedules of the EBPC Act pertaining to the project. The primary search area was defined as the section of the Crooked River catchment traversed by the project and Broughton Creek catchment downstream to its confluence with Shoalhaven River (about 16 kilometres downstream of Berry). A second expanded search included the ecologically significant but distant downstream aquatic habitat of the Shoalhaven/Crookhaven estuary.
- The DTIRIS *Threatened and Protected Species Record Viewer* used to search for records of relevant threatened and protected species listed by Schedules 4, 4A and 5 of the FM Act as occurring in the Kiama and Shoalhaven LGAs and the broader Southern Rivers Catchment Management Authority (CMA) area.
- *The OEH Geographic Region Search tool and NSW Atlas of Wildlife database*: used to determine whether relevant threatened species, populations or aquatic EECs listed under the TSC Act were present. The Illawarra and Jervis sub-regions of the broader Southern Rivers Catchment Management Authority (CMA) area were selected as the search region for the OEH Geographic Region Search and the Kiama and Shoalhaven LGAs were selected as the search region for the *Atlas of Wildlife database*.
- Water Quality Data from The Ecology Lab (1999, 2007).

Searches were done for the presence of significant or critical aquatic habitat such as SEPP 14 and Ramsar wetlands.

2.2 Field sampling methodology

Field investigations of aquatic habitat, biota and water quality were undertaken by Cardno Ecology Lab from 15 April 2009 to 17 April 2009. Additional field investigations to identify four potential sites for temporary creek crossings were done on 28 June 2011 (Crossing K, L, M and T on **Figure 2.1**).

At each site a general habitat description, a Riparian, Channel and Environmental inventory (RCE, NSW Environment Protection Authority (EPA) and Chessman *et al.* 1997) and fish habitat assessment was made. Where appropriate, recordings were made of water quality, macrophyte, macroinvertebrate and fish assemblages and existing waterway crossings. Sampling at each site depended on the nature of the waterway, with factors such as stream width, depth, flow rate and likelihood of target groups occurring in that area.

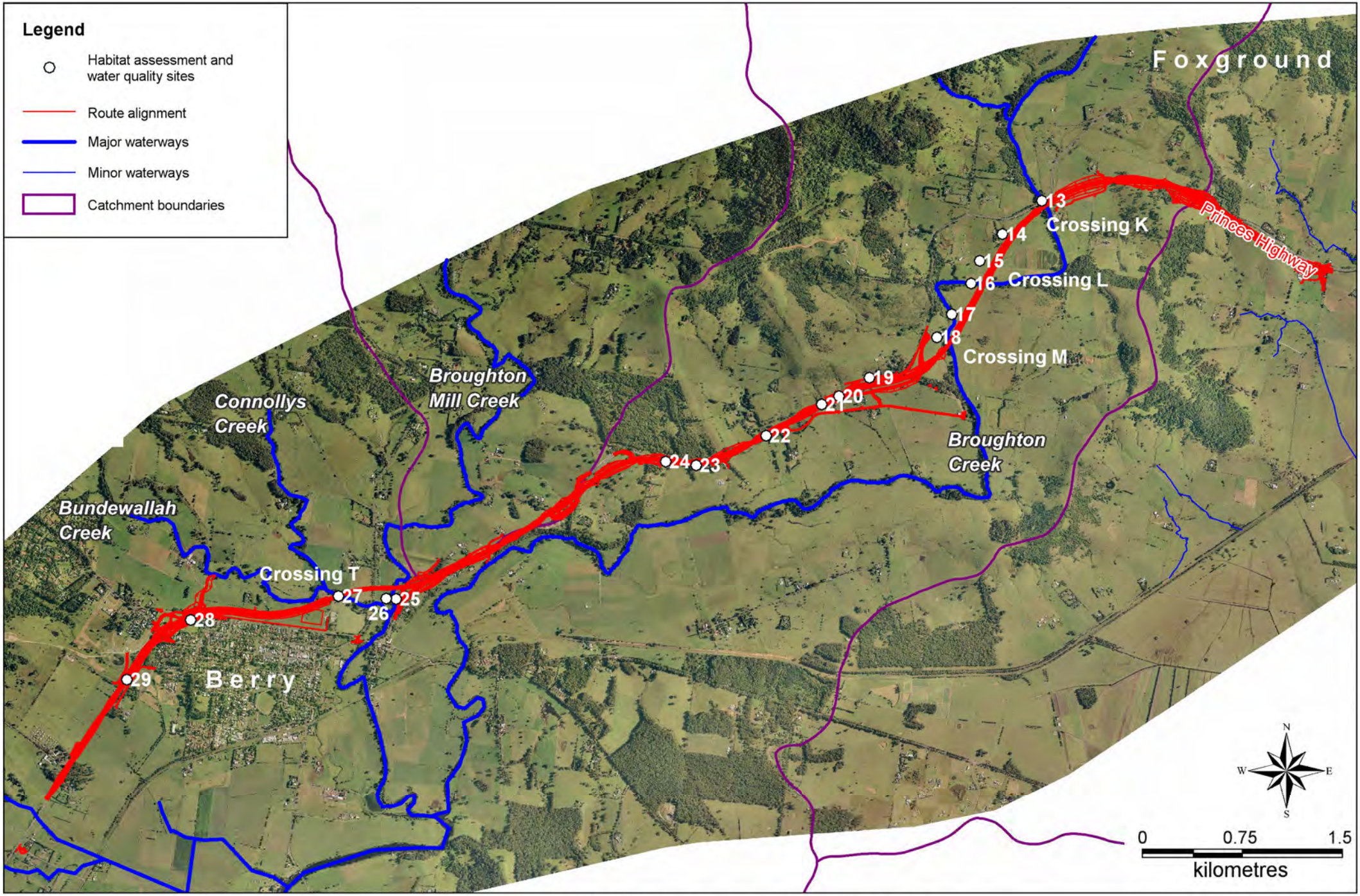

Figure 2.1: Foxground to Berry project area indicating major waterways and sites for habitat assessment and water quality

2.2.1 Site selection

Aquatic ecology and water quality management assessment sites were selected where waterways intersected with the project alignment and/or where aquatic habitat was present that could potentially support threatened species. The aquatic habitat at each site ranged from moderate sized rivers to ephemeral waterways that only flow in high rainfall events. In total, 17 sites were selected along the project (**Figure 2.1**).

RMS identified the need for five temporary creek crossings, for construction purposes, which would be required near the site of each permanent creek crossing by a proposed bridge structure. These include the three crossings of Broughton Creek by Bridge 1, Bridge 2 and Bridge 3 (Crossings K, L and M respectively in the *Foxground and Berry bypass Concept Design report* (RMS 2012)) and the crossings of Broughton Mill Creek and Bundewallah Creek by Bridge 4 (Crossing T in the Concept Design report (RMS 2012)) (**Figure 2.1**). RMS identified the location of the temporary creek crossing at Bridge 1 (Crossing K) as immediately downstream of the proposed bridge site but asked Cardno Ecology Lab and Biosis (terrestrial ecology consultants) to identify suitable locations for the remaining four temporary crossings. Constraints on the location of temporary crossings identified by RMS were:

- Sites may be upstream or downstream of the proposed bridge structures.
- Sites should be dependent on space, environmental issues (eg mature riparian vegetation) and bank shape (shallow low banks preferred).
- Sites should require minimal bank works.
- Sites should be located within RMS owned land.

Cardno Ecology Lab and Biosis Research selected four sites within RMS' identified constraints that would result in the least possible impacts on aquatic and terrestrial ecology and water quality for Crossings L, M and T. The location of the temporary creek crossing at Bridge 1 (Crossing K) was identified by RMS.

2.2.2 Habitat characteristics

Habitats were characterised using three classification schemes.

RCE classification

At each site, a standardised description of adjacent land and condition of riverbanks, channel and bed was recorded using the RCE. RCE is used to scale and quantify the environmental state of particular locations for use in management decisions. The RCE score for each site is calculated by summing the scores for each descriptor noted (Appendix A). The highest score (52) would be assigned to a stream with little or no obvious physical disruption. The lowest score (13) would be assigned to a heavily channelled stream without any riparian vegetation.

This methodology was developed by Peterson (1992) and modified for Australian conditions by Chessman *et al.* (1997) by combining some of the descriptors, modifying some of the associated categories and simplifying the classifications from 1 to 4. Habitat descriptors included:

- Geomorphological characteristics of the waterways.
- Types of land use along the waterway (eg industries associated with the river, recreational uses).
- Riparian vegetation and instream vegetation (eg presence/absence, native or exotic, condition).
- Substratum type (eg rock, sand, gravel, alluvial substrata).

Riparian corridor management classification

Riparian habitat of each waterway was classified according to criteria developed by NSW DIPNR *Riparian Corridor Management Study (RCMS) in the Wollongong Local Government Area* (DIPNR 2004). The aim of an RCMS is to develop a strategic context or long-term vision for how a region's waterways are valued and anticipated to function in the future. RCMS moves away from a simple riparian classification based purely on stream order, as all key aspects of a streams' function and context are considered. The classifications are therefore informed by existing habitat values and also potential value if rehabilitated. In this system, watercourses are assigned to one of three categories, each with different protection requirements and minimum core riparian zone (CRZ) widths. In order of importance, these categories are:

- *Category 1* – Environmental Corridor: The objective is to provide biodiversity linkages by maintaining connectivity for the movement of aquatic species along the riparian corridor and between key destinations (eg bottom and top of catchment or adjacent wetlands). The CRZ is 100 metres (two metre x 40 metre fully vegetated, two metre x 10 metre buffer).
- *Category 2* – Aquatic Habitat: The objective is to provide basic habitat and preserve or emulate as much as possible a naturally functioning stream (not necessarily linking key destinations). The width of the riparian corridor must be sufficient to provide long-term robust habitat and refuge for native fauna. The CRZ is 60 metres (two metre x 20 metre fully vegetated, two metre x 10 metre buffer).
- *Category 3* – Bank Stability and Water Quality: The objectives are to prevent accelerated rates of soil erosion and enhance water quality. This category may have limited habitat value but contributes to the overall basic health of a catchment. Although an open watercourse emulating some natural stream function is the preferred option, it is recognised for example, that the practicality and economics of developing urban land may make this difficult. It is this category of watercourse where alternative solutions to deliver the category objectives can be considered. The CRZ is 20 metres (two metre x 10 metre, no buffer).

Note: DIPNR's (2004) holistic riparian classification system considers hydrology, geomorphology, aquatic ecology and terrestrial ecology. The aquatic ecology and water quality management assessment has applied RCMS categories to waterways within the study area on the basis of water quality and aquatic ecological structure and function. Terrestrial ecology is outside the scope of the aquatic ecology and water quality management assessment and therefore assessment and discussion of riparian corridors within the study area from the perspective of terrestrial ecology (linking nodes of vegetation) is contained within the *Terrestrial Flora and Fauna assessment* (Biosis 2012) located at Appendix F of the environmental assessment.

Fish habitat classification

The waterway at each site was classified for fish habitat. The classification of fish habitat in the study area's waterways was done according to *NSW Policy and Guidelines: Aquatic Habitat Management and Fish Conservation* (Smith and Pollard 1999) and guidelines and policies for fish friendly road crossings (Fairfull and Witheridge 2003). The criteria for the fish habitat classifications are reproduced in Appendix B. The assessment of impacts assumed that any waterway crossing would be designed and built to comply with these guidelines and policies.

General observations were also recorded, including water characteristics such as flow rates and colour, the presence of spawning areas (eg gravel beds, riparian vegetation, snags), refugia (eg deep pools) and presence of natural or artificial barriers to fish passage both upstream and downstream (eg weirs, dams, waterfalls and causeways) and the type of existing waterway crossing if present.

2.2.3 Water quality

Water quality was measured at each site (refer **Figure 2.1**) using a Yeo-Kal 611 probe. Physical-chemical properties measured included: electrical conductivity (ms/cm and µs/cm); salinity (ppt); temperature (^{0}C); turbidity (ntu); dissolved oxygen (mg/L and per cent saturation); pH; and ORP (oxidation reduction potential: mV). Alkalinity (mg $CaCO_3$/L) was measured *in situ* using hand-held titration cells from CHEMetrics.

Two replicate measures of each variable were taken from just below the water surface at each site, except for alkalinity, where only one replicate measure was taken.

2.2.4 Macrophytes

The presence of instream macrophyte taxa was recorded. The survey was done at an appropriate time to reveal a comprehensive range of macrophyte species present.

2.2.5 Macroinvertebrates

Macroinvertebrates in the pool edge and riffle habitats of three sites were sampled during the autumn period (defined as the 15 March to 15 June) in accordance with the Rapid Assessment Method (RAM) based on AusRivAS (Turak *et al*. 2004). The three sampled sites were located in Broughton Creek (site 13), Broughton Mill Creek (site 25) and Bundewallah Creek (site 27) (**Figure 2.1**). One edge sample and one riffle sample were collected from each site. Pool edge habitat is defined as areas along creek banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, macrophyte beds, overhanging banks and areas with trailing bank vegetation (Turak *et al.* 2004). Riffle habitat is an area of broken water with rapid current that generally has some cobble or boulder substratum.

Under AusRivAS protocol, the size of sites for macroinvertebrate sampling is determined as a distance ten times the mode channel width or a minimum of 100 metres in length. Samples were collected over a total length of 10 metres of edge or 10 metres of riffle habitat, usually in one to two metre sections, ensuring that all significant sub-habitats within each site were sampled (Turak *et al*. 2004). The chemical and physical variables required for running the AusRivAS predictive model were also recorded from each site.

Dip nets with a mesh size of 250 µm were used to collect invertebrates. The dip net was first used to disturb animals by agitating bottom sediments and suspending invertebrates into the water column. The net was then swept through this cloud of material to collect suspended invertebrates and surface dwelling animals. Each AusRivAS sample was rinsed in the net with local water to minimise fine particles and placed into a white sorting tray. Animals were removed from the tray using forceps and pipettes. Trained staff removed animals for a minimum period of thirty minutes. Thereafter, removals were performed in ten minute periods to a total of one hour, at which time removals would cease if no new taxa were found in a ten minute period. The animals collected were placed inside a labelled jar containing 70 per cent ethanol and taken to the laboratory. Finally, debris remaining in the tray after processing was returned to the creek in the locality where the sample was originally collected.

2.2.6 Fish

Electrofishing was used in appropriate habitats at four sites to sample fish and large mobile macroinvertebrates. These techniques are non-destructive, and all but introduced pest species such as the mosquito fish (*Gambusia holbrooki*), were returned unharmed to the water. The sampled sites were Broughton Creek (site 13), unnamed watercourse (site 22), Broughton Mill Creek (site 25) and Bundewallah Creek (site 27) (**Figure 2.1**). Sampling for fish was not possible at many of the waterways that cross the project as they were either dry or did not contain enough standing water.

Electrofishing is a commonly used, non-destructive technique for sampling fish in freshwater habitats such as creeks, drainage ditches and streams. The technique involves discharging an electric pulse into the water which stuns fish, allowing them to be easily netted, counted, identified and released. Electrofishing was done in riffles, shallow pools and beneath overhanging banks and vegetation. One staff member used the electrofisher, whilst a second handled a dip net and was primarily responsible for the capture of stunned fish. Captured fish were placed into a fish box, filled with stream water, which was handled by a third person on the bank. The third person acted as a safety officer for the other two.

The entire length of each site was electrofished and duration of fishing recorded. The amount of fishable habitat varied among sites and therefore time fished varied. Fishing power (amps) was standardised across sites by adjusting voltage output according to the electrical conductivity of the water. All fish caught were identified in the field and released as quickly as practicably possible.

Surveys of fish were undertaken once during autumn (April 2009) and revealed the fish present at the time at each site. This survey provides no information on potential variation in fish populations through time; rather it presents an appropriate 'snapshot' of fish communities. Electrofishing was preferred to sampling with baited fish traps, as the latter can be relatively ineffective if certain taxa or individuals are not feeding.

2.3 Data analysis

2.3.1 Water quality

The results of water quality analysis collected *in situ* during site inspections by Cardno Ecology Lab were used to assess water quality within the study area in terms of the health of aquatic ecosystems by comparison with the Australian and New Zealand Environment Conservation Council (ANZECC) guidelines for low-land rivers in south-eastern Australia.

As water quality data was collected only once, it is a 'snapshot' in nature, and does not provide information on possible variations through time. The data is supported by data collected from previous studies (AWT 1999, The Ecology Lab 1999, 2007).

2.3.2 Macroinvertebrate AusRivAS models

The AusRivAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at undisturbed, reference sites. Observed freshwater macroinvertebrate assemblages (ie those collected in the field) are compared to macroinvertebrate assemblages expected from reference (undisturbed) waterways of the same type, to provide a basis to assess the health of the stream. The data from this study was analysed using the NSW model for pool edge habitats sampled in autumn. The AusRivAS predictive model generates the following indices:

- OE50Taxa – This is the number of macroinvertebrate families with a greater than 50 per cent predicted probability of occurrence that were actually observed (ie collected) at a site expressed as a ratio of the number of macroinvertebrate families with a greater than 50 per cent probability of occurrence expected to occur at pristine sites with similar physical and chemical characteristics. OE50 taxa values range from zero to slightly greater than one and provide a measure of the impairment of macroinvertebrate assemblages at each site. Values close to zero indicate an impoverished assemblage while values close to one indicate that the condition of the assemblage is similar to that of the reference streams.
- Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. AusRivAS Autumn bands are graded as follows (E = Edge and R = Riffle):
  - **Band X** = Richer invertebrate assemblage than reference condition (OE50 > 1. 17 (E) 1. 13 (R)).
  - **Band A** = Equivalent to reference condition (OE50 upper limit = 1. 17(E) 1. 13 (R)).
  - **Band B** = Sites below reference condition (ie significantly impaired) (OE50 upper limit = 0. 81 (E) 0. 86 (R)).
  - **Band C** = Sites well below reference condition (ie severely impaired) (OE50 upper limit = 0. 46 (E) 0. 6 (R)).
  - **Band D** = Impoverished (OE50 upper limit = 0. 11 (E) 0. 34 (R)).

The revised SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between one and 10 to each macroinvertebrate family or taxa found, based largely on their responses to chemical pollutants. The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index.

The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

- SIGNAL > 6 = Healthy habitat.
- SIGNAL 5 – 6 = Mild pollution.
- SIGNAL 4 – 5 = Moderate pollution.
- SIGNAL < 4 = Severe pollution.

Two SIGNAL scores produced by the AusRivAS predictive model were also examined:

- O0Signal index - observed SIGNAL score for taxa that have a probability of occurrence greater than zero per cent. This is calculated by averaging the SIGNAL grades for all the taxa observed and is equivalent to the SIGNAL score developed by Chessman (1995).
- OE0Signal index - the ratio of the observed to expected SIGNAL score per site for taxa that have a probability of occurrence of more than zero per cent.

3 Results

3.1 Existing information

3.1.1 Description of study area and aquatic habitats

The study area is contained within the Southern Region catchment. The project originates in the Illawarra sub-region of the Southern Region catchment and extends south into the Shoalhaven sub-region.

Physical setting

The study area is bordered to the north and west by the foothills of the Illawarra escarpment and ranges. The junction of Toolijooa Road and the Princes Highway lies near the base of a spur coming off the ridge that connects Toolijooa Hill to Currys Mountain. Whilst this section of the project lies within the upper Crooked River catchment the proposed alignment does not intersect any significant or even ephemeral waterways as it ascends the spur, cutting through the Toolijooa Ridge and crossing into the adjacent Broughton Creek catchment. The project corridor crosses Broughton Creek on three occasions before ascending into the foothills of the Illawarra Range that run parallel to the north. The project traverses these foothills before descending into Berry on the spur used by the existing highway alignment. It bypasses the township of Berry on its northern side, crossing Broughton Mill Creek and Bundewallah Creek in the process (**Figure 2.1**).

Crooked River and Broughton Creek both originate in the ranges to the west as a number of secondary streams. The Crooked River flows in a south-easterly direction into a coastal floodplain before discharging into the ocean via the estuarine Crooked River Lagoon. Broughton Creek flows in a south-west direction, bordered by the lower slopes of the Illawarra Range on its north and a ridge linking a series of hills to the south. At Berry it is joined by Broughton Mill Creek at the entrance of a coastal floodplain and eventually discharges into the lower Shoalhaven River. The Crooked River and Broughton Creek catchments are separated by the ridge that extends from Currys Mountain to Toolijooa Hill, Moeyan Hill and eventually Coolangatta Mountain.

Crooked River catchment

The creeks and streams that form the Crooked River originate at Currys Mountain and flow south-east. Just downstream of the crossing of the Princes Highway, the Crooked River turns south-west and flows across the floodplain traversing a small section of the study area, and is joined by tributaries that originated on the south side of Currys Mountain in Willow Vale and the saddle between Toolijooa Hill and the Cambewarra Range. The Crooked River floodplain includes the low-lying areas to the south-west of Gerringong, generally between Toolijooa Road or the Princes Highway and the railway line. There have been substantial drainage works in the area to improve its use for agriculture. Crooked River then broadens substantially for its final 2.5 kilometres where it becomes an estuary and enters the ocean at the northern end of Seven Mile Beach adjacent to Black Head and Gerroa.

There are other small watercourses that flow east from Toolijooa Hill and Harley Hill and become a series of modified channels (eg those found in Foys Swamp) and eventually drain into the Crooked River lagoon via Blue Angel Creek. A few ephemeral creeks also drain south-west into Crooked River from the elevated landforms on the coast that link Gerroa and Gerringong.

Two small freshwater wetlands occur within the Crooked River catchment (Chafer, 1997). The 5.5 hectare Willow Vale wetlands occur to the west of the Princes Highway and the three hectare Gerringong Wetlands forms a small series of pondages east of the Princes Highway (Chafer 1997).

Broughton Creek catchment

The Broughton Creek catchment lies adjacent to the Crooked River catchment. Broughton Creek is the dominant watercourse in this catchment and originates just below the Illawarra Plateau at around 500 metres AHD (Australian height datum) (see **Figure 3.1**). The upper reach flows in a southerly direction and is joined by a number of tributaries migrating south-east off the Illawarra Range. After crossing the existing Princes Highway corridor it meanders in a southerly direction before heading west towards Berry. The Broughton Creek valley is bordered to the north by the lower slopes of the Illawarra Ranges and to the south by a moderate ridge originating at Currys Mountain. This southern ridge includes Toolijooa Hill, Harley Hill, Moeyan Hill and after a final saddle continues to Coolangatta Mountain, located to the west of Shoalhaven Heads. The Broughton Creek Catchment upstream of Berry is about 30 square kilometres.

To the north and north-west of Berry are the Broughton Mill Creek and Bundewallah Creek catchments, respectively (see **Figure 3.1**). Broughton Mill Creek originates underneath the Illawarra Plateau as a number of secondary streams. It flows south through Broughton Vale and crosses the existing Princes Highway near the Woodhill Mountain Road intersection on the eastern edge of Berry, about two kilometres upstream of its confluence with Broughton Creek. Bundewallah Creek originates to the north-west of Berry and flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. Connollys Creek enters Bundewallah Creek 600 metres upstream of the point Bundewallah Creek joins Broughton Mill Creek. Bundewallah Creek and Connollys Creek have catchments of around 1500 hectares and 630 hectares respectively (RTA 2008). Broughton Mill Creek has a catchment of around 2000 hectares immediately upstream of the confluence with Bundewallah Creek (RTA, 2008).

Town Creek is a small ephemeral watercourse that passes directly through the Berry township. It has a catchment of 70 hectares upstream of Berry. Town Creek crosses the undeveloped section of North Street, on the north-west edge of Berry, before traversing the town between Princess Street and Queen Street and exiting via Prince Alfred Street. Town Creek flows south east before joining Broughton Mill Creek near its confluence with Broughton Creek.

After being joined by Broughton Mill Creek to the north-west of Moeyan Hill, the Broughton Creek channel widens considerably and enters a coastal floodplain. At this point Broughton Creek is estuarine and has a permanent saline influence. It flows in a southerly direction across the floodplain and is joined by a number of creeks flowing south-east off the Cambewarra Range south of Berry, such as Jaspers Creek, Flying Fox Creek and Tandingulla Creek. Broughton Creek eventually discharges into the lower reach of Shoalhaven River to the north of Numbaa Island, around five kilometres west of Shoalhaven Heads.

Geology

The geology of the area is characterised by the Gerringong Volcanics and the Berry Formation, which together form the Permian Shoalhaven Group. The Gerringong Volcanics are younger and typically found along the ridgelines of Mount Pleasant, Toolijooa Hill and Harley Hill, whereas the sandstone, siltstone and shales of the Berry Formation are more common south-east of the Crooked River (RTA, 2008). The lowland floodplains are overlain by recent fluvial and estuarine sediments. Estuarine soil deposits occur in the vicinity of the Broughton Creek floodplain.

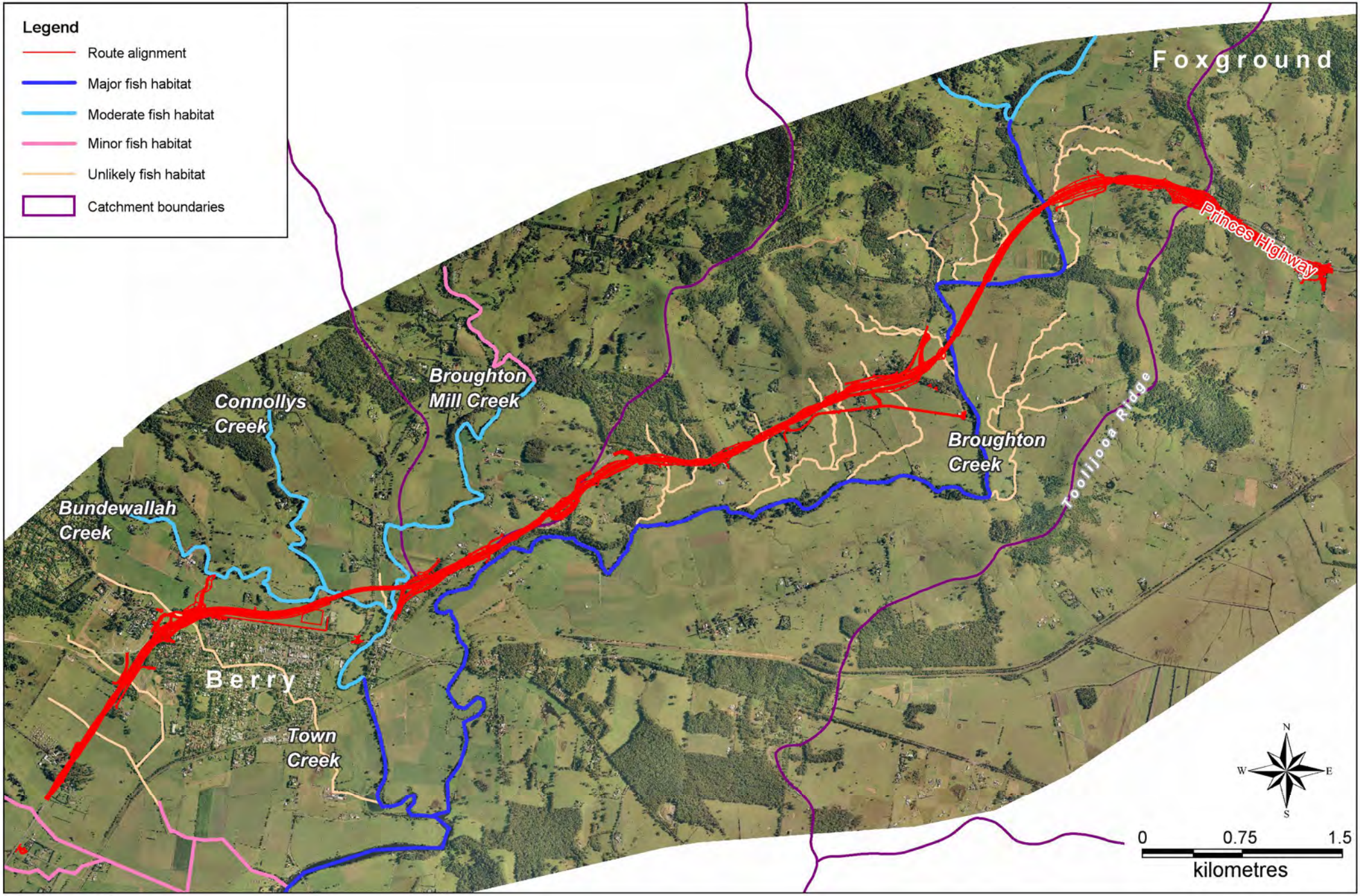

Figure 3.1: Watercourses and physical setting within the study area

The project generally passes over geological conditions mapped by the then Department of Land and Water Conservation (DLWC, 1997) as having no known occurrence of acid sulfate soils (ASS), with only one area of low ASS risk occurring at depths greater than four metres close to a section of the project south of Berry (refer to Figure 8-1 of the environmental assessment which shows ASS in the project area). Areas of no known occurrence generally correspond with landforms above 10 metres AHD and are based on an assessment of the geomorphic processes occurring there.

Following further consideration of the known geological information for the project area, an additional area of low risk of potential acid sulfate soils (PASS) being encountered has been identified. This corresponds with areas with alluvial floodplain soils at the Broughton Creek floodplain, and to a lesser extent at the bypass of Berry (refer to Figure 8–2 of the environmental assessment which shows additional areas of PASS soil risk).

Land use

Pasture and rural settlement are defining features of land use within the study area. The largest agricultural influence has historically come from the dairy industry although there has been a more recent shift to crop farms and vineyards (RTA 2008).

Agricultural activities have created the general pattern of vegetation clearance observed today. Much of the region's woodland and riparian vegetation has been removed, and where it does occur it is often dominated by introduced species such as coral trees, willow, camphor laurel, privet and lantana. Broughton Creek does support sections of relatively intact riparian vegetation in its upper reaches. More ephemeral creek lines have often been cleared entirely and colonised by pasture grasses. In the low-lying floodplain, waterways have been highly modified to improve the drainage of arable lands.

The project corridor passes along the northern edge of the Berry township. The Berry town centre has a small distinct urban zone and is surrounded by low density residential areas. Outside of Berry, the residential development is predominantly isolated rural dwellings.

Groundwater

"Based on the available borehole data and geological mapping, it can be assumed that the study area is characterised by relatively shallow unconfined groundwater which would be expected to closely mimic the natural topography. Due to undulating terrain, a number of sub-basins would be expected, superimposed on the regional system. This unconfined groundwater profile may include some areas of perched water table. Several boreholes indicate possibly confining layers below the unconfined aquifers comprising clays or hard sandstones (p 46, RTA, 2010)."

"Below this are several different confined or semi-confined water bearing layers, mainly within fractured shales and sandstones within areas of the Berry formation, and within fractured tuff and basalt in areas characterised by Gerringong Volcanics. These deeper aquifers are accessed by the majority of licensed bores within the study area generally at depths ranging between 15 metres and up to 50 metres below ground level (p 46, RTA 2010)."

"Areas of shallow groundwater generally coincide with the occurrence of soft soils. However, shallow groundwater was also identified further upstream in the Broughton Creek floodplain and in the area immediately north of Berry, where a number of watercourses converge. In these areas, groundwater levels are typically between 0.37 metres and 2.5 metres below ground level (p 46, RTA 2010)."

Water quality

There are numerous water quality issues facing watercourses within the Shoalhaven area due to past and present land use practices. These include: elevated nutrient levels, heavy metal contamination, suspended sediment resulting from erosion of soils, low dissolved oxygen, bacterial pollution and drainage of ASS (EPA, 1997).

Previous studies have found water quality within the study area to be typical of aquatic ecosystems that have been disturbed by agricultural practices (The Ecology Lab 1999, 2007). The long-term agricultural land use in the area has resulted in pollution of surface waters that exceeds levels considered to be required for the sustainability of ecosystem integrity. This is corroborated by other studies that have used aquatic macroinvertebrate communities as indicators of disturbance (The Ecology Lab, 1999).

Levels of phosphorus within the Crooked River and Broughton Creek catchments frequently exceeded ANZECC threshold values for the protection of aquatic ecosystems (AWT 1999, The Ecology Lab 1999, 2007). The likely source of these nutrients is fertilizer applied to improve grazing pastures and livestock manure. The effects of cattle access to the creeks is also evident as numbers of faecal coliform bacteria in surface water samples often exceeded guidelines for recreational use of water (AWT, 1999).

Crooked River, Broughton Creek and Broughton Mill Creek have previously been found to be within ANZECC aquatic ecosystem threshold limits for a range of organochlorine pesticides, oxides of nitrogen and trace elements, although all exceeded ANZECC guidelines for chloride. Crooked River also exceeded ANZECC guidelines for copper and recorded concentrations of oil and grease, and suspended solids, that were much higher than samples taken from sites within the Broughton Creek catchment (The Ecology Lab, 2007).

Previous studies within Crooked River and Broughton Creek catchments have found that water quality was generally within the ANZECC threshold limits for pH and conductivity, and to a lesser extent, turbidity (The Ecology Lab, 1999; 2007). Sampling carried out in 2007 during a period of low rainfall found that sites within Crooked River and Broughton Creek catchments were frequently below ANZECC lower limits for dissolved oxygen (The Ecology Lab, 2007). Low dissolved oxygen values can be caused by low flow conditions and/or high in-stream organic loads. An earlier study had also recorded low dissolved oxygen levels from sites within the Crooked River (The Ecology Lab, 1999).

Aquatic habitats

Crooked River catchment

Previous assessments have found that freshwater habitat within the Crooked River catchment was degraded. Riparian vegetation is either absent or composed of exotic species and banks are often unconsolidated, eroded and trampled by livestock. Channel substratum is often dominated by loose accumulations of soft-sediments and substantial macrophyte and/or algal growth observed in the channel 'wetted-width'.

Freshwater sites within Crooked River catchment have previously been assessed as providing minimal fish habitat (Class 3 Waterways, after Fairfull and Witheridge 2003) and occasionally as moderate fish habitat (Class 2 Waterway) on some sections of the Crooked River (The Ecology Lab, 2007). The more ephemeral creek lines in the area, such as those that flow off Toolijooa Hill, have been considered unlikely to provide fish habitat (Class 4 Waterways), as they only flow during larger events, have poorly defined channels with few standing pools and are often colonised by pasture grasses (The Ecology Lab, 2007).

The Willow Vale and Gerringong wetlands within the Crooked River catchment are both highly degraded. The majority of standing water within Willow Vale wetlands is contained within farm dams or open pondages without riparian vegetation. The Gerringong wetlands are predominantly creek swamp habitat on a degraded watercourse that passes through the outskirts of Gerringong.

The Crooked River estuarine lagoon is located downstream of the project. It is usually open to the sea and the lower part of the estuary is predominantly marine. Tidal flushing is vigorous although it declines in the upper reaches due to siltation (The Ecology Lab, 1999). Occasionally, however, the entrance can be blocked by a low sandbar (Chafer, 1997). The lagoon contains mangrove (0.008 square kilometres of *Avicennia marina*), saltmarsh (0.017 square kilometres) and seagrass (0.046 square kilometres of *Zostera capricorni*) habitat (Williams *et al*., 2006). All these habitats are protected under DTIRIS's *'Fish Habitat Protection Plan No. 1* (2005). Most of the banks are vegetated with a thin riparian strip of native species (eg *Eucalyptus* sp. and *Casuarina* sp.) and considerable amounts of sandflat and mudflat habitat are present.

Broughton Creek catchment

The reach of Broughton Creek upstream of Berry is surrounded by cleared agricultural land although there are significant sections with relatively intact native riparian vegetation (dominated by river oak (*Casuarina cunninghamiana* subsp. *Cunninghamiana* and *Eucalyptus* spp.), significant riffle-pool sequences and instream fish habitat (snags, rocks and deep holes). Closer to Berry riparian vegetation becomes sparse and there is greater access of livestock to the creek. The channel also becomes wider and there are longer, deep pool sections with cleared steep banks. Previous surveys have found Broughton Creek to provide major fish habitat (Class 1 waterway) and it has recorded relatively high RCE scores (The Ecology Lab 2007). The ephemeral tributaries of upper Broughton Creek have been considered unlikely to provide fish habitat (Class 4 Waterways), as they only flow during larger events, have poorly defined channels with few standing pools and are often colonised by pasture grasses (The Ecology Lab 2007).

Habitat within the Broughton Mill Creek and Bundewallah Creek catchments are relatively degraded (The Ecology Lab, 2007). Riparian vegetation is sparse or dominated by river oak and mixed exotic species and banks are often unconsolidated and eroded. Assessments completed during a prolonged dry period in Bundewallah Creek and Connollys Creek found minimal fish habitat (Class 3 waterway), whereas the sections of Broughton Mill Creek just above and below the Bundewallah Creek confluence were considered to provide moderate fish habitat (Class 2 waterway). This watercourse had a sequence of pools and riffles, with some large snags and deeper holes. The larger proportion of the Town Creek catchment is urbanised and unlikely to provide fish habitat (Class 4 Waterway), and reaches of the creek to the north and south of the urbanised reaches have poorly defined channels with few standing pools and are often colonised by pasture grasses.

The Agars Lane Bridge crossing of Broughton Creek marks the downstream extent of freshwater habitat. Further downstream the channel becomes considerably wider (up to 50 metres) and is estuarine. It meanders through the Broughton floodplain which has been cleared for agricultural use and the riparian vegetation is thin and sparse. There have been historical flood mitigation works in this area and a number of tributaries of Broughton Creek have been straightened and contain tidal gates. The estuarine reach of Broughton Creek has been previously classed as major fish habitat (Class 1 waterway) (The Ecology Lab 2007).

Aquatic habitats adjacent to, or downstream of the study area

There is considerable wetland habitat within the region, beyond the study area.

The SEPP 14 listed Coomonderry Swamp lies behind Seven Mile Beach National Park on the eastern side of the ridge that separates the Broughton Creek valley and floodplain from the coast. Coomonderry Swamp is a 670 hectare semi-permanent freshwater swamp fed by surface and groundwater from the eastern slopes of Harley Hill, Moeyan Hill and Coolangatta Mountain (NSW National Parks and Wildlife Service (NPWS) 1998). The maximum water depth is around one metre and the swamp is dominated by sedges and aquatic herbs. At the swamp edge extensive reed beds and sedgelands merge into thickets of *Casuarina*, paperbark (*Melaleuca* spp.), tea tree (*Leptospermum* spp.) and swamp mahogany (*Eucalyptus robusta*). The swamp feeds water to an aquifer in the sand dunes to the east and also flows out via a narrow drainage channel dug from the southern end to the Shoalhaven River. The drainage of Coomonderry Swamp would be unaffected by works associated with project.

In the estuarine reach of Broughton Creek, downstream of the study area there is a relatively continuous mangrove community (grey mangrove, *Avicennia marina*) (NSW Fisheries, 2004).

The Shoalhaven/Crookhaven estuary is located downstream of the Broughton Creek and Shoalhaven River confluence. It supports a number of significant estuarine wetlands, many of which are SEPP 14 listed, including the Comerong Island Nature Reserve. The eastern side of Comerong Island consists of a marine sand barrier on which dunes have formed. The northern part of this sand barrier is a sandpit across the Shoalhaven River entrance which is only intermittently open during flooding. The estuary entrance at Crookhaven Heads five kilometres to the south is permanently open. The remainder of Comerong Island and the other islands within the estuary have built up on river silt behind the sand barrier. The islands are joined by mudflats at low tide. The Shoalhaven and Crookhaven estuaries support 4.24 square kilometres of seagrass beds (*Z. capricorni* and *Halophila ovalis*), 4.18 square kilometres of mangroves (grey mangrove, *A. marina* and river mangrove, *Aegiceras corniculatum*) and 2.06 square kilometres of saltmarsh habitat (West *et al*., 1985; NSW Fisheries, 2004; Umwelt, 2005).

Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are ecosystems that have their species composition and natural ecological processes determined by groundwater (DLWC 2002). A GDE may either be entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water. GDEs include base flow in streams, wetlands, terrestrial vegetation and aquifer and cave ecosystems (DLWC 2002).

Shallow alluvial groundwater systems have been identified upstream in the Broughton Creek floodplain and in the area immediately north of Berry, where Broughton Mill Creek, Bundewallah Creek and Connollys Creek converge (RTA, 2010). In these areas, groundwater levels are typically between 0.37 metres and 2.5 metres below ground level. Shallow alluvial groundwater systems are often in direct connection with surface water bodies, such as coastal waterways. These systems can be quickly recharged and water levels restored when droughts break (DLWC, 2002). The groundwater system in the study area is likely to support surface base flows, hyporheic ecosystems and terrestrial vegetation such as riparian forests. The hyporheic zone is a fluctuating region where water exchanges between the surface and groundwater and is an important habitat for many aquatic invertebrates and a refuge during droughts and floods.

Shallow groundwater can support riparian forest either permanently or seasonally. The groundwater needs to be sufficiently high to sustain the vegetation therefore the sections of riparian habitat most dependent on groundwater within the study area probably occur in areas where the water table is closest to the surface. However, the relationship between groundwater and persistence of riparian habitat in the study area is not known. Groundwater can also be important for the persistence of aquatic macrophytes stands during periods of no flow, such as cumbungi (*Typha orientalis*), whose roots and rhizomes penetrate beneath creek beds.

Groundwater contributions to base flow typically emerge as springs or diffuse flow from saturated sediments. It can be an important component of instream flow and critical to the health and persistence of shallow aquatic habitat, such as riffles, which support its own particular aquatic assemblages and were common within the major waterways of the study area. It can also be important to the persistence of discontinuous pools during droughts which function as refugia for aquatic biota unable to utilise the hyporheic zone. The importance of groundwater to baseflow of waterways within the study area is not known. There are no known significant springs in the study area.

Coomonderry Swamp is a well-known GDE within the region, but its groundwater inflows originate from outside the study area catchment to the east of Harley Hill, Moeyan Hill and Coolangatta Mountain and therefore would be unaffected by works associated with the project.

Aquatic biota

Macrophytes

Previous surveys of creeks within the Crooked River and Broughton Creek catchments recorded cumbungi (*Typha* sp.), spikerush (*Isolepis prolifera*), starwort (*Aster* sp.), duckweed (*Lemna* sp.), water ribbons (*Triglochin procerum*), arum lilies (*Zantedeschia aethopica*), tall spikerush (*Eleocharis sphacelata*), river clubrush (*Schoenoplectus validus*), unidentified rush (*Cyperus* sp.), common reed (*Phragmites australis*), knotweed (*Persicaria* sp.), water plantain (*Alisma plantago-aquatica*), watermilfoil (*Myriophyllum* sp.), watercress (*Nasturtium officinale*) and blunt pondweed (*Potamogeton ochreatus*) (The Ecology Lab, 1999; 2007).

Macroinvertebrates

A study of aquatic macroinvertebrates from slow-flowing ‘pool edge’ freshwater habitat in the Crooked River and adjacent Ooaree Creek catchments recorded 41 taxa (The Ecology Lab, 1999). Consistent with results for water quality the most common macroinvertebrates collected from pool habitat were midge fly larvae (family Chironomidae), which are tolerant to pollution or degraded habitat. Other relatively abundant taxa included the families; Leptophlebiidae, Hydroptilidae, Physidae, Tricladidae, Baetidae, Tasimiidae and the sub-family Orthocladiinae (The Ecology Lab, 1999).

The estuarine Crooked River lagoon benthos is dominated by the polychaete families Nephtyidae and the Orbiniidae. The lagoon’s benthic macroinvertebrate assemblage is structured by its high proportion of sandy sediments, which reflect its predominantly ‘open’ nature (The Ecology Lab, 1999). A previous survey on benthic assemblages of the lower Shoalhaven River (downstream of the confluence with Broughton Creek) found the community dominated by the polychaete families of Nephtyidae and Oweniidae and the bivalve, *Arthritica helmsi* (The Ecology Lab, 1995). Other taxa included phoronid worms, nemerteans and crustaceans (such as amphipods, mysids and the ghost shrimp, *Calllianassa arenosa*).

Fish

A literature and database search was conducted to obtain an inventory of freshwater fish fauna for the region of the study area (**Table 3.1**). Sources included Australian Museum and DTIRIS (fisheries) collections, published distributions of freshwater fish, other surveys and a historical recreation of fish communities in the Shoalhaven River. Given the relatively small size of the project corridor there have been few formal fish surveys conducted in the study area (exceptions include the surveys documented in; The Ecology Lab, 1999; 2007). The results of other surveys conducted within nearby and equivalent reaches of the Shoalhaven River system (ie of similar elevation, morphology and habitat to the study area) were also incorporated into **Table 3.1**, for example; the surveys documented in; Faragher, 1999; Gehrke *et al*. (2001) and Harris and Gehrke (1997).

Thirty six fish species were identified as potentially existing or have historically existed within the region of the project. Of these, 33 are native species and three are exotic species. Two native species in **Table 3.1** are listed as threatened. The FM Act lists the Macquarie perch (*Macquaria australasica*) as a vulnerable species and Australian grayling (*Prototroctes maraena*) as a protected species. The Macquarie perch and the Australian grayling are listed under the EPBC Act as endangered and vulnerable respectively. The Australian grayling has been recorded by Australian Museum from Broughton Mill Creek, to the south-east of Berry and from the lower section of Jaspers Creek, just upstream of its confluence with Broughton Creek.

It is probable that not all 36 species identified in **Table 3.1** occur within the study area. The estimate was obtained by including surveys from a wider area, including the larger Shoalhaven River system, which has historically provided considerable fish habitat at altitudes ranging from sea level to over 500 metres AHD. The Broughton Creek catchment supports an estuarine floodplain and freshwater reach, but the catchment is still relatively small and most of the higher altitude streams are ephemeral and are unlikely to provide fish habitat. It is possible that some species, particularly the larger and more sensitive, may not be present.

Moreover, not all sources were in agreement on the composition of the regional freshwater fish assemblage. Gehrke *et al*. (2001) did not consider it likely that the mountain galaxid (*Galaxias olidus*) historically occupied sites at elevations lower than 130 metres AHD yet Allen (2003) describe the species as occupying watercourses from 1800 metres AHD to sea level. Similarly, the Macquarie perch is generally thought to inhabit higher freshwater reaches than those commonly found in the study area (NSW DPI 2005), particularly in the presence of Australian bass (*Macquaria novemaculeata*), but Gehrke *et al*., (2001) claim that Macquarie perch was historically present (prior to the construction of the Tallowa dam) in reaches of the Shoalhaven River as low as 30 metres ASL. Equivalent low elevation habitat exists, albeit smaller and more degraded, within the study area.

Table 3.1 **Species of freshwater fish that have been recorded in the region of the proposed Foxground and Berry bypass or whose published distribution includes the study area**

Family name	Species name	Common name	Cardno Ecology Lab (2009)[a]	The Ecology Lab (2007)	The Ecology Lab (1999)	Bionet[b]	Faragher (1999)[c]	Harris & Gehrke (1997)	Gehrke *et al.* (2001)	McDowall (1996)	Allen *et al.* (2003)
Mordaciidae	*Mordacia mordax*	Shortheaded Lamprey							s, h	d	d
Anguillidae	*Anguilla australis*	Shortfinned Eel			s				s, h	d	d
Anguillidae	*Anguilla reinhardtii*	Longfinned Eel	s[1]	s	s		s[2,3]	s	s, h	d	d
Clupeidae	*Potamalosa richmondia*	Freshwater Herring					s[3]	s	s, h	d	d
Galaxiidae	*Galaxias brevipinnis*	Climbing Galaxias							h	d	d
Galaxiidae	*Galaxias maculatus*	Common Jollytail	s[1]		s		s[2,3]		s, h	d	d
Galaxiidae	*Galaxias olidus*	Mountain Galaxias									d
Retropinnidae	*Retropinna semoni*	Australian Smelt	s[1]	s		s	s[2,3]	s	s, h	d	d
Prototroctidae	*Prototroctes maraena*	Australian Grayling**, ***				s	s[3]		h	d	d
Cyprinidae	*Carassius auratus*	Goldfish #						s	s, h	d	d
Cyprinidae	*Cyprinus carpio*	Common Carp #					s[3]	s	s	d	d
Poeciliidae	*Gambusia holbrooki*	Mosquito Fish #	s[1]	s	s			s		d	d
Atherinidae	*Atherinosoma microstoma*	Small-mouthed Hardyhead								d	d

Family name	Species name	Common name	Cardno Ecology Lab (2009)[a]	The Ecology Lab (2007)	The Ecology Lab (1999)	Bionet[b]	Faragher (1999)[c]	Harris & Gehrke (1997)	Gehrke *et al.* (2001)	McDowall (1996)	Allen *et al.* (2003)
Psuedomugilidae	*Psuedomugil signifer*	Pacific Blue-eye		s					h	d	d
Scorpaenidae	*Notesthes robusta*	Bullrout	s[1]				s[3]	s	s, h	d	d
Chanidae	*Ambassis marianus*	Estuary Perchlet		s						d	d
Percichthyidae	*Macquaria australasica*	Macquarie Perch*, **, ***							h		
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	s[1]				s[1,3]	s	s, h	d	d
Percichthyidae	*Macquaria colonorum*	Estuary Perch							s, h	d	d
Sparidae	*Acanthopagrus australis*	Yellowfin Bream								d	d
Mugilidae	*Myxus elongatus*	Sand Mullet						s		d	
Mugilidae	*Myxus petardi*	Freshwater Mullet					s[3]	s	s, h		
Mugilidae	*Mugil cephalus*	Sea Mullet		s			s[3]	s	s, h	d	d
Mugilidae	*Aldrichetta forsteri*	Yellow-eyed Mullet								d	d
Mugilidae	*Liza argentea*	Flat-tail Mullet								d	
Gobiidae	*Philypnodon grandiceps*	Flathead Gudgeon	s[1]	s			s[2]	s	s, h	d	d
Gobiidae	*Philypnodon* sp.	Dwarf Flathead Gudgeon						s	s, h	d	d

Family name	Species name	Common name	Cardno Ecology Lab (2009)[a]	The Ecology Lab (2007)	The Ecology Lab (1999)	Bionet[b]	Faragher (1999)[c]	Harris & Gehrke (1997)	Gehrke *et al.* (2001)	McDowall (1996)	Allen *et al.* (2003)
Gobiidae	*Gobiomorphus coxii*	Cox's Gudgeon			s		s[2,3]	s	s, h	d	d
Gobiidae	*Gobiomorphus australis*	Striped Gudgeon	s[1]	s	s		s[2,3]	s	s, h	d	d
Gobiidae	*Hypseleotris compressa*	Empire Gudgeon		s	s			s	s, h	d	d
Gobiidae	*Hypseleotris galii*	Firetailed Gudgeon								d	d
Gobiidae	*Psuedogobius* sp. 9	Blue Spot Goby								d	d
Gobiidae	*Redigobius macrostoma*	Large Mouth Goby								d	d
Gobiidae	*Acentrogobius bifrenatus*	Bridled Goby								d	
Gobiidae	*Afurcagobius tamarensis*	Tamar River Goby								d	d
Gobiidae	*Mugilogobius platynotus*	Flat-backed Goby									d

** = vulnerable species (NSW FM Act), ** = vulnerable species (EBPC Act), *** = endangered species (EPBC Act), # = alien species, s = sampled, h = historically recreation, d = published distribution includes proposed route for the project*

[a] Cardno Ecology Lab field survey –4 - 17 April 2009 was done in Ooaree Creek, Crooked River and Broughton Creek catchments. [1] = fish sampled in the region of the project.

[b] The BioNet search area (decimal degrees) was defined as North -34.733 East 150.772 South -34.779 West 150.682

[c]Faragher's survey (1999) included sites: at Broughton Mill Creek = [1]; a downstream freshwater reach of Broughton Creek = [2]; on the Shoalhaven River below Tallowa Dam = [3]

The Ecology Lab (1999) surveys were done in freshwater reaches of the Ooaree Creek and Crooker River catchments. The Ecology Lab (2007) surveys were done in Ooaree Creek, Crooked River and Broughton Creek catchments.

Source: Field data recorded by Cardno Ecology Lab (15/04/2009 - 17\04\2009) and The Ecology Lab (29/01/2007 – 01/02/2007) and literature review (McDowall 1996, Harris and Gehrke 1997, Faragher 1999, The Ecology Lab 1999, Gehrke et al. 2001, Allen et al 2003)

A previous survey of waterways intersecting the project recorded nine species of freshwater and estuarine fish (The Ecology Lab, 2007). Four species were recorded within freshwater habitat from the Broughton Creek catchment: Longfinned Eel (*Anguilla reinhardtii*), Flathead Gudgeon (*Philypnodon grandiceps*), Striped Gudgeon (*Gobiomorphus australis*) and Empire Gudgeon (*Hypseleotris compressa*). In addition to flathead gudgeon, another five species were recorded at the upper tidal limit in the Broughton channel: Australian Smelt (*Retropinna semoni*), Pacific Blue-eye (*Psuedomugil signifer*), Estuary Perchlet (*Ambassis marianus*), Sea Mullet (*Mugil cephalus*) and the introduced Mosquito Fish (*Gambusia holbrooki*) (The Ecology Lab, 2007).

There are a large number of fish species that utilise estuarine waters in this region at some time during their life history. The estuaries found downstream of the project in Crooked River lagoon and Shoalhaven/Crookhaven system are considered to be major fish habitat (Class 1 Waterways). A survey of Crooked River lagoon recorded fish from 20 families, representing 29 species (**Table 3.2**; The Ecology Lab, 1999). Of these, 13 species were of commercial interest. Crooked River lagoon was characterised by Luderick (*Girella tricuspidata*), Flat-tail Mullet (*Liza argentea*), Sea Mullet (*Mugil cephalus*), Tarwhine (*Rhabdosargus sarba*), Sand Whiting (*Sillago ciliata*), Yellow-finned Leatherjacket (*Meuschenia trachylepsis*), Swan River Goby (*Pseudogobius olorum*), Blue Groper (*Achoerodus viridis*) and Eastern King Prawn. Many of the most abundant species were found associated with seagrass habitat.

The Shoalhaven/Crookhaven estuary supports a significant fish assemblage. The estuary supports commercial fishing in the NSW Estuary General Fishery which utilises a variety of gears to target fish such as luderick, whiting (Sillaginidae), mullet (Mugilidae), flathead (Platycephalidae), bream (Sparidae) and crab species. A number of threatened and protected species either occur or suitable habitat for them may occur in the region of the estuary (**Table 3.3**).

Table 3.2: The means and standard errors (SE) for numbers of fish and mobile invertebrates caught using seine nets over seagrass and bare substratum habitats in Crooked River estuary. Source: The Ecology Lab (1999)

Family name	Species name	Common name	Crooked River Estuary				
			Seagrass			Bare Substratum	
			Mean	S.E.		Mean	S.E.
Hemiramphidae	*Hyporhamphus sp.*	Garfish*	0.0	0.0		2.2	0.9
Platycephalidae	*Platycephalus fuscus*	Dusky Flathead*	0.0	0.0		0.5	0.3
Sillaginidae	*Sillago ciliata*	Sand Whiting*	0.0	0.0		22.5	21.5
Pomatomidae	*Pomatomus saltatrix*	Tailor*	0.0	0.0		0.3	0.2
Sparidae	*Rhabdosargus sarba*	Tarwhine*	57.2	29.1		0.0	0.0
Sparidae	*Acanthopagrus australis*	Yellow-finned Bream*	2.2	1.6		0.0	0.0
Girellidae	*Girella tricuspidata*	Luderick*	380.1	67.5		0.0	0.0
Mugilidae	*Mugil cephalus*	Sea mullet*	60.5	15.5		9.3	8.7
Mugilidae	*Myxus elongatus*	Sand Mullet*	0.0	0.0		4.8	2.3
Mugilidae	*Liza argentea*	Flat-tail Mullet*	228.8	90.8		0.0	0.0
Bothidae	*Pseudorhombus jenynsii*	Small-toothed Flounder*	0.0	0.0		0.7	0.5
Monacanthidae	*Meuschenia trachylepis*	Yellow-finned Leatherjacket*	53.9	23.2		0.2	0.2
Monacanthidae	*Monacanthus freycineti*	Six-spined Leatherjacket*	10.5	6.7		0.0	0.0
Scorpaenidae	*Centropogon australis*	Fortescue	15.4	7.2		0.0	0.0
Ambassidae	*Ambassis sp.*	Perchlets	12.7	4.2		0.0	0.0
Terapontidae	*Pelates sexlineatus*	Eastern Striped Trumpeter	2.2	2.2		0.0	0.0
Gobidae	*Pseudogobius olorum*	Swan River Goby	386.7	200.8		0.0	0.0
Gobidae	*Redigobius macrostoma*	Large-mouth Goby	19.3	12.0		0.0	0.0

Family name	Species name	Common name	Crooked River Estuary				
			Seagrass			Bare Substratum	
			Mean	S.E.		Mean	S.E.
Gobidae	*Gobiopterus semivestita*	Glass Goby	1.7	1.1		0.0	0.0
Gobidae	*Favonigobius tamarensis*	Tamar River Goby	3.9	1.3		0.2	0.2
Gobidae	*Favonigobius exquisitus*	Exquisite Goby	0.6	0.6		0.0	0.0
Eleotridae	*Philypnodon grandiceps*	Flathead Gudgeon	8.3	4.1		0.0	0.0
Eleotridae	*Philypnodon sp.*	Dwarf Flathead Gudgeon	3.9	2.5		0.0	0.0
Tetraodontidae	*Tetractenos glaber*	Smooth Toadfish	0.0	0.0		1.5	0.4
Microcanthidae	*Microcanthus strigatus*	Stripey	2.8	1.6		0.0	0.0
Labridae	*Achoerodus viridis*	Blue groper	24.2	12.2		0.0	0.0
Carangidae	*Pseudocaranx dentex*	Silver Trevally*	0.6	0.6		0.3	0.2
Triglidae	*Chelidonichthys kumu*	Red Gurnard	0.0	0.0		0.2	0.2
Clupeidae	*Hyperlophus vittatus*	Sandy Sprat	0.0	0.0		11.8	7.6
Penaeidae	*Penaeus plebejus*	Eastern King Prawn*	172.2	89.7		0.3	0.3

** Indicates species of commercial importance.*

Table 3.3: Threatened and Protected Species listed under s248 of the Commonwealth *Environmental Protection and Biodiversity Conservation Act (EPBC) 1999*

a. Matters of National Environmental Significance		
Species name	**Common name**	**Status**
Mammals		
Eubalaena australis	Southern Right Whale	Endangered
Megaptera novaeangliae	Humpback Whale	Vulnerable
Reptiles		
Dermochelys coriacea	Leatherback Turtle	Endangered
Caretta caretta	Loggerhead Turtle	Endangered
Chelonia mydas	Green Turtle	Vulnerable
Eretmochelys imbricata	Hawksbill Turtle	Vulnerable
Sharks		
Carcharias taurus	Grey Nurse Shark (east coast population)	Critically Endangered
Carcharodon carcharias	Great White Shark	Vulnerable
Rhincodon typus	Whale Shark	Vulnerable
Ray-finned fishes		
Macquaria australasica	Macquarie Perch*	Endangered
Prototroctes maraena	Australian Grayling*	Vulnerable

** MNES within the Broughton Creek catchment*

b. Migratory marine species		
Species name	**Common name**	
Mammals		
Balaenoptera edeni	Bryde's Whale	Protected
Caperea marginata	Pygmy Right Whale	Protected
Eubalaena australis	Southern Right Whale	Protected
Lagenorhynchus obscurus	Dusky Dolphin	Protected
Megaptera novaeangliae	Humpback Whale	Protected
Orcinus orca	Orca	Protected
Reptiles		
Dermochelys coriacea	Leatherback Turtle	Protected
Caretta caretta	Loggerhead Turtle	Protected
Chelonia mydas	Green Turtle	Protected
Eretmochelys imbricata	Hawksbill Turtle	Protected
Sharks		
Carcharodon carcharias	Great White Shark	Protected
Rhincodon typus	Whale Shark	Protected

c. Listed marine species		
Species name	**Common name**	
Mammals		
Arctocephalus forsteri	New Zealand Fur-seal	Protected
Arctocephalus pusillus	Australian Fur-seal	Protected
Reptiles		
Dermochelys coriacea	Leatherback Turtle	Protected
Caretta caretta	Loggerhead Turtle	Protected
Chelonia mydas	Green Turtle	Protected
Eretmochelys imbricata	Hawksbill Turtle	Protected
Ray-finned fishes		
Acentronura breviperula	Shortpouch Pygmy Pipehorse	Protected
Cosmocampus howensis	Lord Howe Pipefish	Protected
Heraldia nocturna	Upside-down Pipefish	Protected
Hippocampus abdominalis	Bigbelly Seahorse	Protected
Hippocampus breviceps	Shorthead Seahorse	Protected
Hippocampus whitei	White's Seahorse	Protected
Histiogamphelus briggsii	Crested Pipefish	Protected
Kimblaeus bassensis	Trawl Pipefish	Protected
Lissocampus runa	Javelin Pipefish	Protected
Maroubra perserrata	Sawtooth Pipefish	Protected
Notiocampus ruber	Red Pipefish	Protected
Phyllopteryx taeniolatus	Weedy Seadragon	Protected
Solegnathus spinosissimus	Spiny Pipehorse	Protected
Solenostomus cyanopterus	Robust Ghostpipefish	Protected
Stigmatopora argus	Spotted Pipefish	Protected
Stigmatopora nigra	Widebody Pipefish	Protected
Syngnathoides biaculeatus	Double-end Pipehorse	Protected
Urocampus carinirostris	Hairy Pipefish	Protected
Vanacampus margaritifer	Mother-of-pearl Pipefish	Protected
Vanacampus phillipi	Port Phillip Pipefish	Protected

d. Whales and other Cetaceans		
Species name	**Common name**	
Balaenoptera acutorostrata	Minke Whale	Protected
Balaenoptera edeni	Bryde's Whale	Protected
Caperea marginata	Pygmy Right Whale	Protected
Delphinus delphis	Common Dolphin	Protected
Eubalaena australis	Southern Right Whale	Protected
Grampus griseus	Risso's Dolphin	Protected
Lagenorhynchus obscurus	Dusky Dolphin	Protected
Megaptera novaeangliae	Humpback Whale	Protected
Orcinus orca	Orca	Protected
Tursiops aduncus	Indian Ocean Bottlenose Dolphin	Protected
Tursiops truncatus s. str.	Bottlenose Dolphin	Protected

3.2 Field site assessments

Assessment of waterways within the study area was conducted on 15 April 2009 to 17 April 2009. Observations were made following a period of relatively significant rainfall (ie 37.6 millimetres of rainfall at Kiama in the week preceding the survey). Field assessment of temporary waterway crossing sites was done on 28 June 2011. In addition to aquatic ecological assessments, an assessment of riparian and terrestrial plant community condition within the area potentially affected by the proposed diversion of Town Creek into Bundewallah Creek was carried out by one botanist from Biosis on 8 November 2011.

Each waterway was assessed using three classification systems (Section 2.2.2). For each watercourse **Table 3.4** presents fish habitat classification, RCE scores and DIPNR Riparian classification. Appendix A details the categories and descriptors used to calculate RCE scores (after Chessman *et al*., 1997). Criteria for fish habitat classification according to NSW Fisheries Guidelines are contained in Appendix B. DIPNR classification categories are described in Section 2.2.2 (after DIPNR, 2004). Where appropriate, recordings were made of water quality, macrophyte, macroinvertebrate and fish assemblages and existing waterway crossings.

3.2.1 Crooked River catchment

No sites were sampled in this section as there were no waterways (permanent or ephemeral) intersecting the project in the Crooked River catchment.

3.2.2 Broughton Creek catchment

Twenty two sites (sites 13 to 29 and five temporary creek crossing sites) within the Broughton Creek catchment were sampled along the project (**Table 3.4**, **Figure 2.1** and **Figure 3.2**).

Table 3.4: Sites established for the Foxground and Berry bypass. Suggested waterway crossing structures based on criteria established by Fairfull and Witheridge (2003)

Site	Easting	Northing	Catchment	Watercourse	Fish habitat classification	RCE score	Riparian category	Existing drainage structure	Suggested drainage structure
13	294853	6152838	Broughton Creek	Broughton Creek	1	37	1	Bridge - Two Span (Flood Overflow Box Culvert - Double)	Bridge, arch structure or tunnel
14	294534	6152719	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Double*	Culvert, causeway or ford
15	294313	6152364	Broughton Creek	Unnamed	4	23	3	None	Culvert, causeway or ford
16	294326	6152222	Broughton Creek	Broughton Creek	1	36	1	None	Bridge, arch structure or tunnel
17	294163	6152024	Broughton Creek	Broughton Creek	1	34	1	None	Bridge, arch structure or tunnel
18	293980	6151861	Broughton Creek	Unnamed	3/4	25	2	Box Culvert - Single*	Culvert or ford
19	293568	6151519	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Single	Culvert, causeway or ford
20	293340	6151384	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Single	Culvert, causeway or ford
21	293212	6151323	Broughton Creek	Unnamed	4	23	3	Box Culvert - Single	Culvert, causeway or ford
22	292790	6151089	Broughton Creek	Unnamed	3/4	25	2	Box Culvert - Triple	Culvert or ford
23	292270	6150868	Broughton Creek	Unnamed	4	26	3	Pipe Culvert - Single	Culvert, causeway or ford

Site	Easting	Northing	Catchment	Watercourse	Fish habitat classification	RCE score	Riparian category	Existing drainage structure	Suggested drainage structure
24	292042	6150896	Broughton Creek	Unnamed	4	25	3	Pipe Culvert - Single	Culvert, causeway or ford
25	290000	6149879	Broughton Creek	Broughton Mill Creek	2	33	1	None	Bridge, arch structure, culvert or ford
26	289956	6149873	Broughton Creek	Unnamed	4	21	3	None	Culvert, causeway or ford
27	289854	6149826	Broughton Creek	Bundewallah Creek	2	32	1	Bridge - Three Span*	Bridge, arch structure, culvert or ford
28	288497	6149713	Broughton Creek	Unnamed	4	22	3	None	Culvert, causeway or ford
29	288021	6149269	Broughton Creek	Unnamed	4	23	3	Pipe Culvert - Triple	Culvert, causeway or ford

**Drainage structure located short distance upstream/downstream of site at an existing road or Princes Highway crossing*

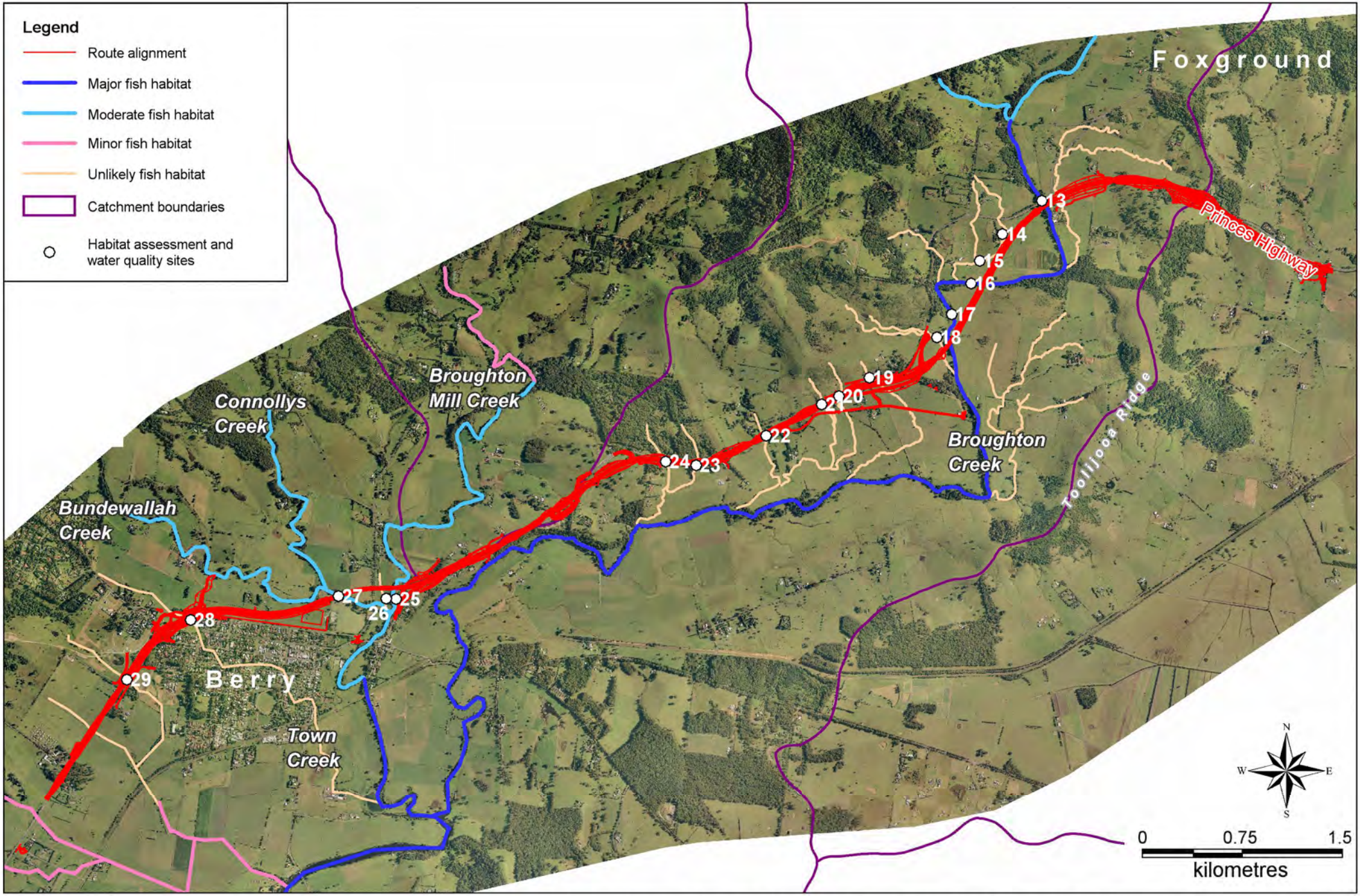

Figure 3.2: Waterways and aquatic ecology monitoring sites within the study area. Classifications are based on criteria established by Fairfull and Witheridge (2003)

Site 13 – Broughton Creek

Site 13 was established at the existing Princes Highway crossing of Broughton Creek 1.2 kilometres south of the intersection with Foxground Road. This site is one of the three proposed crossings of Broughton Creek by the project. The existing crossing is a two-span bridge and the bridge support piles are located in the wetted-width of the channel (Plate 1a provided at the end of this section). This section of Broughton Creek had a moderate RCE score (**Table 3.4**) and provided major fish habitat (Class 1 Waterway; **Figure 3.1**). The surrounding land had been cleared for agricultural use but there was considerable remaining riparian vegetation, although the understory was often dominated by exotic shrubs and annual weeds. There was frequent alternation of riffles and pools and the stream bed was composed primarily of cobble and pebble (Plate 1b provided at the end of this section). Broughton Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**). Forty metres west of the channel a twin box culvert had been installed in the highway embankment as a flood overflow measure (Plate 1c provided at the end of this section).

Water quality was moderate for the physical parameters measured *in situ* (**Table 3.5**). Dissolved oxygen and pH recorded from site 13 on Broughton Creek were within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) (**Table 3.5** and Appendix C). Conductivity and turbidity were outside the ANZECC lower thresholds (**Table 3.5** and Appendix C).

The composition of the aquatic macroinvertebrate assemblage indicates that Broughton Creek was moderately impaired due to pollution and/or local habitat degradation. A total of 34 unique taxa were recorded, 25 from pool edge habitat and 18 from riffle habitat (Nine taxa were found in both pool edge and riffle habitat). AusRivAS assessment classified macroinvertebrate assemblages from both pool edge and riffle habitat as significantly impaired (Band B) indicating that some of the taxa predicted to occur were absent, however edge habitat OE50 Taxa scores were at the upper limit for Band B and just below the lower limit for reference condition (Band A; **Table 3.6**). The O0Signal scores of 4.06 (edge habitat) and 4.50 (riffle habitat) signify a creek with moderate pollution and/or degraded habitat as the macroinvertebrate assemblage was dominated by pollution-tolerant taxa. The OE0 Signal scores were less than one in both habitat types indicating that the assemblages in these habitats had a greater proportion of pollution-tolerant taxa than at equivalent reference sites (**Table 3.6**).

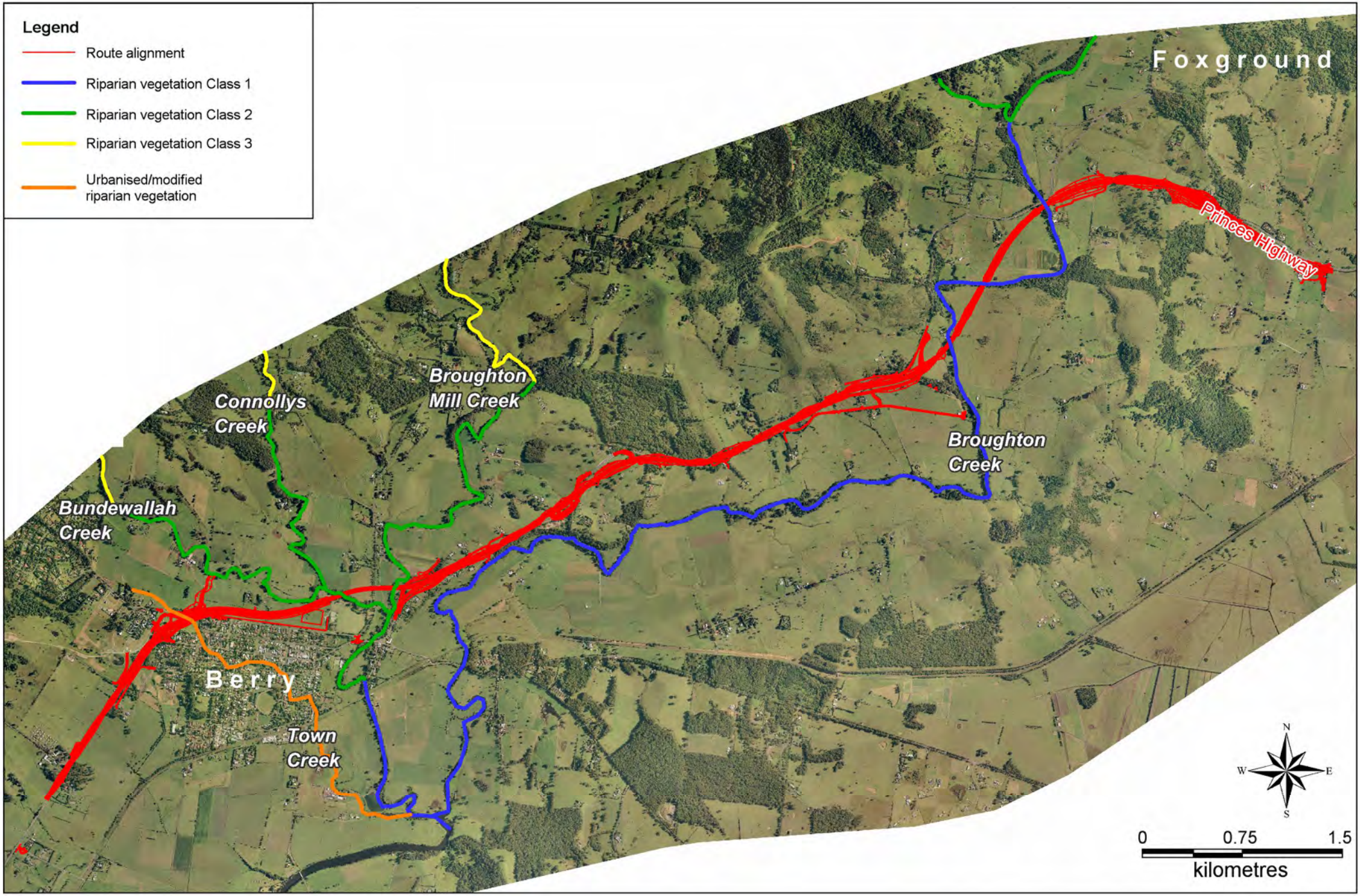

Figure 3.3: Map of waterways based on riparian habitat classification

Table 3.5: Water quality measured *in situ* in the study area in comparison with ANZECC (2000) guidelines for low-land watercourses in south-east Australia

Site	Watercourse	Conductivity (us/cm)	pH	Dissolved oxygen (% sat.)	Turbidity (NTU)
		1–5 - 2200	6.5 - 8.0	85 - 110	6 - 50
13	Broughton Creek	↓	✓	✓	↓
16	Broughton Creek	↓	✓	✓	↓
17	Broughton Creek	↓	✓	↑	↓
25	Broughton Mill Creek	↓	✓	↑	↓
27	Bundewallah Creek	✓	✓	✓	↓

↓= below guidelines, ↑= above guidelines, ✓= within guidelines
Recorded by Cardno Ecology Lab (15/04/09 - 17/04/09)

Table 3.6: AusRivAS scores for macroinvertebrates from edge and riffle habitat in April 2009

a. Edge habitat (Autumn 2009)												
Site	**Watercourse**	**NTE50**	**NTP50**	**NTC50**	**OE50**	**E50Signal**	**O50Signal**	**OE50Signal**	**E0Signal**	**O0Signal**	**OE0Signal**	**Band**
13	Broughton Creek	13.65	19	11	0.81	4.36	3.82	0.87	4.36	4.06	0.93	B
25	Broughton Mill Creek	13.85	20	15	1.08	4.34	4.47	1.03	4.38	4.56	1.04	A
27	Bundewallah Creek	10.39	14	10	0.96	4.20	4.20	1.00	4.48	4.14	0.92	A
b. Riffle habitat (Autumn 2009)												
Site	**Watercourse**	**NTE50**	**NTP50**	**NTC50**	**OE50**	**E50Signal**	**O50Signal**	**OE50Signal**	**E0Signal**	**O0Signal**	**OE0Signal**	**Band**
13	Broughton Creek	16.25	21	13	0.80	5.53	5.15	0.93	5.53	4.50	0.81	B
25	Broughton Mill Creek	16.25	21	13	0.80	5.53	5.31	0.96	5.55	4.67	0.84	B
27	Bundewallah Creek	15.40	19	12	0.78	5.79	5.75	0.99	5.86	5.00	0.85	B

Note: AusRivAS band categories: Band X = macroinvertebrate assemblage at the site is richer (more taxa) than the reference condition; Band A = assemblage is similar to the reference condition; Band B = assemblage is significantly impaired relative to the reference condition; Band C = assemblage is severely impaired relative to the reference condition; Band D = the assemblage is impoverished. Source: field data recorded by Cardno Ecology Lab (15 April 2009 to 17 April 2009).

All seven species of fish recorded at site 13 were native (Appendix D). Site 13 had the greatest diversity of fish fauna among all sites sampled. Species observed included bullrout (*Notesthes robusta*) and Australian bass (*Macquaria novemaculeata*); the latter is an important species to recreational fishers. A number of young-of-year (YOY) bass were caught in deep pool habitat and under overhanging banks. Juvenile bass initially develop in estuaries where adults spawn and then migrate upstream into freshwater habitat where they mature. The timing of the field survey in April is considered to be towards the end of this period of upstream migration.

Site 14 – unnamed watercourse

The watercourse at site 14 was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The existing road crossing upstream at the Princes Highway was a double pipe culvert and a small stand of cumbungi (*Typha* sp.) had formed in a temporary pool section above the culvert (Plate 1d provided at the end of this section). The watercourse channel was devoid of riparian vegetation and has been colonised by pasture grasses. The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 15 – unnamed watercourse

The watercourse at site 15 was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The channel was relatively undefined, devoid of riparian vegetation and had been colonised by pasture grasses and annual weeds (Plate 2a provided at the end of this section). The site was located near the confluence of the waterway that passed through site 14 and a parallel watercourse to the west, which was similarly ephemeral and highly degraded (**Figure 2.1**). The channel continued west before entering Broughton Creek. The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 16 – Broughton Creek

Site 16 was the second of the three proposed crossings of Broughton Creek by the project and was located approximately 1.3 kilometres downstream of site 13 (**Figure 2.1**). This section of Broughton Creek had a moderate RCE score (**Table 3.4**) and provided major fish habitat (Class 1 Waterway; **Figure 3.2**). The surrounding land had been cleared for agricultural use. Riparian vegetation was composed of river oak and exotic shrubs and annuals and was sparse in places (Plate 2b provided at the end of this section). Livestock had access to the creek from the south which had degraded areas of bank and channel bed. There was frequent alternation of riffles and pools and the stream bed was composed primarily of cobble and pebble. Submerged woody debris was relatively abundant. Broughton Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**).

Water quality was moderate for the physical parameters measured *in situ* (**Table 3.5**) Dissolved oxygen and pH were within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) (**Table 3.5** and Appendix C). Conductivity and turbidity were marginally outside the ANZECC lower thresholds (**Table 3.5** and Appendix C).

Site 17 – Broughton Creek

Site 17 was the third of the three proposed crossings of Broughton Creek by the project and was located around 400 metres downstream of site 16 (**Figure 2.1**). This section of Broughton Creek had a moderate RCE score (**Table 3.4**) and provided major fish habitat (Class 1 Waterway; **Figure 3.2**). The surrounding land had been cleared for agricultural use. Riparian vegetation was sparse and where present was composed primarily of river oak, annual weeds and pasture grasses. The channel bank on the eastern side of the creek was heavily eroded with frequent sections of collapsed bank (Plate 2c provided at the end of this section). Livestock had access to the creek from both the western and eastern bank. There were frequent alternation of riffles and pools and the stream bed was composed primarily of cobble and pebble. Submerged woody debris was relatively abundant. Broughton Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**).

Water quality was variable for the physical parameters measured *in situ* (**Table 3.5**). pH was within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) whilst conductivity and turbidity were marginally outside the ANZECC lower thresholds (**Table 3.5** and Appendix C). Dissolved oxygen was well above the ANZECC upper limits and may have been indicative of relatively high local algal activity. This was not unexpected given the low shading in this section of the creek and high nutrient levels.

The project continues parallel to Broughton Creek for a number of kilometres downstream (**Figure 2.1**). The project does not cross Broughton Creek downstream of site 17 but does cross a number of tributaries upstream of their confluence with Broughton Creek.

Site 18 – Unnamed watercourse

The watercourse at site 18 had a low RCE score (**Table 3.4**) and was considered minimal to unlikely fish habitat (Class 3 – 4 Waterway; **Figure 3.2**). Riparian vegetation was sparse and where present was composed predominantly of exotic shrubs. Much of the banks were eroded and lined with pasture grasses. A narrow pooling section is present downstream for 120 metres downstream of the existing Princes Highway crossing (Plate 2d provided at the end of this section). The unnamed watercourse and its riparian zone 3). The road crossing at the Princes Highway is a single box culvert. were classed as a Category 2 waterway (Aquatic Habitat; **Table 3.4** and **Figure 3.3**).

Site 19 – Unnamed watercourse

The road crossing at site 19 was a single pipe culvert. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and has been colonised by pasture grasses. Upstream of the Princes Highway crossing was a brief section of riparian vegetation including native trees and exotic shrubs. The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 20 – Unnamed watercourse

The road crossing at site 20 was a single pipe culvert. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and had been colonised by pasture grasses. Artificial dams were present upstream and downstream of the road crossing. The upstream dam contained a small stand of cumbungi (*Typha* sp.). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 21 – Unnamed watercourse

The road crossing at site 21 was a single box culvert. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and had been colonised by pasture grasses. The section of the waterway at the road crossing was dominated by invasive weed lantana (*Lantana camara*). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 22 – Unnamed watercourse

The road crossing at site 22 was a triple box culvert. The waterway channel was degraded, had a low RCE score (**Table 3.4**) and was considered minimal to unlikely fish habitat (Class– 3 - 4 Waterway; **Figure 3.2**). Riparian vegetation was sparse on the section of waterway which crossed the Princes Highway and where present was dominated by exotic trees, shrubs and annuals (Plate 3a provided at the end of this section). There were small pooling sections in the channel and introduced mosquito fish (*Gambusia holbrooki*) were observed downstream of the crossing. The unnamed watercourse and its riparian zone were classed as a Category 2 waterway (Aquatic Habitat; **Table 3.4** and **Figure 3.3**).

Site 23 – Unnamed watercourse

The road crossing at site 23 was a single pipe culvert. The waterway had a moderate RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The upstream section of the watercourse had relatively complete riparian vegetation dominated by native trees with some exotic understorey species. Downstream of the Princes Highway crossing water flowed over a rock fall which was a significant barrier to upstream passage for non-climbing fish species (Plate 3b provided at the end of this section). The banks were relatively unstable and eroded. Further downstream the riparian vegetation disappeared and the channel became indistinct and colonised by pasture grasses as it crossed farmland. The unnamed watercourse and its riparian habitat were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 24 – Unnamed watercourse

The road crossing at site 24 was a single pipe culvert. The waterway had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). The upstream section of the watercourse had relatively complete riparian vegetation comprised of mixed native and exotic trees and shrubs. A pool had formed on the downstream side of the road crossing. Downstream of this point the riparian vegetation became absent as the watercourse entered pasture. The channel eventually joins the watercourse from site 23 before discharging into Broughton Creek (**Figure 2.1**). The unnamed watercourse and its riparian habitat were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 25 – Broughton Mill Creek

Site 25 was the proposed crossing of Broughton Mill Creek by the project. The waterway had a moderate RCE score (**Table 3.4**) and was considered moderate fish habitat (Class 2 Waterway; **Figure 3.2**). The land to the west had been cleared for agricultural use and to the east there was a large maintained lawn. Riparian vegetation on the west bank contained a mixture of native and exotic trees and shrubs, but was largely absent on the eastern bank. There was a frequent alternation of riffle and pools and submerged woody debris was relatively abundant (Plate 3c provided at the end of this section). Broughton Mill Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**).

Water quality was variable for the physical parameters measured *in situ* (**Table 3.5**). pH was within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC 2000) whilst conductivity and turbidity were outside the ANZECC lower thresholds (**Table 3.5** and Appendix C). Dissolved oxygen was above the ANZECC upper limits and may have been indicative of relatively high local algal activity.

The composition of the aquatic macroinvertebrate assemblage indicated that Broughton Mill Creek was relatively healthy but exhibited some evidence of pollution and/or local habitat degradation. A total of 32 unique taxa were recorded, 27 from pool edge habitat and 20 from riffle habitat. (15 taxa were found in both pool edge and riffle habitat). AusRivAS assessment classified macroinvertebrate assemblages from pool edge as equivalent to reference condition (Band A). Riffle habitat was assessed as significantly impaired (Band B) indicating that some of the taxa predicted to occur were absent. O0Signal scores of 4.56 (edge habitat) and 4.67 (riffle habitat) suggested that the reach at site 25 was moderately polluted or degraded as the macroinvertebrate assemblage was dominated by pollution-tolerant taxa (**Table 3.6**). The OE0 Signal score of less than one for the riffle indicated that the assemblages in this habitat had a greater proportion of pollution-tolerant taxa than at equivalent reference sites. The composition of pollution-tolerant and pollution-sensitive fauna in pool edge habitat was equivalent to that of reference sites (**Table 3.6**).

All three species of fish recorded at site 25 were native: Australian Bass (Plate 3d provided at the end of this section), Australian Smelt (*Retropinna semoni*) and Longfinned Eel (*Anguilla reinhardtii*) (Appendix D).

Site 26 – Unnamed watercourse

Site 26 was a small ephemeral watercourse or drainage ditch that ran parallel to, and in between, Broughton Mill Creek and Woodhill Mountain Road (**Figure 2.1**, Plate 4a provided at the end of this section). The waterway had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway: **Figure 3.2**). The channel was bordered by cut grass from a turf farm on either side and had been colonised by annual weeds and pasture grass (Plate 4a provided at the end of this section). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

Site 27 – Bundewallah Creek

Site 27 was the proposed crossing of Bundewallah Creek by the project. The waterway had a moderate RCE score (**Table 3.4**) and was considered moderate fish habitat (Class 2 Waterway; **Figure 3.2**). The surrounding land had been cleared for agricultural use and recreation. The riparian vegetation was relatively continuous and composed of native trees (river oak) and exotic shrubs, climbers and annuals. There was a frequent alternation of riffle and pools and submerged woody debris was relatively abundant (Plate 3b provided at the end of this section). Bundewallah Creek and its riparian habitat were classed as a Category 1 waterway (Environmental Corridor; **Table 3.4** and **Figure 3.3**). The existing Woodhill Mountain Road crossing of Bundewallah Creek downstream of the project crossing was a two span bridge with the bridge piles positioned within the channel wetted-width.

Water quality was generally good for the physical parameters measured *in situ* (**Table 3.5**). Conductivity, pH and dissolved oxygen were all within the ANZECC threshold limits for the protection of aquatic ecosystems (ANZECC, 2000) whilst turbidity was outside the ANZECC lower thresholds (**Table 3.5** and Appendix C).

The composition of the aquatic macroinvertebrate assemblage indicated that Bundewallah Creek was relatively healthy but exhibited some evidence of pollution and/or local habitat degradation. A total of 33 unique taxa were recorded, 22 from pool edge habitat and 19 from riffle habitat. (Eight taxa were found in both pool edge and riffle habitat). AusRivAS assessment classified macroinvertebrate assemblages from pool edge as equivalent to reference condition (Band A). Riffle habitat was assessed as significantly impaired (Band B) indicating that some of the taxa predicted to occur were absent. O0Signal scores of 4.14 (edge habitat) and 5.00 (riffle habitat) suggest that the reach at site 25 was mildly to moderately polluted and/or degraded as the macroinvertebrate assemblage was characterised by pollution-tolerant taxa (**Table 3.6**). The OE0 Signal score of less than one for the riffle indicated that the assemblages in this habitat had a greater proportion of pollution-tolerant taxa than at equivalent reference sites. The OE0 Signal scores were less than one in both habitat types indicating that the assemblages in these habitats had a greater proportion of pollution-tolerant taxa than at equivalent reference sites, although the disparity was greater for riffle habitat (**Table 3.6**).

All four species of fish recorded at site 27 were native: Australian Bass, Common Jollytail (*Galaxias maculatus*), Australian Smelt and Longfinned Eel (Appendix D).

Site 28 – Town Creek

Site 28 was the proposed crossing of Town Creek by the project. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Much of the watercourse channel was undefined and had been colonised by pasture grasses and annual weeds (Plate 4c provided at the end of this section). Within the urbanised reaches of Town Creek the patches of vegetation present were characterised as disturbed riparian open woodland. South of the urban centre Town Creek flowed through pasture land with riparian vegetation consisting of closed grassland, then through a constructed wetland adjacent to the Berry Sewage Treatment Works, and subsequently through disturbed riparian open woodland habitat before its confluence with Broughton Mill Creek.

The water quality within Town Creek is expected to be characteristic of a watercourse with a developed residential and agricultural catchment. The long-term urban and agricultural land use in the area has likely lead to elevated nutrient levels (e.g. from fertilisers and livestock manure), low dissolved oxygen and raised suspended solids resulting from the erosion of soils.

Site 29 – Unnamed watercourse

The road crossing at site 29 was a triple pipe culvert. The site was located around 75 metres north-east of the Hitchcocks Lane intersection with the Princes Highway. The waterway was ephemeral, had a low RCE score (**Table 3.4**) and was considered unlikely fish habitat (Class 4 Waterway; **Figure 3.2**). Upstream of the highway crossing the watercourse had a relatively undefined channel and had been colonised by pasture grasses (Plate 4d provided at the end of this section). Further downstream the channel straightened, crossed the railway line and eventually entered Broughton Creek downstream of Wharf Road Bridge (**Figure 2.1**). The unnamed watercourse and its riparian zone were classed as a Category 3 waterway (Bank Stability and Water Quality; **Table 3.4** and **Figure 3.3**).

3.2.3 Temporary creek crossings

Temporary creek crossings are required at each proposed bridge structure during the construction period. Each proposed bridge location was surveyed and preferred temporary creek crossing sites were identified (**Figures 3.4**, **Figure 3.5** and **Table 3.7**). Preferred sites for temporary creek crossings were located such that impacts to terrestrial and aquatic ecology and water quality would be minimised. Important criteria considered during the temporary creek crossing identification process included (but were not limited to):

- Potential loss of native riparian vegetation. In particular, mature river oak (*Casuarina cunninghamiana* subsp. *cunninghamiana*) which is part of the EEC River-Flat Eucalypt Forest on Coastal Floodplain.
- Channel form. Preferences were for crossings over deeper channel sections, such as pools or runs, rather than riffles. Allowing for deeper water under temporary bridge crossings would minimise potential behavioural impacts on upstream fish passage.

Bridge1 – Broughton Creek

The temporary crossing of Broughton Creek at Bridge 1 had been determined by RMS prior to the field assessment. The temporary crossing site was located immediately downstream of the proposed Bridge 1 crossing of Broughton Creek (Site 13), within the existing alignment footprint.

Broughton Creek was a Class 1 waterway (major fish habitat) with Category 1 (environmental corridor) riparian habitat at the site of the proposed temporary crossing. The crossing would pass over riffle habitat dominated by cobble and boulder substrata. The riparian zone was dominated by river oak and the understorey was relatively sparse.

Bridge 2 – Broughton Creek

Broughton Creek was a Class 1 waterway with respect to fish habitat and riparian classification at the location of the proposed Bridge 2 crossing. See Site 16 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary creek crossing site was located to the east of the proposed bridge structure, around 20 metres upstream and within the concept design footprint (B2 BC in **Figure 3.4**, **Table 3.7**). The crossing would pass over pool habitat downstream of a cobble bar and associated riffle. There was a gap of around 24 metres separating mature river oak on the northern bank. Loss of riparian vegetation at this location would include some native and exotic shrubs. Depending on the orientation of the temporary crossing one mature river oak on the southern bank would likely be removed.

Bridge 3 – Broughton Creek

Broughton Creek was a Class 1 waterway with respect to fish habitat and riparian classification at the location of the proposed Bridge 3 crossing. See Site 17 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary crossing site was located south of the proposed bridge structure, about 10 metres downstream and within the concept design footprint (B3 BC in **Figure 3.4**, **Table 3.7**). The crossing would pass over pool habitat about 15 metres across and over one metre deep and a channel bed dominated by cobble and boulders. There was a narrow but continuous stand of mature river oak along the western bank.

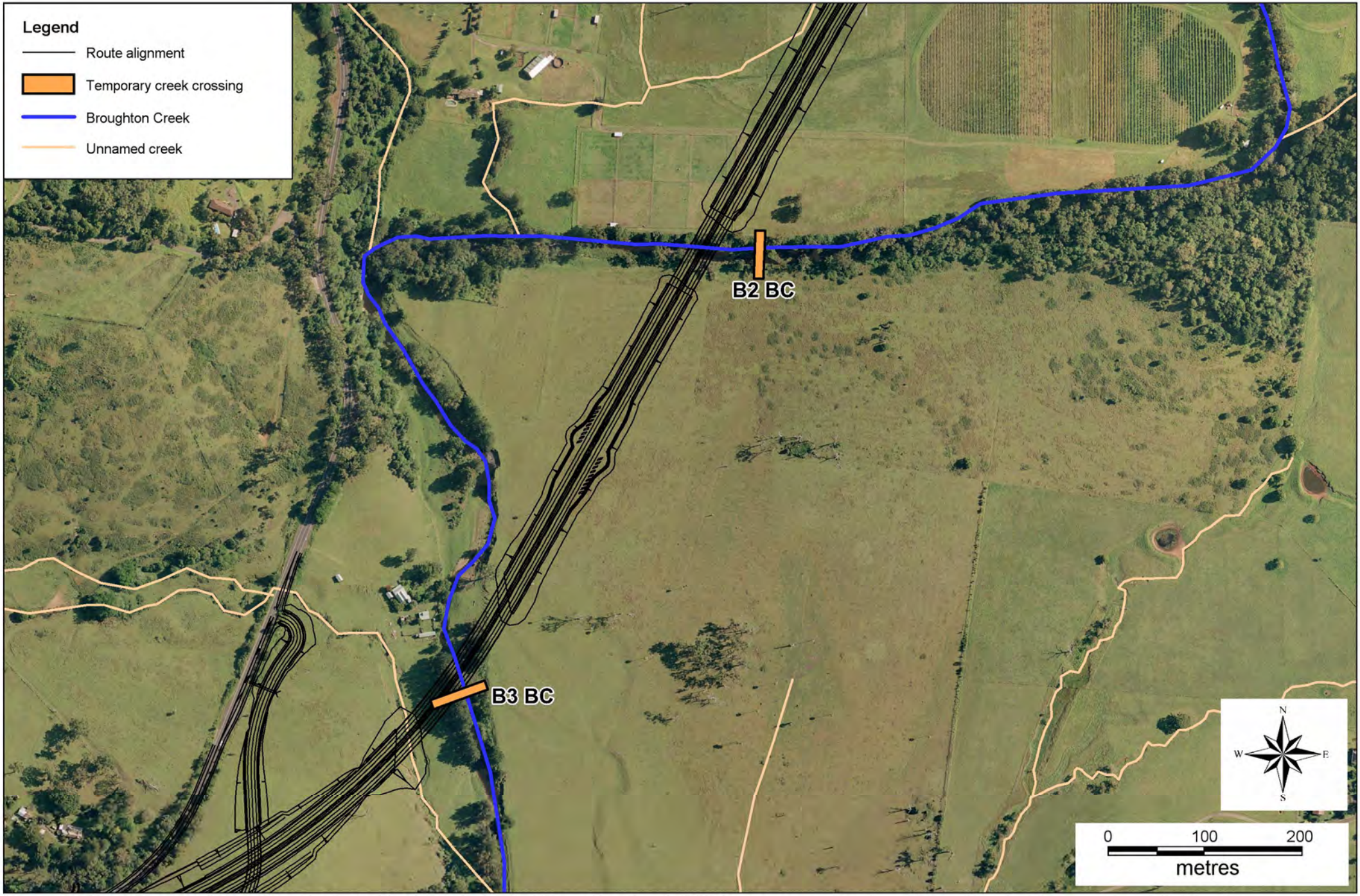

Figure 3.4: Temporary creek crossing sites for Bridge 2 and Bridge 3 at Broughton Creek. B2 BC = temporary crossing of Broughton Creek near proposed bridge 2. B3 BC = temporary crossing of Broughton Creek near proposed bridge 3

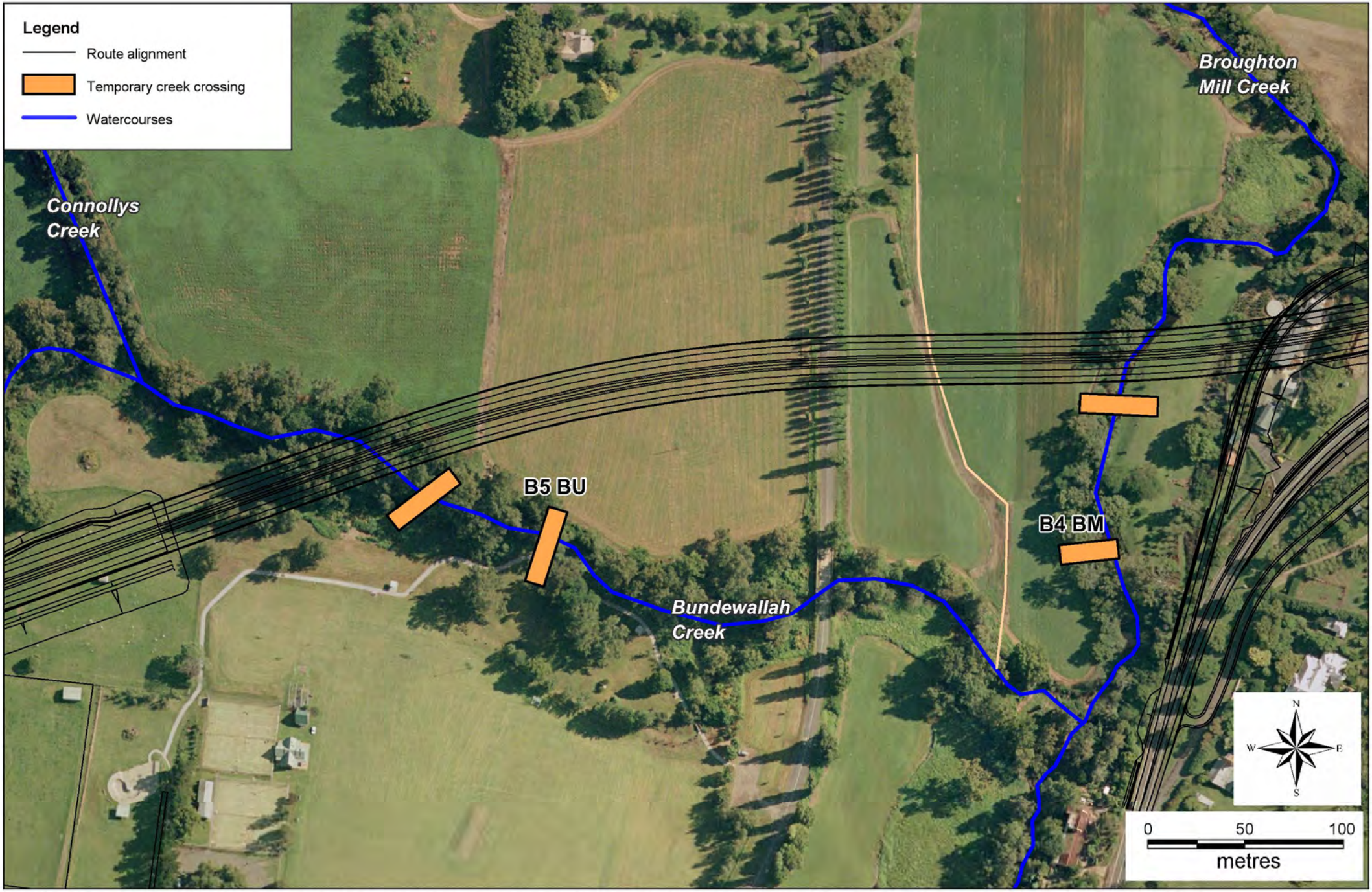

Figure 3.5: Temporary creek crossing sites for Bridge 4 at Bundewallah Creek and Broughton Mill Creek. B4 BM = temporary crossing of Broughton Mill Creek near proposed bridge 4. B4 BU = temporary crossing of Bundewallah Creek near proposed bridge 4

Table 3.7: Temporary creek crossing sites for the Foxground and Berry bypass project (suggested crossing drainage structures based on criteria established by Fairfull and Witheridge, 2003)

Bridge	Watercourse	Figure label	Easting	Northing	Fish habitat classification	Riparian category	Total area spanning vegetation and creek (sq. m)	Recommended temporary crossing structure
Bridge 1*	Broughton Creek	n/a	294889	6152780	1	1	700	Bridge
Bridge 2	Broughton Creek	B2 BC	294478	6152233	1	1	500	Bridge
Bridge 3	Broughton Creek	B3 BC	294150	6151749	1	1	500	Bridge
Bridge 4	Broughton Mill Creek	B4 BM	289994	6149851	2	1	300	Bridge, arch structure, culvert or ford
Bridge 4	Bundewallah Creek	B4 BU	289718	6149855	2	1	400	Bridge, arch structure, culvert or ford
						Total	2400	

** Estimated loss of riparian vegetation in addition to that represented by the project alignment and ancillary infrastructure footprint.*

Bridge 4 – Broughton Mill Creek

Broughton Mill Creek was a Class 2 waterway (moderate fish habitat) and Category 1 (environmental corridor) riparian habitat at the site of the proposed temporary creek crossing. See Site 25 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary creek crossing site was located south of the proposed bridge structure, about 25 metres downstream and within the concept design footprint (B4 BM in **Figure 3.5**, **Table 3.7**). The crossing would traverse an eight metre wide and one metre deep section of pool habitat. The channel bed was composed primarily of pebble and sand substrata. There was a gap of about 15 metres separating mature river oak on the western bank. Introduced camphor laurel (*Cinnamomum camphora*) and privets (*Ligustrum* spp.) were also present within the riparian zone. In addition to the removal of introduced trees and shrubs some lower branches of the mature river oaks would likely be required for the temporary creek crossing.

The actual location of the temporary creek crossing of Broughton Mill Creek would be determined during detailed design with consideration of the final alignment and would be selected to minimise disturbance of existing riparian vegetation and aquatic habitat.

Bridge 4 – Bundewallah Creek

Bundewallah Creek was a Class 2 waterway (moderate fish habitat) and Category 1 (environmental corridor) riparian habitat at the site of the proposed temporary creek crossing. See Site 27 assessment (Section 3.2.2) for a complete description of aquatic ecology and water quality. The preferred temporary creek crossing site was located east of the proposed bridge structure, around 20 metres downstream and within the concept design footprint (B4 BU in **Figure 3.5**, **Table 3.7**). The crossing would traverse a five metre wide and 0.8 metre deep section of run habitat. The channel bed was dominated by cobble and pebble substrata. There was a gap of about 11 metres separating mature river oak on the southern bank. Many of the younger native trees within the riparian zone were plantings and introduced groundcovers and annuals were common. Construction of the temporary creek crossing would require the removal of planted native trees and shrubs on the southern bank and trimming of some lower branches of retained river oaks.

The actual location of the temporary creek crossing of Broughton Mill Creek would be determined during detailed design with consideration of the final alignment and would be selected to minimise disturbance of existing riparian vegetation and aquatic habitat.

Temporary construction pads

Temporary constructions pads are likely to be required during the construction phase of the project to assist with bridge construction. Construction pads may involve the temporary placement of rocks or other construction materials within waterways. The main potential aquatic ecology impact would be the blockage of fish passage, in particular for Australian Bass.

The construction method employed should avoid complete blockage of the stream, be of minimum possible duration and involve full removal of all construction material from the waterway.

a

b

c

d

Plates 1a – 1d. (a) Site 13, view downstream of existing Princes Highway two span bridge crossing (b) Site 13, riffle habitat in the foreground and pool habitat upstream (c) Site 13, flood overflow culvert in Princes Highway embankment near the existing Broughton Creek bridge crossing (d) Watercourse at Site 14, view north from Princes Highway and stand of cumbungi (*Typha* sp.).

a

b

c

d

Plates 2a – 2d. (a) Site 15, view upstream from property road crossing (b) Site 16, view upstream from the proposed second crossing of Broughton Creek by the project (c) Deep pool at Site 17, area of proposed third crossing of Broughton Creek by the Foxground and Berry bypass project (d) Site 18, view downstream from Princes Highway. Larger trees in the background mark the channel of Broughton Creek.

a

b

c

d

Plates 3a – 3d. (a) Site 22, view upstream from Princes Highway (b) Site 23, view downstream from Princes Highway crossing (c) Site 25, alternating riffle and pool habitat in Broughton Mill Creek (d) Australian bass (*Macquaria novemaculeata*) caught at Site 25, Broughton Mill Creek.

a

b

c

d

Plates 4a – 4d. (a) Site 26, ephemeral watercourse or drainage ditch lying in between Broughton Mill Creek and Woodhill Mountain Road (b) Site 27, Bundewallah Creek, view upstream (c) Site 28, Town Creek, view upstream to North Street (d) Site 29, view upstream from Princes Highway.

3.3 Threatened and protected species, populations, communities and key threatening processes

3.3.1 Listings under the EPBC Act

Threatened species

The DSEWPaC Protected Matters Search Tool linked to the EPBC Act indicated that one endangered fish species, the Macquarie Perch and one vulnerable fish species, the Australian Grayling may either occur in the study area or suitable habitat for them may occur in the study area.

Macquarie Perch

There are two distinct populations of Macquarie Perch in NSW, a western form found in the Murray-Darling Basin, and an eastern form found in south-eastern coastal NSW, including the Hawkesbury-Nepean catchment and the adjacent Shoalhaven catchment (DPI NSW 2005a). Macquarie Perch have also been translocated into a number of river systems. They are found in lake and river habitats, particularly in the upper reaches of rivers and their tributaries. This species spawns in spring or summer in shallow upland streams or flowing parts of rivers. The eggs settle among stones and gravel of the stream or river bed. This species is threatened by:

- Changes in water quality associated with agriculture and forestry.
- Modification of natural river flows and temperatures as a result of the construction of dams and weirs.
- Spawning failures resulting from cold water releases from dams.
- Competition from introduced fish species.
- Diseases, such as epizootic haematopoietic necrosis, which is carried by Redfin Perch.
- Over-fishing in the past.

Australian Grayling

The historical distribution range of Australian Grayling included coastal streams from the Grose River, west of Sydney, southwards through NSW, Victoria and Tasmania (DPI NSW 2006a). On mainland Australia, this species has been recorded from rivers flowing east and south of the main dividing ranges. Grayling has been recorded historically in the Broughton catchment (**Table 3.1**). Australian Grayling form fast-moving shoals in clear stream and rivers with moderate flow. Eggs of Australian Grayling develop in gravel beds, and once hatched the larvae are swept downstream to marine habitat where they develop before returning upstream to freshwater at six months of age (DPI NSW 2006a). Threats to Australian Grayling include:

- Construction of weirs and dams, which prevent downstream and upstream migration.
- Land clearing that degrades water quality and causes siltation.
- Smothering of gravel beds by fine sediment.
- Competition from the introduced brown trout.

Expanded threatened species search

An expanded search which included the distant downstream Shoalhaven/Crookhaven estuary identified nine additional aquatic threatened species; two mammals, four reptiles and three sharks (**Table 3.3**). One is listed as critically endangered, three as endangered and five as vulnerable.

Invasive species

The Environmental Reporting Tool identified Alligator Weed (*Alternanthera philoxeroides*) as potentially occurring in the region. Alligator Weed is a *Weed of National Significance*. It poses a significant environmental and economic threat and is highly invasive. Infestations can take over wetlands such as creeks and drainage channels, displacing native vegetation, preventing flow and reducing oxygen exchange. It can also invade land and displace or cause the failure of agricultural crops. Alligator Weed does not produce viable seed in Australia but instead grows through vegetative reproduction and is spread easily from fragments. It has been spread in landfill and attached to machinery and vehicles (eg bulldozers).

Alligator Weed is a Class 2 Noxious Weed in the Shoalhaven and Kiama LGAs, and as such the land must be kept free of Alligator Weed and it must be eradicated when identified.

Migratory marine species, listed marine species, whales and other cetaceans

An expanded search which included the distant downstream Shoalhaven/Crookhaven estuary identified 49 species that are given general protection and listed under s248 of the EPBC Act, as either (i) migratory marine species, (ii) listed marine species, or (iii) whales and other cetaceans (**Table 3.3** Migratory marine species, listed marine species and whales and other cetaceans).

Twelve species are listed as migratory marine species, comprising six mammals, four reptiles and two sharks (**Table 3.3** Migratory marine species). There are 26 listed marine species, comprising two mammals, four reptiles and 20 ray-finned fish from the order Syngnathiformes (including pipefish, pipehorses, seahorses, seadragons, and ghost pipefish) (**Table 3.3** Listed marine species). A number of the Syngnathiformes can be found in coastal embayments or estuaries, often associated with seagrass habitat. Eleven species are listed as whales and other cetaceans (**Table 3.3** Whales and other cetaceans). Several species of marine mammals are listed under both migratory marine species and whales and other cetaceans categories.

3.3.2 Listings under the TSC Act

Endangered ecological communities (EECs)

Geographic Region Search tool identified two EECs as present within the Illawarra and Jervis sub-regions of the Southern Rivers Catchment Management Region:

- Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions (Coastal Saltmarsh).
- Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (Freshwater Wetlands).

Coastal Saltmarsh

About 0.017 square kilometres and 2.06 square kilometres of Coastal Saltmarsh is present downstream of the study area in the Crooked River and Shoalhaven/Crookhaven estuaries respectively. "*Coastal Saltmarsh is a mostly treeless plant community recognised by a low mosaic of succulent herbs, salt tolerant grasses and sedges, found in the tidal flats of estuaries and on edges of intermittently opened coastal lagoons*" (p1 DECC 2007). Saltmarsh is usually found in the upper limits of the intertidal zone and are only intermittently flooded by medium to high tides.

Threats to saltmarsh include:

- In-filling for development.
- Modification of tidal flows by artificial structures.
- Changes to salinity and increasing nutrient levels from stormwater discharge.
- Weed invasion, particularly by *Juncus acutus*.
- Physical damage from human disturbance, domestic and feral animals.
- Pollution.
- Invasion by mangroves.
- Inappropriate fire regimes.

Freshwater Wetlands on Coastal Floodplains

Freshwater Wetlands on Coastal Floodplains are "*an ecological community associated with periodic, semi-permanent or permanent inundation by freshwater, although there may be minor saline influence in some wetlands*" (p1 DECC 2008). Freshwater Wetlands typically occur on silts, muds or humic loams in low-lying parts of floodplains, alluvial flats, depressions, drainage lines, backswamps, lagoons and lakes but may also occur in back barrier landforms where floodplains adjoin coastal sand plains. They generally occur below 20 metres elevation on level areas. The structure and composition of the community varies both spatially and temporally depending on the water regime. They are dominated by herbaceous plants and have very few woody species. Meadows of grasses, sedges and rushes occur where submersion is not prolonged, while aquatic herbs dominate where semi-permanent or permanent standing water is present. Under the influence of saline water tall reeds and rushes dominate.

Threats to this community include:

- Land clearing.
- Fragmentation and degradation.
- Flood mitigation and drainage works.
- Filling associated with urban and industrial development.
- Pollution and eutrophication from urban and agricultural runoff.
- Weed invasion.
- Overgrazing, trampling by livestock.
- Activation of acid sulfate soils.
- Dumping of landfill, rubbish and garden refuse.
- Native fauna is threatened by predation, particularly by mosquito fish.
- Anthropogenic climate change.

Only two areas of potential coastal floodplains freshwater wetland occur within the Crooked River catchment: the Willowvale and Gerringong Wetlands; although they are small, highly degraded and located on the fringes of the Crooked River floodplain, extending up into the foothills. Whilst the Coomonderry Swamp constitutes significant coastal freshwater wetland habitat it lies outside of the catchments traversed by the project and therefore would be unaffected by associated works.

Key threatening processes

"*Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands*" is listed as a KTP on Schedule 3 of the TSC Act (DECC 2005). Human activities that reduce or increase flows, change the seasonality of flows, change the frequency, duration, magnitude, timing, predictability and variability of flow events, alter surface and subsurface water levels and change the rate of rise or fall of water levels can all alter the natural flow regimes of water courses. The project requires the crossing of a number of water courses. Inappropriate road crossing structures can change the natural flow regime of a waterway.

The flow regime is a key driver of river ecology, and changes to flow can alter the geomorphological process of sediment erosion, transport and deposition that structure a variety of important channel habitat forms, change macrophyte communities, influence water properties important to biological assemblages and alter in-stream connectivity, isolating habitats and populations.

Examples of impacts on aquatic biota associated with altering natural flow regimes include:

- Restricted access to habitat for foraging, refuge or reproduction (eg reduced fish passage).
- Disruption of natural environmental cues necessary for reproductive cycles.
- Reductions in flow can decrease the amount of organic matter on which invertebrates and vertebrates depend on.
- Changes in flow can increase erosion and lead to sedimentation impacts on aquatic communities and degradation of the riparian zone.
- Deeper and more permanent standing water can facilitate the establishment and spread of exotic species.

These alterations can pose a threat to species, populations or ecological communities which rely on natural flow regimes for their short-term and long-term survival and thereby contribute to loss of biological diversity and ecological function in aquatic ecosystems.

3.3.3 Listings under the FM Act

Threatened species

One endangered species, Macquarie Perch and one vulnerable species, Black Cod (*Epinephelus daemelii*), listed under the FM Act potentially occur within the region of the study area, or in aquatic habitats downstream of the study area. Another endangered species, the Sydney Hawk Dragonfly (*Austrocordulia leonardi*), has been recorded from coastal catchments south of Sydney. The Macquarie Perch is described in Section 3.3.1 of this report.

Black Cod

Black Cod is a large carnivorous reef-dwelling species. They are generally found in warm temperate and subtropical parts of the south-western Pacific. Adults are usually found in caves and gutters on rocky reefs. Small juveniles are often found in coastal rock pools and larger juveniles around rocky shores and estuaries (DPI 2007a). BioNet had a record for Black Cod near Gerringong Harbour in 2001. Threats to Black Cod include:

- Impacts on juvenile Black Cod due to the loss or degradation of estuarine nursery habitats.
- Overharvesting by line, net and spearfishers.
- Accidental capture by hook and line fishing.

Sydney Hawk Dragonfly

This species was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney, and has subsequently been found in the Nepean River at Maldon Bridge near Wilton. The species is also known to occur in the Georges River and Port Hacking catchments. This dragonfly spends most of its life as an aquatic larva, with adults emerging from the water and living for only a few weeks or months. The larvae appear to have specific habitat requirements and have only been found under rocks in deep, cool, shady pools (NSW DPI, 2007b). This species is threatened by:

- River regulation and changes in flows that cause the disappearance of natural deep pools.
- Habitat degradation associated with removal of riparian vegetation, drainage works and sedimentation.
- Water pollution and sedimentation due to land clearing, waste disposal and stormwater runoff from urban, industrial and agricultural development in the catchment.
- Chance events such as natural disasters (drought) that eliminate the remaining local populations.

The Sydney Hawk Dragonfly is extremely rare. Despite extensive sampling it has only been collected in small numbers at only a few locations in a small area to the south of Sydney, between Audley and Picton, suggesting it has a highly restricted distribution (NSW DPI 2007). There are no records for this species within the Illawarra sub-catchment of the Southern Rivers Catchment Management Region, nor the adjacent Shoalhaven sub-catchment. It is therefore considered unlikely that this species occurs within the study area and as such it is not included in the assessment of potential impacts provided in Chapter 4.

Protected species and habitats

Listed protected species under the FM Act that may inhabit the study area (including distant downstream aquatic habitats), include:

- Australian Grayling.
- All Syngnathiformes (seahorses, seadragons, pipefish, pipehorses, ghost pipefish and seamoths).

There are currently 31 syngnathids (seahorse, pipefish, pipehorses and seadragon), four solenostomids (ghost pipefish) and two species of pegasids (seamoths) known to exist in NSW waters. Syngnathiformes are found in a variety of habitats, including seagrass beds, coastal embayments and artificial structures such as jetties or mesh nets. Threats to Syngnathiformes in NSW include degradation of habitats, such as seagrass and soft-bottom habitats through pollution, urban runoff, dredging and sewerage.

Protected aquatic habitat in NSW (Fish Habitat Protection Plan No.1 and Fish Habitat Protection Plan No. 2) that may be present in the study area includes: seagrass, mangroves, saltmarshes, wetlands, mudflats, sand and gravel substrata, reed beds and other aquatic plants, large woody debris and rocks.

The Estuary Cod (*Epinephelus coioides*) is also a listed protected species in NSW. Estuary Cod occur in tropical and warm temperate marine waters of the Indo-Pacific. In Australia they are most common in Queensland, the Northern Territory and Western Australia, and NSW represents the southern extend of their distribution. Whilst juvenile Estuary Cod inhabit shallow estuaries, the species has not been recorded in waters south of Sydney and therefore will not be considered in the assessment of potential impacts (DPI, 2006b).

Key threatening processes

Three KTPs listed under the FM Act, "*Degradation of Riparian Vegetation*", "*The Removal of Large Woody Debris from NSW Rivers and Streams*" and "*Instream Structures and Mechanisms that Alter Natural Flow*" are relevant to the project (DPI NSW 2005b, 2005c).

Degradation of riparian vegetation

The term "riparian vegetation" refers to the plants that occur on the land that adjoins, directly influences or is influenced by bodies of water, such as creeks, rivers, lakes and wetlands on river floodplains. Riparian vegetation is important ecologically because it provides a source of organic matter; shade and large woody debris. Riparian vegetation stabilises river beds and banks, protecting the channel against erosion and acts as a filter for sediments and nutrients entering watercourses. For example; Australian Bass show a relatively high degree of reliance on terrestrial food sources and therefore the destruction of riparian habitat may affect inputs of allochthonous matter and have serious implications for food availability (Pusey *et al*., 2004).

Native riparian vegetation within the study area forms part of the EEC *River Bank Eucalypt Forest on Coastal Floodplain* listed under the TSC Act.

Removal of large woody debris

Instream woody debris provides complex habitat for macroinvertebrates and particularly fish, including refuge from predation, habitat for prey and as damming structures that create pools.

Instream structures and mechanisms that alter natural flow

Instream structures, such as floodgates, bridges, culverts, flow regulators, erosion control structures and causeways, can all modify natural flow regimes of waterways (Section 3.3.2 KTPs). Of particular concern can be the impacts these structures have upon the passage of fish. Crossings of watercourses, or construction in the vicinity of a watercourse, would minimise potential impacts on aquatic habitat and biota if they comply with the NSW Fisheries 'Guidelines and Policies for Aquatic Habitat Management and Fish Conservation' and 'Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings' (Fairfull and Witheridge, 2003).

4 Assessment of potential impacts

The assessment of potential impacts of the project is based on the information provided in Concept Design report (RMS 2012), Foxground and Berry Bypass Preliminary Environmental Assessment (PEA) (RTA 2010), provisional location of ancillary infrastructure (as of 14 July 2011) and through correspondence with AECOM and RMS.

The potential environmental impacts from the construction and operation of the project on aquatic ecology relate to: sedimentation; pollution; ASS; changes to hydrology; obstructions to fish passage; degradation of riparian habitat; removal of large woody debris and impacts on threatened species, populations and EECs.

4.1 Potential environmental constraints

4.1.1 Sediment mobilisation

The project would be a major works project. Sediments may be mobilised into the study area's aquatic habitats from earthworks required for the construction of the project and from ongoing erosion of disturbed areas during operation. Relevant works include:

- Excavation, drilling and blasting of road cuttings.
- Preparation of the highway surface.
- Excavation associated with installation of drainage structures such as culverts, bridges, stormwater drains.
- Construction of bridge piers within the wetted-width of waterways.
- Construction of ancillary infrastructure such as site compounds, temporary creek crossings, temporary construction pads and temporary traffic facilities and diversion networks.
- Construction of a large raised earth embankment connecting Bridge 2 and Bridge 3.
- Landscaping works.
- Run off from stockpiles of construction materials and spoil. Particularly the proposed RMS stockpile site straddling the southern end of the project area between Schofields Lane and Andersons Lane which covers two upstream tributaries of a small unnamed watercourse that crosses the alignment to the south of the project area.
- Operation of crushing plant and transport of materials.
- Creation of airborne dust and use of dust suppression/washdown facilities.
- Erosion of earth embankments, particularly embankment connecting Bridge 2 and Bridge 3 from changes to the flooding regime caused by Bridge 2 (see Section 4.2.3).
- Runoff and erosion of exposed cutting faces, particularly the more dispersive rock and soil types such as Berry Siltstones and soft alluvial soils.
- Ground conditioning works such as possible replacement of alluvial soils with engineered fill.
- Removal of riparian vegetation.
- Excavation and potential erosion associated with creation of permanent creek bed to facilitate the diversion of flows from Town Creek into Bundewallah Creek.

Downstream aquatic habitats in the Broughton Creek catchment may also be at risk as increases in suspended sediment have been detected for long distances (kilometres) downstream of construction sites (Wheeler *et al*., 2005). Compaction in works areas may reduce infiltration of surface waters and also contribute to sediment load in runoff.

In a worst case scenario, an increase in sediment load can degrade water quality and important habitat features resulting in a loss of biodiversity and a shift towards a more pollution-tolerant biotic assemblage. For example, sedimentation can cause:

- Mortality and decreased growth. Suspended particles could clog respiratory gills and/or feeding apparatus of fish and macroinvertebrates.
- Degradation of habitat. Siltation could infill deep water refugia and interstitial spaces in the stream bed and smother aquatic macrophytes beds and spawning grounds.
- Reduced water quality. Increased light attenuation could decrease primary productivity and nutrients bound in mobilised sediments could increase eutrophication.

Increased sedimentation is considered a threat to Australian Grayling, Macquarie Perch and Freshwater Wetlands (EEC).

Increased sedimentation would be a concern for significant local freshwater habitat and biota downstream of the construction works, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. The sections of Broughton Mill Creek and Bundewallah Creek crossed by the project supported pool edge macroinvertebrate communities equivalent to reference condition and are both Class 2 waterways for fish habitat. There would be works associated with three proposed crossings of Broughton Creek and at a number of smaller watercourses in the catchment that subsequently discharge into Broughton Creek. The reaches of Broughton Creek crossed by the project were classed as major fish habitat (Class 1 Waterways). AusRivAS assessment found macroinvertebrate communities at the existing Princes Highway crossing of Broughton Creek were impaired, reflecting elevated nutrient levels in water and localised degradation of habitat, however there are significant downstream sections with relatively intact riparian vegetation and aquatic habitat. Major fish habitat was also located further downstream, outside the project area in the Crooked River estuary, the estuarine reach of lower Broughton Creek and the Shoalhaven/Crookhaven estuary.

A considerable amount of freshwater habitat within the study area was relatively degraded, particularly the smaller more ephemeral streams. Channel substratum was affected by loose accumulations of soft-sediments, covering and sometimes infilling interstitial spaces of underlying larger-sized substrata (eg cobble, pebble and gravel). This indicated a historical and ongoing mobilisation of sediments from the disturbed catchment into the waterways. As such, the fish and macroinvertebrate taxa more commonly observed in these areas were relatively tolerant to sedimentation and degraded habitat. Fish have the added advantage of being relatively mobile and therefore have a better opportunity to seek out more favourable conditions during short-term elevations in suspended sediments and to recolonise areas following the disturbance.

In the absence of mitigation measures a typical scenario for disturbance of these degraded waterways would result in further degradation of existing habitat and impairment of biotic assemblages. The likelihood and magnitude of impacts would be greater closer to the construction sites, with aquatic habitat furthest downstream, particularly the Shoalhaven/Crookhaven estuary, least likely to be affected.

The Concept Design report (RMS, 2012) and the environmental assessment outline a number of strategies designed to mitigate sediment mobilisation into waterways. These include:

- No bridge pier placements within the wetted-width of waterways (under average flow conditions) where practicable. (Note: Four bridge piers would be required in Bundewallah Creek).
- Protection of surfaces at risk from erosion, for example:
  - Energy dissipaters provided to outlets of drainage structures that have the potential to cause scour.
  - Control of surface water flow into cuttings.
  - Scour protection of raised embankment between Bridge 2 and Bridge 3.
  - Protection of banks and bed of newly created channel for diversion of flow from Town Creek into Bundewallah Creek.
- Permanent spillage containment basins and vegetated swales to capture and treat first flush from pavement surfaces. MUSIC (model for urban stormwater improvement conceptualisation) modelling suggests that 300 cubic metres of sediment basin (or vegetated swale equivalents) would remove 81 per cent of total suspended solids (TSS). Although the Concept Design notes that vegetated swales may not provide complete spill capture capability for larger flow events.
- Sediment and erosion control measures on construction sites such as silt fences, and sediment basins.
- Dispersion testing of excavated soils to determine suitability for use in earthworks.
- Location and layout of ancillary infrastructure at least 50 metres from waterways where possible.
- Dust suppression and washdown.

Conclusion

Mobilised sediments are unlikely to pose a significant threat to the aquatic ecology of the study area, provided standard sediment and erosion control measures are implemented (see proposed mitigation strategies (Sections 5.1.1 and 5.1.2)). Similarly, regionally significant aquatic habitat in the Shoalhaven/Crookhaven estuary is too far downstream to be affected by controlled works associated with the project.

4.1.2 Pollution

In a typical scenario in the absence of mitigation measures the construction and operation of the project has the potential to mobilise contaminants into aquatic habitat. Possible pollution may include (but not limited to):

- Pollutants associated with materials used in the process of road construction. There is a diverse array of materials used in the construction and maintenance of roads, for example: asphalt materials, asphalt additives, cementitious materials, cement admixtures, dust palliatives and aggregates. Industrial waste by-products are also increasingly being approved for road construction, such as petroleum refinery residuals, coal combustion fly ash, scrap tyres/recycled rubber, mining waste and reclaimed concrete pavement (Eldin, 2002). Many of these materials can be toxic in their pure (non-amended) states, eg fly ash and asphalt cement crumb rubber elutriates (Eldin, 2002). Contamination may result from spills on site or after construction from long-term runoff directly into aquatic habitats.

- Pollutants associated with heavy vehicles used on site during construction and from ongoing traffic use of the project, such as aromatic hydrocarbons (lubricating oils and fuels) and heavy metals (eg copper in brake linings, and zinc and cadmium in tyres).
- Contaminant spills of materials transported via the highway. For example, large tank trucks are used to transport a variety of potentially hazardous liquid goods, such as gasoline, diesel and industrial chemicals.
- Heavy metal leachate and runoff (eg aluminium, iron and zinc) from disturbed ASS.
- Leachate from waste dumps established onsite.
- Overflow from dams/ponds used to trap and recycle contaminated/'dirty' water onsite.
- Organic pollutants in stormwater runoff (eg nitrogen and phosphorus).
- Pollutants bound to disturbed sediments may be mobilised into aquatic habitat.

Pollution impacts from road construction and operation can be either 'pulse' impacts (impacts that occur immediately, eg from spills) or 'press' impacts (impacts that accumulate over time, eg from long-term runoff). Aquatic biota vary in their sensitivity to pollutants. In a typical scenario in the absence of mitigation measures contamination of aquatic habitats can cause a loss of biodiversity, a shift towards biotic assemblages dominated by pollution-tolerant taxa and degradation in ecological function. Pollution is considered a threat to Coastal Saltmarsh and Freshwater Wetlands on Coastal Floodplain, both EECs under the TSC Act.

Increased pollution would be a concern for the significant local freshwater habitat and biota downstream of the construction within the study area, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. Whilst previous studies have suggested that regional agricultural land use has had a detrimental impact on water quality within the study area, the major waterways still represent major to moderate fish habitat (Class 1-2 Waterways) and function as significant environmental corridors (Category 1 waterway and riparian zones). Further pollution would increase the stress on these aquatic ecosystems.

The Concept Design report (RMS, 2012) and the environmental assessment outline a number of strategies designed to mitigate contamination of aquatic habitat and biota. These include:

- Operational runoff would be collected in a longitudinal drainage system and treated using non-point source or dispersed techniques. For example, the use of grass swales, table drains, grass buffer strips, edge drains and grassed median strips.
- The bridge drainage system has been designed so that all collected water is conveyed longitudinally to the abutments, rather than allowing scuppers to discharge directly into receiving waters.
- In sensitive environmental locations and where required, sedimentation basins installed for the construction phase would be converted to water quality treatment basins for the operational phase.
- Ancillary infrastructure would be located at least 50 metres away from waterways where possible.

It is recommended that vegetated swales of one metre base width, 80 metres in length with three per cent longitudinal grade and 250 millimetre vegetation height be used, as this configuration would remove 81 per cent of TSS, 65 per cent of total phosphorus (TP) and 16 per cent of total nitrogen (TN) (based on MUSIC modelling). Whilst the Concept Design notes that vegetated swales may not provide complete spill capture capability for larger flow events, the runoff would not contain levels of TSS, TN or TP in excess of receiving waters (AECOM, 2011). No concrete batching plants for the construction of bridges are proposed.

Conclusion

The project is expected to have a relatively minor impact on water quality through careful design and best practice environmental management. See proposed mitigation strategies (Sections 5.1.1 and 5.1.2).

4.1.3 Acid sulfate soils

ASS are widespread in estuaries, coastal floodplains, backswamps and coastal wetlands. ASS are formed when the naturally occurring iron sulphides (pyrite) in the soil become exposed to air through drainage or excavation and subsequently oxidise, forming sulphuric acid.

The project generally passes over geological conditions mapped by the then Department of Land and Water Conservation (DLWC, 1997) as having no known occurrence of ASS, with only one area of low ASS risk occurring at depths greater than four metres close to a section of the project south of Berry (refer to Figure 8-1 of the environmental assessment which shows ASS in the project area). Areas of no known occurrence generally correspond with landforms above 10 metres AHD and based on an assessment of the geomorphic processes occurring there.

Following further consideration of the known geological information for the project area, an additional area of low risk of PASS being encountered has been identified. This corresponds with areas with alluvial floodplain soils at the Broughton Creek floodplain, and to a lesser extent at the bypass of Berry (refer to Figure 8–2 of the environmental assessment which shows additional areas of PASS risk).

The Broughton Creek floodplain to the east and north of Berry would be disturbed during construction of the project. The pH measured at Bundewallah Creek and Broughton Mill Creek was marginally within the ANZECC lower threshold values for the protection of aquatic ecosystems (Appendix C). The section of project corridor between the Bridge 3 crossing of Broughton Creek and the Bridge 4 crossing of Broughton Mill Creek traverses the lower foothills at the base of the Illawarra Ranges and has a much lower risk of disturbing ASS.

Project works that risk disturbing ASS include:

- Excavation and construction of transverse drainage structures, eg culverts and bridges.
- Excavation of sediment basins and installation of swales.
- Excavation and removal of soft alluvial soils for ground conditioning.
- Stockpiling of excavated ASS.
- Dewatering in ASS areas (eg during installation of drainage structures).
- Excavation required to create permanent channel for the diversion of flows from Town Creek north of the upgrade into Bundewallah Creek.

In a worst case scenario ASS can have major environmental impacts and constrain development and construction in affected areas if not properly managed. Impacts on aquatic ecology caused by ASS include: habitat degradation, fish kills, reduced aquatic food resources, reduced migration potential of fish, reduced fish recruitment, altered macrophyte communities, weed invasion by acid-tolerant plants and secondary water quality changes. ASS can also increase the susceptibility of fish to fungal infections which may lead to diseases such as epizootic ulcerative syndrome or ‘red spot disease’. Red spot disease is considered a threat to Macquarie Perch.

Conclusion

In the worst case scenario there is a risk of disturbing unknown ASS in areas that may intersect with relevant project works.

Any development in areas with ASS risk requires extensive consideration of construction methodology to avoid or minimise the potential impacts on the aquatic ecology in the study area and in downstream environments. See proposed mitigation strategies (Sections 5.1.1 and 5.1.2).

4.1.4 Groundwater dependent ecosystems

Works associated with the project that have the potential to impact on GDEs within the study area are the same as those that could affect groundwater flows (Section 4.2.3). These include:

- Ground conditioning using preloading or replacement with engineered fill in areas where settlement has been assessed as a geotechnical issue, eg alluvial soils of floodplain areas.
- Cuttings at various locations along the project, the largest of which would be 900 metres long and up to 26 metres deep where the project traverses Toolijooa Ridge.

The shallow alluvial groundwater systems within the study area support GDEs such as hyporheic habitat, base flow to significant waterways such as Broughton Creek, Broughton Mill Creek, Bundewallah Creek and Connollys Creek and riparian forest. Native riparian forest within the study area is often the EEC *River Flat Eucalypt Forest on Coastal Floodplains*.

The natural variability of shallow alluvial groundwater systems can make them more robust and able to tolerate fluctuating water levels but in the worst case significant changes to groundwater hydrology (eg groundwater falling below a threshold or falling too quickly) can lead to ecosystem damage (DLWC, 2002). The exact importance of groundwater to these GDEs is unknown and therefore it is difficult to accurately predict impacts associated with the project. GDEs most sensitive to changes in the groundwater regime would be: hyporheic ecosystems; shallow aquatic habitat (and associated biota) such as riffles and discontinuous pool refugia; and low-lying riparian forest.

Groundwater seepage into road cuttings would be collected by a longitudinal drainage system and transferred to vegetated swales or sediment basins within the Broughton Creek catchment. The *Foxground and Berry bypass Surface Water, Groundwater and Flooding Technical Paper* (AECOM, 2012) prepared for this environmental assessment and provided at Appendix H of the environmental assessment found that typically soft-soils treatments may cause some reduction of permeability of underlying soils but groundwater would still flow, particularly through the sandy soil horizon.

Conclusion

It is anticipated that the project would have a minor and localised effect on groundwater flows and therefore is unlikely to cause any significant impacts to GDEs within the study area.

4.1.5 Invasive species

Alligator Weed was not observed at any site within the study area, nor were any records found for its occurrence within the study area. The species is known to be present within the Illawarra region.

In a worst case scenario if Alligator Weed became established within the study area it is possible that its distribution could be increased by construction activities associated with the project. See proposed mitigation strategies (Section 5.1.2).

4.2 Listed key threatening processes

4.2.1 Degradation of riparian vegetation

Project works that could degrade riparian vegetation include:

- Clearings made within the project corridor at each waterway crossing.
- Clearings at each of five temporary creek crossings.
- Clearings associated with temporary constructions pads.
- Clearings made for ancillary infrastructure: eg the proposed RMS stockpile site straddling the southern end of the project area between Schofields Lane and Andersons Lane. The stockpile covers two upstream tributaries and riparian habitat of a small unnamed watercourse that crosses the alignment to the south of the project area.
- Works that could alter the groundwater contribution to riparian forest (Section 4.1.4).
- Clearing made on the western bank of Bundewallah Creek to connect the channel which would divert water from Town Creek into Bundewallah Creek.

The benefits of riparian vegetation to freshwater biota are outlined in Section 3.3.2 *Key threatening processes*.

Typically, riparian vegetation was already extremely degraded along many of the smaller waterways that intersect the project. Large woody vegetation was often absent or composed of exotic species. Therefore, it is unlikely that the project could further degrade riparian habitat at these locations such that it would cause a significant impact on aquatic ecology.

Riparian vegetation was generally more intact at the larger creeks in the catchment, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. These creeks and their adjacent riparian zones were considered Category 1 waterways (Environmental Corridors) under the RCMS classification system (**Table 3.4**). Native riparian vegetation within the study area forms part of the EEC *River Bank Eucalypt Forest on Coastal Floodplain* listed under the TSC Act.

The estimated loss of riparian vegetation due to direct and indirect edge effects associated with construction of the project is outlined in **Table 4.1**.

Table 4.1: Estimated loss of riparian vegetation associated with construction of the project

Project works	Area of riparian forest (hectares)
Permanent roadway	2.6
Ancillary facilities	0
Temporary creek crossings	0.2
Town Creek diversion	0.1
Total direct effects	**2.9**
Indirect edge effects	7.1
Total direct and indirect effects	**10**

Indirect edge effects were measured as the amount of riparian vegetation lost within a 50 metre buffer of the project footprint, and are independent of the condition of the vegetation condition (Refer to the *Terrestrial Flora and Fauna Assessment* (Biosis, 2012) provided at Appendix F to the environmental assessment).

The diversion of Town Creek would require the creation of a permanent channel from the diversion point to the western bank of Bundewallah Creek. The diversion channel would provide new aquatic habitat, assuming that its design would incorporate:

- A natural alignment (ie curved, not linear).
- A creek bed form that mimics those of natural creeks.
- Appropriate channel definition.
- Bank configuration suitable for planting riparian vegetation.

Given appropriate riparian vegetation communities are planted and maintained, the diversion channel would create approximately 0.4 linear kilometres of habitat, compared to the approximately 2.9 linear kilometres of habitat in the existing Town Creek alignment that would be further degraded as a result of the flow diversion.

Conclusion

The project would cause an estimated loss of riparian habitat within the study area of 2.9 hectares (**Table 4.1**). See recommended offsets and mitigations measures (Sections 5.1.1, 5.1.2 and 5.2).

4.2.2 Removal of large woody debris

The benefits of instream large woody debris to freshwater biota is outlined in Section 3.3.2 *Key threatening processes*.

There is little large woody debris in many of the smaller waterways that intersect the project. Therefore it is unlikely that the project could further degrade large woody debris habitat at these locations such that it would cause a significant impact on aquatic ecology.

There is large woody debris present within the larger watercourses in the catchment, such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek. Bridge pier placement within Bundewallah Creek and the temporary crossings constructed near each bridge site would potentially involve instream works. For example, removal of a large snag extending from the bank into the water to facilitate placement of pier footings would require instream disturbance. In a worst case scenario it is possible that project works could lead to the removal of large woody debris. See recommended mitigation strategy (Section 5.1.2).

4.2.3 Alteration to natural flow regimes of rivers, streams, floodplains and wetlands

The TSC Act listed KTP *Alteration to Natural Flow Regimes of Rivers, Streams, Floodplains and Wetlands* is equivalent to *Instream Structures and Mechanisms That Alter Natural Flow* and they are considered as one in this section. The ecological importance of maintaining natural flows and fish passage is outlined in Section 3.3.2 *Key threatening processes*.

Project works that may affect surface water and groundwater flows

The following works could affect surface and groundwater flows within the study area:

- Ground conditioning using preloading or replacement with engineered fill in areas where settlement has been assessed as a geotechnical issue, eg alluvial soils of floodplain areas.
- Cuttings at various locations along the project, the largest of which would be 900 metres long and up to 26 metres deep where the project traverses Toolijooa Ridge.
- Provision of drainage structures (such as culverts and bridges) within the road embankment for flood mitigation during flow events.
- Bridge pier placement within the wetted-width of Bundewallah Creek (under average flow conditions).
- Five temporary creek crossings in the vicinity of the proposed bridge structures (above) during the construction phase.
- Temporary construction pads in the vicinity of the proposed bridge structures during the construction phase.
- Longitudinal drainage and retention basin/swale system to control and discharge drainage from cuttings, embankments and construction sites.
- Construction of a raised embankment linking Bridge 2 and Bridge 3.
- Ancillary infrastructure constructed near or over existing waterways. For example: RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane; landscaping and creation of hard stand areas at site compounds.
- Diversion of Town Creek to the north of the upgrade into Bundewallah Creek upstream of its confluence with Connollys Creek.

It has been estimated that around 100 megalitres of water per year of construction would be required. Water for construction purposes would be sourced as follows in order of priority:

- Recycled effluent from the tertiary treatment plant at Gerringong Gerroa and/or Berry.
- Surface water, sourced from on-site detention basins.
- Surface water, sourced from watercourses where it would not be detrimental to the aquatic environment of the waterway.
- Potable water.
- Groundwater, sourced from de-watering that may be required at the Toolijooa Ridge cutting.

The re-use of treated water from sediment basins would have negligible effects on surface water and groundwater flows.

Construction of Bridge 4 would include the placement of bridge piers within Bundewallah Creek which would potentially impact on surface water flows. There would be no instream works associated with the construction of Bridges 1, 2 and 3. Any significant changes to these aspects of the concept design would need to be assessed for potential impacts on aquatic ecology and water quality.

Impact of project works on surface water and groundwater flows

The *Foxground and Berry bypass Surface Water, Groundwater and Flooding Technical Paper* (AECOM, 2012) prepared for this project and provided at **Appendix H** of the environmental assessment addressed impacts on surface water and groundwater flows. Relevant impacts have been summarised here. For more detail and quantification of the impacts, refer to **Appendix H** of the environmental assessment.

The project would have an insignificant effect on groundwater flows within the study area. Groundwater seepage into road cuttings would be collected by a longitudinal drainage system and transferred to vegetated swales or sediment basins within the Broughton Creek catchment.

Placement of the pier structure in Bundewallah Creek would alter the hydrology of the creek. A general decrease in velocity (0.1 to 0.2 m/s) immediately upstream of the piers would be observed, with a corresponding slight increase in water levels. There would also be localised increases in velocity downstream of the piers, of a similar magnitude to those identified above. The increases in velocity would not extend across the entire flow width at the pier cross section and are relative to predevelopment velocities.

The five proposed temporary creek crossing structures or the potential impacts they may have on surface flows are not considered in the concept design, as it relates to the design of the project and drainage structures not associated with construction.

The longitudinal drainage and retention basin/swale system to control and discharge drainage from cuttings, embankments and construction sites would have a negligible effect on the hydrology of the major waterways within the study area.

The proposed RMS stockpile site straddling the southern end of the project area between Schofields Lane and Andersons Lane appears to have an unnamed watercourse and its tributary flowing through it. The waterway intersects the proposed Princes Highway upgrade outside of the project area, at the beginning of the Hitchcocks Lane to Bomaderry stage. Further downstream, this waterway is joined by the watercourse that passed through Site 29 before eventually discharging into the estuarine reach of Broughton Creek downstream of the Coolangatta Road bridge crossing. Details of the stockpile within this location were not available at time of writing, however the environmental criteria adopted for the project specify that project works and ancillary infrastructure (including stockpiles) would not take place within 50 metres of any waterway. There is sufficient space on the site to stockpile outside this exclusion zone.

The diversion of Town Creek from a point north of the upgrade into Bundewallah Creek would alter hydrology in the catchment, with changes including:

- Increases in frequency, volume and velocity of flows in Bundewallah Creek, with potential for erosion of creek beds near the point of confluence.
- Increase in flow volume in Bundewallah, Connollys and Broughton Mill Creek.
- Significant decrease in catchment area of Town Creek. After diversion the decrease in Town Creek's total catchment area would be approximately 47 per cent AECOM (2012).
- Slight increase in area for the catchments of Bundewallah, Connollys and Broughton Mills creeks.
- Significant decrease in flow in the reach of Town Creek south of the diversion point.
- Sediment accumulation within the creek as a result of the decrease in overall and flushing flows.

Potential impacts to aquatic ecology and water quality

Longitudinal and transverse drainage structures would not have a significant impact on aquatic ecology or water quality within the study area. The negligible effect on in-channel flows would have minimal impacts on aquatic habitat and biota.

The proposed transverse drainage structures in the Concept Design (RMS, 2012) conform to DTIRIS 'minimum' recommended crossing types outlined in '*Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*' (Fairfull and Witheridge, 2003) and as such should have little or no impact on fish passage and aquatic ecology. Providing recommended crossing types are used at the temporary creek crossing sites, these structures should have minimal impacts on aquatic ecology and water quality.

The decrease in flow and associated sediment accumulation within the creek bed in Town Creek after diversion would alter the aquatic ecology of the creek, with aquatic habitats nearest the diversion point reduced to isolated pools with associated declines in water quality. By reducing water flow, the diversion has potential to degrade approximately 0.1 hectare of riparian forest vegetation along the creekline (see **Table 4.1**).

Aquatic habitats in the southernmost reaches of the creek are expected to change less noticeably because they would receive inflow in the urbanised reach consisting primarily of stormwater runoff. Estimated at a point near the confluence with Broughton Mill Creek, the conservative predicted overall flow volume in Town Creek would decrease to 33 per cent (based on 50 percentile occurrence: AECOM 2012). However, alterations in aquatic habitats, the loss of connected aquatic habitat and reductions in overall flows in Town Creek may have little additional impact on aquatic ecology and water quality, as the waterway is currently ephemeral, has been extremely degraded by agricultural development in its upper catchment and residential development downstream of the upgrade and is not considered important as fish habitat. As there is no aquatic ecological benefit to overbank flooding in large flood events within the Berry township, there would be no loss of ecological function caused by the diversion of flooding flows into Bundewallah Creek.

The comparatively small increase to flow volumes in Bundewallah, Connollys and Broughton Mill creeks would have minor effects on aquatic ecology and water quality in those creeks. The loss of riparian vegetation to facilitate the diversion channel into Bundewallah Creek would be minor.

The changes to hydrology caused by Bridges 1, 3 and 4 would have an insignificant effect on aquatic ecology and water quality. Bridge 2 and the raised earth embankment would increase flood levels upstream for large flood flow events and reduce the floodplain storage and capacity. Overbank flooding provides infrequent but critical lateral connectivity to adjacent habitats for aquatic biota and can drive temporary booms in productivity that can be important for long term population persistence. Flood flows can be particularly important for recharging adjacent wetland areas. A number of native aquatic species spawn at particular times so that their juveniles can benefit from the increased productivity during seasonal flood flows. Although the floodplain area that would be lost to the earth embankment is cleared agricultural land, the reduction in floodplain storage and lateral connectivity could result in some productivity decreases for aquatic assemblages.

The altered hydrology caused by the placement of the bridge pier structures within Bundewallah Creek would not have a significant impact on aquatic ecology and water quality provided appropriate mitigation measures are implemented (Sections 5.1.1 and 5.1.2). The bridge piers are not likely to significantly impede upstream fish passage as velocities and water levels are similar to predevelopment conditions. The expected change in velocity is 0.12 m/s which is within the swimming ability of Australian Bass.

The use of bridges as temporary creek crossings would have an insignificant effect on aquatic ecology given that support structures are located landward of the creek banks and no other in-stream structures are used. The use of appropriate structures for temporary crossings, such as culverts or fords, over Broughton Creek (Class 1 waterway) and Broughton Mill Creek and Bundewallah Creek (during low or zero flow periods), would ensure upstream fish passage and longitudinal connectivity is maintained.

The unnamed waterway between Schofields Lane and Andersons Lane was ephemeral, extremely degraded and only flows during rain events. It drained cleared agricultural land, had a relatively indistinct channel colonised by pasture grass and was considered unlikely to provide fish habitat. This creek flows through the proposed RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane. The creek would not be redirected as part of the project.

Conclusion

The potential impacts to aquatic ecology and water quality resulting from project changes to surface water and groundwater hydrology relate primarily to bridge pier placement in Bundewallah Creek and to the diversion of Town Creek flows, longitudinal and lateral connectivity and floodplain productivity. See recommended mitigation strategies and offsets (Sections 5.1.1, 5.1.2 and 5.2).

4.3 Threatened and protected species, communities and populations

No aquatic threatened or protected species, populations or communities were observed in the study area during field surveys.

4.3.1 Macquarie Perch, *Macquaria australasica*

The Macquarie Perch is listed as endangered under the FM Act and the EPBC Act.

Macquarie Perch usually inhabit the upper reaches of clear, freshwater water courses containing deep, rocky pools with upstream riffle and pool sequences for spawning (Allen *et al*., 2003; DPI NSW, 2005a). They migrate upstream to spawn in October to November and their eggs settle and develop in the gravel and cobble found in riffle habitat. The distribution of the eastern form can also be a function of interactions with other species. For example, if Australian Bass are found in a watercourse then typically Macquarie Perch would only be found upstream of them (McDowall, 1996).

There are no records of Macquarie Perch from within the study area, which has a low coastal elevation. Records for Macquarie Perch do exist in upper tributaries of the adjacent Shoalhaven catchment (eg near Kangaroo River in Kangaroo Valley). However, there were two old records of Macquarie Perch from the Shoalhaven River just below Tallowa Dam. One is an Australian Museum record dated from 1980, which may indicate that a population of perch persisted in the lower Shoalhaven (for a time) after the completion of the dam in 1976. Gehrke *et al*., (2001) only observed Macquarie Perch at 550 metres AHD in the Mongarlowe River but suggested that *M. australasica* was a likely pre-Tallowa Dam inhabitant of a relatively low elevation reaches on the Shoalhaven River (around 30 metres AHD). Bishop (1979) lists *M. australasica* as one of the fish inhabiting the “Lower Reaches to Estuary” zone of the Shoalhaven catchment and also reported that during the 1960s Macquarie Perch were commonly found in the lower Shoalhaven River. Bishop and Bell (1978) collected one Macquarie Perch in December 1976 in a pool below the dam after water flow had been terminated for a period. Gehrke *et al*., (2001) assert that prior to the construction of the Tallowa Dam fish species in the Shoalhaven River formed relatively continuous communities from about 500 metres AHD down to the tidal limit influence.

The study area is considered unlikely to support a viable Macquarie Perch population even though there is low-elevation aquatic habitat similar to that of the Shoalhaven River Macquarie Perch sightings in 1976 and 1980. The only freshwater waterway classed major fish habitat (Class 1 Waterways) within the study area is Broughton Creek. The Broughton catchment is relatively small and flow can be ephemeral in many of the upper reaches. Bass are also common within Broughton Creek and have been observed in the reach just upstream of the existing Princes Highway crossing. Although occasionally observed at lower elevations, Macquarie perch preferentially inhabit and migrate to spawn in relatively undisturbed higher elevation reaches, such as those found in the Mongarlowe River. The reaches upstream of the bass distribution in Broughton Creek are considered unlikely to provide sufficient appropriate habitat for the persistence of a Macquarie Perch population. In addition there have been no low-elevation records of Macquarie Perch in the region for nearly 30 years and none within the Broughton catchment.

However, an assessment of significance for the potential impact of the highway upgrade on the Macquarie Perch was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the project would be unlikely to affect Macquarie Perch, particularly if mitigation measures are implemented. The federal assessment of significance concluded that the project is unlikely to have a significant impact on this species and therefore, a referral under the EPBC Act is not required. It is not necessary to modify the project with respect to the conservation of this species.

4.3.2 Australian Grayling, *Prototroctes maraena*

The Australian Grayling is listed as Protected under the FM Act and Vulnerable under the *EBPC Act.*

Australian Grayling prefer watercourses with low turbidity and gravel substrata, and occupy lowland rivers through to high elevation reaches at 1000 metres AHD (McDowall 1996). Grayling occur in streams and rivers on the eastern and southern flanks of the Great Dividing Range from Sydney southwards to the Otway Ranges in Victoria, and Tasmania (McDowall 1996, DPI NSW 2006a).

The species has an amphidromous life cycle; newly hatched larvae are attracted to the light and swim to the surface where they are swept downstream to estuarine/marine waters and only migrate back to adult freshwater habitats at the age of six months. Populations are therefore very susceptible to barriers to passage. Adults suffer heavy post-spawning mortality so it is possible after a few years without juvenile recruitment to result in local extirpation (Morris *et al*., 2001).

The Australian Grayling has been recorded by the Australian Museum from Broughton Mill Creek, to the south-east of Berry and from the lower section of Jaspers Creek, just upstream of its confluence with Broughton Creek (**Table 3.1**). No date was given with the records but they are likely to have been prior to 1976 as Morris *et al*. (2001) report that since the completion of the Tallowa Dam in 1976 only one grayling specimen has been collected in the Shoalhaven River catchment, in Yalwal Creek outside the Broughton catchment. No Australian Grayling were recorded by the NSW Rivers Survey (Harris and Gehrke, 1997) nor the Tallowa Fishway study (Faragher, 1999).

It is considered unlikely that the Broughton catchment still supports a viable population of Australian Grayling. The Broughton Creek catchment is relatively small and only one individual has been observed over the entire Shoalhaven catchment in the last 30 years. Australian Grayling are relatively sensitive to the degradation of freshwater habitat and water quality that has occurred in the region. Australian Grayling are particularly vulnerable to barriers to passage, such as the flood gates that have been used within the Broughton floodplain in various tributaries and the Tallowa Dam on the Shoalhaven River. However, an assessment of significance for the potential impact of the project was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the project would be unlikely to affect Australian Grayling, particularly if mitigation measures are implemented. The federal assessment of significance concluded that the project is unlikely to have a significant impact on this species and therefore, a referral under the EPBC Act is not required. It is not necessary to modify the project with respect to the conservation of this species.

4.3.3 Black Cod, *Epinephelus daemelii*

The Black Cod is listed as Vulnerable under the *FM Act*.

Black Cod have previously been identified on the coast near Gerringong. Larger juveniles inhabit estuaries and threats to the species include loss or degradation of nursery habitat. It is possible that Crooked River and Shoalhaven/Crookhaven estuary are habitat for juvenile black cod.

Impacts on Black Cod relate to potential impacts of the project on downstream estuarine habitat. These include changes to hydrology, increased sediment loads and pollution. Assuming the installation of appropriate drainage structures at highway crossings, the use of effective erosion and stormwater runoff controls and proper handling of hazardous substances on site, it is considered unlikely that the project would generate significant downstream impacts that might significantly degrade estuarine habitat and potentially affect Black Cod. However, an assessment of significance for the potential impact of the project was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance concluded that the proposed works would be unlikely to have a significant impact on the Black Cod.

4.3.4 Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner bioregions

Coastal Saltmarsh is listed as an EEC under the TSC Act.

Saltmarsh is present downstream of the project within Crooked River and the Shoalhaven/Crookhaven estuaries and covers an estimated area of 0.017 square kilometres and 2.06 square kilometres respectively (West *et al*., 1985; The Ecology Lab, 1999). Threats to Coastal Saltmarsh relevant to the project include pollution and changes to salinity from stormwater discharge.

The section of the project within the Crooked River catchment does not intersect with any significant or even ephemeral waterways as it ascends a spur to the Toolijooa Ridge and as such there is little chance of contaminant spill reaching downstream receiving waters. In addition, the use of sediment ponds and/or vegetated swales would greatly reduce the risk of contaminants or polluted water (transported by the project longitudinal drainage system) reaching sensitive receiving waters within the study area including the distant downstream saltmarsh habitat within the Crooked River and Shoalhaven/Crookhaven estuaries. Groundwater and surface water studies indicate that there is unlikely to be a significant change to hydrology that would affect salinity downstream in the vicinity of the saltmarsh communities.

An assessment of significance for the potential impacts of the project on Coastal Saltmarsh was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the proposed works would be unlikely to have a significant impact on Coastal Saltmarsh.

4.3.5 Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions

Freshwater Wetlands on Coastal Floodplains are listed as an EEC under the TSC Act.

Two small wetlands (areas) were identified by Chafer (1997) within the Crooked River catchment; the Willow Vale wetlands west of the Princes Highway and the Gerringong Wetlands east of the Princes Highway. Coomonderry Swamp lies outside of the catchment potentially impacted by the project. Potential threats to Freshwater Wetlands on Coastal Floodplains relevant to the project include pollution, changes to hydrology and infilling from sedimentation.

The Willow Vale wetlands are highly degraded and are found at the upper elevation limits of what has been defined as Freshwater Wetlands of Coastal Floodplains. They are upstream of the project and are therefore unlikely to be affected by potential downstream impacts. Similarly, the small Gerringong Wetlands are a highly degraded series of pondages and swampland associated with degraded creeks that pass through and near south-west Gerringong. These creeks are considered unlikely to provide fish habitat (Class 4 Waterways) and are infested with annual weeds. This habitat is also at the upper elevations limits of Freshwater Wetlands of Coastal Floodplains and is in a part of the Crooked River catchment associated with the Gerringong upgrade.

The project is not anticipated to have any significant effects on surface or groundwater hydrology that might affect sensitive aquatic habitat within the study area or distant downstream habitats. Similarly, appropriate erosion and stormwater control measures would eliminate potential downstream impacts related to sedimentation and pollution. The section of the project within the Crooked River catchment does not intersect with any significant or even ephemeral waterways as it ascends a spur to the Toolijooa Ridge and as such there is little chance of downstream impacts on the two freshwater wetlands within the Crooked River catchment.

An assessment of significance for the potential impacts of the project on Freshwater Wetlands was carried out as a precautionary measure (Appendix E).

Conclusion

The assessment of significance following the heads of consideration concluded that the proposed works would be unlikely to have a significant impact on Freshwater Wetlands of Coastal Floodplains.

4.3.6 All Syngnathiformes (seahorses, seadragons, pipefish, pipehorses, ghost pipefish and seamoths)

All Syngnathiformes are protected species in NSW under the FM Act.

Some Syngnathiformes inhabit coastal embayments and estuarine habitats, particularly seagrass beds. Seagrass habitat is present in estuaries downstream of the project. The Crooked River lagoon supports 0.046 square kilometres of *Z. capricorni* and the Shoalhaven/Crookhaven estuaries supports 4.24 square kilometres of seagrass beds (*Z. capricorni* and *Halophila ovalis*).

Impacts on Syngnathiformes relate to potential impacts of the project on downstream estuarine habitat. These include changes to hydrology, increased sediment loads and pollution. The project is not anticipated to have any significant effects on surface or groundwater hydrology that might affect sensitive Syngnathiformes inhabiting distant downstream habitats. Similarly, appropriate erosion and stormwater control measures would eliminate potential downstream impacts related to sedimentation and pollution.

Conclusion

The project would have no impact on Syngnathiformes.

4.3.7 Marine species identified by the expanded EPBC search

The primary search area for EPBC listed threatened and protected species was defined as the Broughton Creek catchment downstream to its confluence with Shoalhaven River (around 16 kilometres downstream of Berry) and the section of the Crooked River catchment traversed by the project. A second expanded search was done which included the ecologically significant but distant downstream aquatic habitat of the Shoalhaven/Crookhaven estuary (a further four to 10 kilometres downstream of the Broughton Creek/Shoalhaven River confluence).

The results of this second search highlighted 58 previously unidentified species that were listed as threatened or protected under the EPBC Act (**Table 3.3**). Nine species were listed as threatened in addition to Macquarie Perch (Section 4.3.1) and Australian Grayling (Section 4.3.2) (**Table 3.3**). Forty nine species were also identified as having general protection under s248 of the *EPBC Act* as they were either (i) Migratory marine species, (ii) Listed marine species, or (iii) Whales and other cetaceans (**Table 3.3**). Migratory marine species, Listed marine species and whales and other cetaceans). A number of species were listed under more than one category.

Macquarie Perch and Australian Grayling were identified as potentially occurring within the Broughton Creek catchment by the primary EPBC search and the Assessment of Significance is included in Appendix E. An assessment of potential impacts on the 20 species of Syngnathiformes in the Listed Marine Species (Ray-finned fishes) is covered in Section 4.3.6 as the same species are protected under the FM Act. The remaining 29 species identified in the expanded EPBC search are protected in some form.

There are few records of EPBC threatened and protected species within the Shoalhaven/Crookhaven estuary. There was one record each for Green Turtle and Pygmy Right Whale and several for Bottlenose Dolphins from inside the Shoalhaven/Crookhaven estuary. Outside the Shoalhaven Heads and Crookhaven Heads (and therefore outside the expanded search area) there are records for Grey Nurse Shark, Humpback Whale, Common Dolphin, Southern Right Whale and Bottlenose Dolphin.

A formal Assessment of Significance was not considered necessary for the threatened taxa identified in the expanded EPBC search. Potential downstream impacts relate to increased sedimentation and pollution, however given the implementation of mitigation measures it is extremely unlikely that works associated with the project would cause significant effects on the aquatic habitats and biota of the Shoalhaven/Crookhaven estuary, given their distance downstream. Moreover, the Shoalhaven/Crookhaven estuary does not constitute critical habitat for any of these species, as they are all predominantly either coastal or oceanic, and therefore only likely to use the estuary intermittently (if at all), as demonstrated by the limited records.

Given the implementation of mitigation measures recommended in this report (Section 5.1.1 and 5.1.2) and the Concept Design (RMS, 2012) it is considered unlikely that the project would affect habitat, fragment a population, reduce an area of occupancy, lead to a long-term population decrease, disrupt breeding cycles, introduce disease or invasive species or inhibit recovery of the EBPC listed threatened species in the Shoalhaven/Crookhaven estuary. As such a Referral to the Federal Minister for Sustainability, Environment, Water, Population and Communities is not required.

5 Proposed aquatic ecology and water quality mitigation

The major issues affecting aquatic ecology and water quality that need to be addressed in the detailed design and construction of the project are:

- Mobilisation of sediment into waterways.
- Mobilisation of pollutants into aquatic habitats.
- Disturbance of ASS.
- Establishment of invasive species within the study area.
- Degradation and removal of riparian vegetation.
- Removal of large woody debris.
- Changes to the natural flow regime.
- Obstructions to fish passage.

The majority of potential impacts arising from these issues can be minimised or mitigated by measures recommended in Section 5.1. Project-related impacts that are unavoidable and would fail to 'maintain or improve' biodiversity include:

- Loss of riparian habitat within the project corridor, temporary creek crossings and ancillary infrastructure footprint.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Changes to flood hydrology at Town Creek, Bundewallah Creek and Broughton Creek from diversion and installation of transverse drainage structures.
- Slight changes to hydrology due to placement of pier structures within the waterway at Bundewallah Creek.
- Possible reduced longitudinal connectivity at temporary creek crossings during low flows.

Compensation measures for these impacts are proposed in the biodiversity offset strategy (refer to the *Terrestrial Flora and Fauna Assessment* (Biosis, 2012) provided at Appendix F of the environmental assessment).

Providing the recommended mitigations and biodiversity offset strategy are implemented the project is unlikely to have a significant net impact on aquatic ecology and water quality within the study area.

5.1 Mitigation strategy

5.1.1 Design

The following measures are recommendations to mitigate potential operational impacts related to the project design.

Mobilisation of sediment

Operational sediment issues can be effectively managed through the development of a project specific Erosion and Sediment Control Plan (ESCP). It is recommended that the design of the ESCP follow the RMS *Procedure for Erosion and Sedimentation Management* (RTA, 2008).

Project design should aim to minimise stormwater and disturbed surface runoff entering adjacent waterways by diversion into sediment basins/vegetated swales. These can act as filters, absorbing mobilised sediments potentially carried in runoff. It is recommended that the drainage system preserve existing elements where possible, such as natural channels and riparian vegetation, with treatment being as close as possible to the source of drainage outlets. It is recommended that the longitudinal drainage system on bridges direct runoff into the sediment basin/swale system rather than allowing scuppers to discharge directly into receiving waters untreated.

The Concept Design Report (RMS, 2012) indicated that a series of vegetated swales (Scenario 3a: 80 metres in length, one metre width, three per cent longitudinal grade and 250 millimetres of vegetation height) or sediment basins (Scenario 2a: 300 cubic metres per hectare) could achieve the operational objectives for runoff water quality. However, in areas close to, or upstream from sensitive receiving waters, these vegetated swales may not provide complete capture capability during large rainfall events (RMS, 2012). Therefore, independent post-construction monitoring is required to ensure that the longitudinal drainage and swale system can achieve operational sediment capture objectives. Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads and can be measured as indicators of physical stress on aquatic biota. ANZECC trigger values for the protection of aquatic ecosystems (turbidity range of 6 – 50 NTU for lowland rivers and 0.5 – 10 NTU for estuarine waters) can be used as a starting point to develop locally appropriate thresholds that would trigger a mitigating management response. In addition, consideration could be given to increasing the size of the vegetated swales and/or the use of sediment basins.

The following measures are also recommended to adequately address sedimentation issues relevant to project design:

- Clean water should be redirected around disturbed areas. For example, the use of catch drains to prevent inflow of clean surface water from the outside of cuttings. The catch drains could then convey clean water to the transverse drainage system.
- Energy dissipaters should be provided to outlets to drainage structures that have the potential to cause scour. The dimensions of energy dissipaters or scour protection up and downstream of culverts can vary depending upon site specific factors (eg velocity, tail water conditions, soil type and erodibility).
- Design of suitable batter treatment along the toe of the embankment between Bridge 2 and Bridge 3 to prevent scour from floodwaters.
- Appropriate use of dissipaters and/or batter treatment to ensure the diversion of flows from Town Creek into Bundewallah Creek does not cause scour and erosion.
- Testing of materials for organic content and dispersion to determine their suitability for use in landscaping and embankment construction.
- Appropriate erosion protection measures for Berry Siltstone Rock and other dispersive soils in steep or vertical cuts (eg soil nailing and/or retaining structures).

- Avoid instream works where practicable. For example, position bridge piers (for both permanent and temporary bridges) outside the channel wetted width. (Note: Four bridge piers would need to be located within Bundewallah Creek.
- Stockpiled materials should not be placed over ephemeral creek or drainage lines.

Pollution

Project operational objectives for runoff water quality with respect to contamination can be met through the longitudinal drainage system and water treatment by vegetated swales and sediment basins at discharge points. However, in areas close to, or upstream from, sensitive receiving waters, the vegetated swale system may not provide complete capture capability during large rainfall events (RMS, 2012). Therefore, independent post-construction monitoring is required to ensure that the longitudinal drainage and swale system can achieve operational water quality objectives. ANZECC trigger values for pollutants associated with road runoff (eg heavy metals, hydrocarbons and organics) can be used as a starting point to develop locally appropriate trigger values for the protection of aquatic ecosystems. Sampling should take place after rainfall events, utilise appropriate control sites and include pre-construction sampling to provide baseline information about background patterns in pollutants. An outline for the recommended surface water quality monitoring program is given in Appendix F.

The following measures are also recommended to adequately address contamination issues relevant to project design:

- Procedures in place to detect and respond to an emergency spill incident. Retention methods for a spill should include an oil baffling system and a standard retention capacity for basins/swales. Standard capacity of the basin/swale system (eg Scenario 4c, RMS, 2012) would provide for removal of TSS, TN and TP from stormwater runoff, although it may involve trade-offs with respect to loss of riparian vegetation and/or disturbance of ASS.
- Longitudinal drainage system on bridges should direct runoff into sediment basin/swale system rather than allowing scuppers to discharge directly into receiving waters untreated.

Acid sulfate soils

Best design principles should be implemented to manage ASS in accordance with the RMS '*Guidelines for the Management of Acid Sulphate Materials: Acid Sulfate Soils, Acid Sulphate Rock and Monosulfidic Black Ooze'* (RTA 2005). The RMS '*Guidelines for the Management of Acid Sulphate Materials'* recommend (in order of preference): avoidance of ASS where possible, followed by minimisation strategies and finally neutralisation.

Design-related considerations include:

- Redesign earthworks where possible to avoid/minimise impacts in areas with high risk of ASS.
- Cover *in situ* soils with clean fill to provide adequate depth for infrastructure excavations without disturbing ASS. For example: in areas considered a high ASS risk, water quality structures such as vegetated swales formed from clean fill placed over existing ground would be preferable to excavated sediment basins.
- Where appropriate, diversion channels and transverse drains (eg culverts) could be redesigned to be wider and shallower if it meant that penetrating the ASS layer could be avoided.
- Testing of soils for ASS to determine their suitability for use in landscaping and embankment construction.
- Ground conditioning to avoid settlement: preference for preloading over excavation and replacement with engineered fill.

Degradation of riparian vegetation

The removal of riparian vegetation should be limited to areas within the concept design footprint including those identified for temporary creek crossings and to facilitate diversion channel construction. Compensation for the unavoidable loss of riparian vegetation within the project alignment, ancillary infrastructure and temporary crossing sites is addressed in the Biodiversity Offset Strategy (Section 5.2).

Where possible the construction of vegetated swales should not replace existing native riparian vegetation.

Changes to the natural flow regime

To minimise impacts on the natural surface and groundwater flow regime of the study area, it is therefore recommended that:

- Groundwater seepage into road cuttings be transferred to receiving dependent aquatic habitats via a longitudinal drainage system.
- Transverse drainage structures allow the unrestricted passage of the vast majority of natural flows and allow for changes in the natural flow regime expected as a result of climate change. This would be achieved by design of bridges and culverts to provide flood immunity from 100 year ARI and 50 year ARI respectively.
- Temporary creek crossings structures provide at least two year ARI flood immunity.
- No bridge piers or abutments be positioned within the section of waterway channel (wetted width) that carries median flows, where practicable.

Compensation for the unavoidable changes to the natural flow regime caused by the project is addressed in the Biodiversity Offset Strategy (Section 5.2).

Obstructions to fish passage

Specific guidelines for the design and construction of waterway crossings to maintain fish passage have been developed and are outlined in 'Guidelines and Policies for Aquatic Habitat Management and Fish Conservation' (Smith and Pollard 1999) and '*Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*' (Fairfull and Witheridge, 2003). These guidelines include requirements for:

- Crossing structures appropriate for the size and type of watercourse.
- Preferred crossing designs.
- Maintenance of fish passage throughout construction.
- Preservation of spawning grounds.
- Minimisation of disturbance to and removal of snags.
- Habitat rehabilitation.

Appendix B details the classification criteria for watercourses and recommended waterway crossings that minimise obstruction to fish according to fish habitat class, based on Fairfull and Witheridge (2003). An assessment of minimum recommended crossing requirements for each site assessed in this study has been summarised in **Table 3.4**. This information is provided as input to the detailed design.

Although bridges would generally be preferred to arch structures, culverts, fords and causeways (in this order), as bridges have the least disturbance to fish passage, the cost, geotechnical and engineering considerations are also important in deciding the selection of a crossing. It is recommended that bridges are used for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. Where practicable, bridge piers should be placed outside the main channel to avoid formation of turbulence and bed erosion, and abutments placed away from the bank.

Culverts are considered adequate crossings for the remaining waterways (**Table 3.4**). Fish passage may be maintained by minimising changes to the natural flow, channel width and water depth through the culvert cells. Additionally designs should consider flow rates and substratum that would facilitate movement and provide resting areas (Fairfull and Witheridge 2003). One option is to utilise multiple and differentiated cell designs. A central sunken box cell (or without a bottom) would preserve the natural channel bed level and facilitate fish passage during low flows. Adjacent culvert cells would facilitate the transfer of higher volume flows. Such designs should be considered for Class 3 Fish Habitat waterways or for crossings that have an existing multiple cell culvert. Engineering guidelines in relation to different crossing designs are detailed in Witheridge (2002) and Fairfull and Witheridge (2003).

Compensation for the unavoidable changes to the lateral connectivity caused by the project is addressed in the Biodiversity Offset Strategy (Section 5.2).

5.1.2 Construction

The following measures are intended to mitigate potential construction impacts.

Mobilisation of sediments

Best environmental practice should be implemented to manage erosion and sedimentation during construction in accordance with Landcom's (2004) Soils and Construction: Managing Urban Stormwater and DECCW's *Managing Urban Stormwater – Soils and Construction, Volume 2D – Main Road Construction* (DECCW, 2008). The ESCP should include (but not be limited to):

- Erosion and sediment controls, such as bunding, silt fences/curtains, sediment basins and vegetated swales. These measures should be able to operate effectively during high rainfall events.
- Diversion of runoff from disturbed areas, stockpiles and dust suppression/washdown facilities into erosion and sediment controls.
- Diversion of clean water around disturbed areas.
- Use of appropriate measures to minimise sedimentation from possible instream works associated with the construction of temporary creek crossings (eg silt curtains).
- Minimisation of the area and duration of exposed unconsolidated soils on landforms constructed as part of the works, including the proposed embankment linking Bridge 2 and Bridge 3, construction material and spoil stockpiles, surface of cuttings etc.
- Revegetation and restoration of disturbed areas as quickly as possible. Erosion and sediment control measures should be in place to treat runoff from these areas until adequate cover is established.
- Project works and ancillary infrastructure should not take place within 50 metres of waterways with Category 1 (Environmental Corridor) riparian habitat. The objective for Category 1 waterways is to maintain or rehabilitate 40 metres of riparian vegetation either side of the waterway with an additional 10 metre buffer zone. The 40 metre exclusion zone for construction and ancillary works outlined in the concept design (RMS 2012) would be adequate for Category 2 and Category 3 waterways.

- Ancillary infrastructure sites should be established only on sites already cleared of native vegetation.
- Restricting work within disturbed areas during rainfall.
- Batching plants comply with relevant environmental requirement regarding dust collection and waste management.
- Construction pads would be constructed to minimise environmental impact and impacts would be identified and minimised during the detailed design phases of the project.
- Flood proof stockpiles or locate them outside flood zone. A number of stockpiles are positioned within the flood affected area of the 100 year ARI event.

It is recommended that independent surface water quality monitoring be incorporated into the ESCP with protocols in place for guideline breaches. Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads and can be measured as indicators of physical stress on aquatic biota. ANZECC trigger values for the protection of aquatic ecosystems (turbidity range of 6 – 50 NTU for lowland rivers and 0.5 – 10 NTU for estuarine waters) can be used as a starting point to develop locally appropriate thresholds that would trigger a mitigating management response. The monitoring program should involve daily sampling over the construction period, utilise appropriate control sites and include pre-construction sampling to provide baseline information about background patterns in turbidity. An outline for the recommended surface water quality monitoring program is given in Appendix G.

Pollution

The majority of measures recommended above to minimise sedimentation during construction would have a similar mitigating effect on pollution. Additional measures required to achieve construction water quality objectives include:

- Proper handling, storage, transport and disposal of hazardous substances within the study area.
- Management of any on-site waste dump to prevent any leaching of contaminants.
- Regular inspections of work practices.
- Independent surface water quality monitoring should be carried out during construction with protocols in place for guideline breaches. ANZECC trigger values for pollutants associated with road construction (e.g. heavy metals, hydrocarbons and organics) can be used as a starting point to develop appropriate thresholds that would trigger a mitigating management response. The monitoring program should involve regular sampling over the construction period (including rainfall events), utilise appropriate control sites and include pre-construction sampling to provide baseline information about background patterns in contamination.

Acid sulfate soils

Best environmental practice should be implemented to manage ASS during construction in accordance with the RMS 'Guidelines for the Management of Acid Sulphate Materials: Acid Sulfate Soils, Acid Sulphate Rock and Monosulfidic Black Ooze' (RTA 2005). Where disturbance of ASS is unavoidable, preferred management strategies are minimisation of disturbance and neutralisation. Construction-related considerations include:

- Minimise project-related activities that would cause groundwater fluctuations, such as removal of vegetation and dewatering.
- Receiving waters are not to be used as a means of diluting and/or neutralising ASS or associated contaminated waters.
- Stockpiling of untreated ASS above the permanent groundwater table with (or without) containment is not an acceptable long-term management strategy (RTA 2005). ASS that are to be stockpiled, disposed of, used as fill, placed as a temporary or permanent cover on land should be treated or managed. Neutralisation treatments include use of alkaline materials or hydraulic separation. Stockpiling after excavation and prior to treatment is still a risk in the short term if there is sufficient time for oxidation to occur. Leachate and runoff must be collected and treated. The Construction Environmental Management Plan (CEMP) should detail the timing, methods and location for treatment, storage and disposal of ASS.
- Neutralisation methods can represent a significant environmental risk and should be managed appropriately.
- Monitoring of ASS and receiving waters should be incorporated into the independent water quality monitoring program undertaken during construction. ANZECC trigger values for the protection of aquatic ecosystems (pH range of 6.5 – 8 for lowland rivers and 7 – 8.5 for estuarine waters) can be used as a starting point to develop locally appropriate thresholds that would trigger a mitigating management response.
- Where ASS would be disturbed during excavation works (eg diversion channel construction, installation or upgrade of drainage structures), the ASS should either be (i) removed and replaced with clean fill or (ii) strategically reburied back under the groundwater table. Strategic reburial is the least preferred option and should not occur if the ASS have had time to oxidise.

Invasive species

Positive identifications of Alligator Weed within the construction area should be reported to Kiama and Shoalhaven councils. Staff should be trained in the identification and disposal of Alligator Weed and heavy machinery should be regularly inspected to ensure that the species is not spread to new areas.

Degradation of riparian vegetation

Compensation for the unavoidable loss of riparian vegetation within the project alignment, ancillary infrastructure or temporary creek crossing sites is addressed in the Offset Strategy (Section 5.2).

Construction-related mitigation measures include:

- Temporary creek crossings should be located immediately south of the proposed bridge alignments and within the existing footprint. Such positioning would minimise the requirement for additional clearing of riparian habitat in the approaches to temporary crossings.
- Ancillary infrastructure should only be established on sites where native vegetation has already been cleared. For example, the layout of the RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane should be structured so that there is no loss of riparian vegetation.
- Cleared areas, new creek channels and landforms in riparian zones should be rehabilitated where possible following the completion of works. Rehabilitation includes replanting of native riparian species and/or removal of exotic species and regeneration.

Removal of large woody debris

Where large woody debris is encountered, lopping should be considered the first management response with removal only adopted as a last resort.

Should removal be required then consideration should be given to the introduction of engineered log jams or submerged woody debris as compensation within the offset strategy. Subject to relevant approvals and conditions, there is potential for trees removed as a consequence of the project to be utilised for fish habitat and bank stability within the creeks of the project area. The plan for tree reuse should consider factors such as stream width, bank slope, flow regime and long term stability of the reused trees.

Changes to natural flow regime

The structure of the five temporary creek crossings would have minor effects on surface water flow if they provide flood immunity for the in-channel two year ARI. It is recommended that low bridges are used for the three crossings of Broughton Creek and the crossings of Broughton Mill Creek and Bundewallah Creek. Where practicable, bridge piers should be placed outside the main channel to avoid formation of turbulence and bed erosion, and abutments placed away from the bank. Bridges are generally preferred to arch structures, culverts, fords and causeways (in this order) as they cause the least disturbance to flow.

Placement of bridge piers in waterways would represent an obstruction to flows and will result in a localised change in velocity and water levels. These impacts should be mitigated through provision of scour protection which would assist in upstream fish passage.

The layout of the RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane should be structured to minimise effects on the flow regime of waterways that run through the property. A realignment or within-site crossing of this waterway was not identified in the Concept Design report (RMS 2012). A culvert providing flood immunity from the 50 year ARI would provide sufficient protection to the natural flow regime for this waterway should the need for a crossing be identified in the detailed design phase.

Temporary creek crossings used during construction should adhere to guidelines for the design and construction of waterway crossings to maintain fish passage (Smith and Pollard 1999, Fairfull and Witheridge 2003). The preference is for low hollow-core bridge structures to be used for all five temporary creek crossings. Broughton Creek is major fish habitat and a bridge is the recommended crossing structure (**Table 3.4**). Broughton Mill Creek and Bundewallah Creek are Class 2 Waterways and the recommended crossing structures include bridges, arch structures, culverts or fords. Of these options, the preference is for bridge structures to be used for the two temporary creek crossings at Bridge 4.

If culverts are considered for the Broughton Mill Creek and Bundewallah Creek temporary creek crossings, they should conform to design criteria outline in Section 5.1.1. The preferred locations for the temporary creek crossings (**Table 3.7**, **Figures 3.4** and **3.5**) were selected to maximise water depth under the crossing and minimise the head differential therefore reducing behavioural impacts on fish passage. Instream works associated with the construction of temporary creek crossing should be staged so that upstream passage is always possible (eg that silt curtains do not create a complete barrier across the waterway).

A culvert or ford is the recommended structure for the Class 4 waterway passing through the RMS stockpile straddling the southern end of the project area between Schofields Lane and Andersons Lane should the need for a crossing be identified in detailed design phase.

The design of the diversion channel from Town Creek to Bundewallah Creek should overall aim to mimic a natural creek in alignment, depth, creek bed formation and bank configuration. Locally sourced, native riparian species should be used to vegetate creek banks and appropriate methodology and techniques employed to reduce erosion while riparian vegetation is established. If adjacent landuse includes grazing livestock, measures should be included to exclude grazing from riparian vegetation areas.

Ecological monitoring

It is recommended that regular aquatic ecological monitoring be done in conjunction with water quality monitoring (refer to Appendix G). A monitoring program should include sampling in the pre-construction, construction and operational periods.

Aquatic macroinvertebrates and Australian Bass would be appropriate biota to sample given their ecological and social importance and the type of impacts potentially associated with the project. AusRivAS method uses the composition of aquatic macroinvertebrates assemblages as a metric of waterway 'health' or condition. Samples could be collected twice a year, during the two AusRivAs periods of 'Spring' (15 March – 15 June) and 'Autumn' (15 September – 15 December). Declining AusRivAS scores (and the presence of pollution-sensitive taxa) could indicate environmental impacts and trigger management action. Similarly, population trends for macroinvertebrate taxa could be monitored by more frequent sampling using quantitative methods.

Monitoring locations should include the created diversion channel between Town Creek and Bundewallah Creek in order to provide an indication of the successful establishment of a natural creek ecosystem.

Australian Bass is an important species to recreational fishers and is a common large predator within the study area that has a significant structuring effect on aquatic biotic assemblages. Australian Bass populations should be monitored at regular intervals to identify potential trends that might indicate impacts associated with the construction and/or operation of the project.

5.2 Biodiversity offset strategy

Residual impacts on aquatic ecology and water quality that cannot be adequately mitigated and fail to 'maintain or improve' biodiversity include:

- Loss of 2.9 hectares of riparian habitat within the project area, ancillary infrastructure and temporary crossing footprint.
- Reduced floodplain storage, productivity and lateral connectivity in the region of Bridge 2 embankment.
- Slight changes to hydrology due to placement of pier structures within the waterway of Bundewallah Creek.
- Potential reduced longitudinal connectivity at temporary crossings during low flows.
- Changes to hydrology at Town Creek, Bundewallah Creek and Broughton Creek from creek diversion and the installation of transverse road drainage structures.

DTIRIS has a policy of 2:1 environmental compensation for direct loss of aquatic or riparian habitat (Smith and Pollard 1999). Compensation for the unavoidable loss of riparian habitat caused by the project is addressed in the Biodiversity Offset Strategy. This strategy is detailed in the *Terrestrial Flora and Fauna Assessment (*Biosis, 2012) which is provided at Appendix F of the environmental assessment.

The primary action that would be implemented in the strategy is additional revegetation and rehabilitation of riparian vegetation in strategic locations. As the majority of riparian vegetation that would be lost in the project is part of the *River-Flat Eucalypt Forest on Coastal Floodplain* EEC, this action would compensate for impacts on aquatic ecology and water quality as well as losses to terrestrial biodiversity.

Restoration works would be carried out by accredited organisations and include where appropriate: revegetation of native riparian species, removal of exotic species and restoration/protection of existing riparian habitat (eg fencing protection from livestock etc).

Should the recommended mitigation measures and Biodiversity Offset Strategy be implemented as outlined, then the project should result in no net/residual/long term impacts on aquatic ecology and water quality.

6 References

AECOM (2012) *Foxground and Berry bypass Surface Water, Groundwater and Flooding Technical Paper*

Allen, G.R. (2003). *Freshwater Fishes of Australia*. West Australian Museum, Perth, Australia, 394pp.

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

AWT (1999). Gerringong Gerroa Surface Water Quality Baseline Monitoring. Phase 1 and Phase 2A. Sydney Water Corporation, Special Projects Branch.

Backhouse, G., Jackson, J. and O'Connor, J. 2008a. National Recovery Plan for the Australian Grayling Prototroctes maraena. Department of Sustainability and Environment, Melbourne.

Backhouse, G., Jackson, J. and O'Connor, J. 2008b. Background and Implementation Information for the Australian Grayling *Prototroctes maraena* National Recovery Plan. Department of Sustainability and Environment, Melbourne.

BIOSIS (2012) *Foxground and Berry bypass Terrestrial Fauna and Flora Technical Paper*

Bishop, K. A. (1979). *Fish and Aquatic Macroinvertebrate Communities of a Coastal River (Shoalhaven River, NSW) during the Development of a Water Diversion Scheme*. MSc thesis, Macquarie University, North Ryde.

Bishop, K. A. and Bell, J. D. (1978). Observations on the fish fauna below Tallowa Dam (Shoalhaven River, New South Wales) during river flow stoppages. *Australian Journal of Marine & Freshwater Research* **29**, pp. 543-549.

Brooks, A.P., Gehrke, P.C., Jansen, J.D. and Abbe, T.B. (2004). Experimental reintroduction of woody debris on the Williams River, NSW: geomorphic and ecological responses. *River Research and Applications*, **20**, pp. 513-536.

Chafer, C.J. (1997). Biodiversity of Wetlands in the Illawarra Catchments: An Inventory. Illawarra Catchment Management Committee.

Chessman, B. C. (1995). Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology* **20**, pp. 122-129.

Chessman, B. C. (2003). New sensitivity grades for Australian river macroinvertebrates. *Marine & Freshwater Research* **54**, pp. 95-103.

Chessman, B., Growns, I., Kotlash, A.R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: application to the Hunter River system, New South Wales. *Marine and Freshwater Research*, **48**, 159-172.

Department of Environment and Climate Change (DECC) (2005). *Threats. Key threatening process. Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands*. http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/threat_profile.aspx?id=20002 (Accessed 4 June 2009).

DECC (2007). *Coastal Saltmarsh. Identification Guidelines for Endangered Ecological Communities*. http://www.environment.nsw.gov.au/resources/threatenedspecies/Coastal_Saltmarsh_A3_110108.pdf (Accessed 4 June 2009).

Department of Environment, Climate Change and Water (DECCW) (2010). South Coast Regional Conservation Plan. Department of Environment, Climate Change and Water, Sydney.

Department of Environment and Climate Change (DECC) (2008). *Freshwater Wetlands on Coastal Floodplains (Freshwater Wetlands). Identification Guidelines for Endangered Ecological Communities*. http://www.environment.nsw.gov.au/resources/threatenedspecies/EECfreshwaterwetlandsA3highres.pdf (Accessed 4 June 2009).

Department of Environment and Conservation/Department of Primary Industries (DEC/DPI) (2005). Draft Guidelines for Threatened Species Assessment.

Department of Land and Water Conservation (DLWC) (2002). The NSW State Groundwater Dependent Ecosystems Policy. Prepared by Department of Land and Water Conservation.

Department of Primary Industries New South Wales (DPI NSW) (2005a). *Primefact 9. Threatened Species in NSW Macquarie perch Macquaria australasica*. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/5102/Primefact_Macquarie_perch.pdf (Accessed 17 December 2008).

DPI NSW (2005b). *NSW DPI Primefact 10. Key Threatening Processes in NSW. Instream Structures and Other Mechanisms that Alter Natural Flows*. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/34252/Primefact_Instream_structures.pdf (Accessed 25 January 2009).

DPI NSW (2005c). *NSW DPI Primefact 12. Key Threatening Processes in NSW. Degradation of Native Riparian Vegetation along NSW Water Courses*. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0015/34251/Primefact_Degradation_of_Native_Riparian_Vegetation.pdf http://www.environment.gov.au/cgi-bin/wetlands/report.pl. Accessed 04 November 2008 (Accessed 25 January 2009).

NSW DPI (2005d). *Reducing the Impact of Road Crossings on Aquatic Habitat in Coastal Waterways – Southern Rivers, NSW*. Report to New South Wales Environmental Trust. NSW Department of Primary Industries, Flemington, NSW.

DPI NSW (2006a). *NSW DPI Primefact 162. Australian grayling Prototroctes maraena*. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/76242/Australian-grayling-Primefact-162---final.pdf (Accessed 17 December 2008).

DPI NSW (2006b). *NSW DPI Primefact 167. Estuary cod, Epinephelus coioides*.

DPI NSW (2007a). *NSW DPI Primefact 189. Black cod, Epinephelus daemelii.*

DPI NSW (2007b). NSW DPI Primefact 184. Threatened species in NSW. Sydney Hawk dragonfly *Austrocordulia leonardi*. (Accessed 05 November 2008). http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/144127/sydney-hawk-dragonfly.pdf Accessed 04 November 2008. (Accessed 05 November 2008).

DIPNR (2004). *Riparian Corridor Management Study (RCMS) in the Wollongong Local Government Area*. NSW Department of Infrastructure, Planning and Natural Resources.

Eldin, N.N. (2002). Road construction: Material and Methods. *Journal of Environmental Engineering*, **128**(5):423-430.

Environmental Protection Authority (1997). *Proposed Interim Environmental Objectives for NSW Waters: Shoalhaven Catchment*. Prepared for: NSW Government. Environment Protection Authority of NSW (EPA), Chatswood, NSW.

Faragher, R.A. (1999). A survey of the threatened fish species, Australian grayling, *Prototroctes maraena* Gunther: distribution and abundance in New South Wales. Cooperative Research Centre for Freshwater Ecology and NSW Fisheries Research Institute, Cronulla, NSW.

Fairfull, S. and Witheridge, G. (2003). *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*. NSW Fisheries, Cronulla, 16 pp.

Gehrke, P. C., Gilligan, D. M. and Barwick, M. (2001). *Fish Communities and Migration in the Shoalhaven River – Before Construction of a Fishway*. NSW Final Report Series No. 26. NSW Fisheries, Port Stephens, 129pp.

Harris, J.H. (1984). Impoundment of coastal drainages of south eastern Australia, and a review of its relevance to fish migrations. *Australian Zoologist* **21**(3), pp.235-250.

Harris, J. H. and Gehrke, P. C. (1997). *Fish & Rivers in Stress: The NSW Rivers Survey*. NSW Fisheries, Cronulla, NSW, 298 pp.

Industry and Investment NSW (2011). Black Cod (*Epinephelus daemelii*) Recovery Plan. Port Stephens Fisheries Institute.

McDowall, R. (1996). *Freshwater Fishes of South-Eastern Australia*. Reed Books, Sydney NSW, 1-247 pp.

Morris, S. A., Pollard, D. A., Gehrke, P. and Pogonoski, J. J. (2001). *Threatened and Potentially Threatened Freshwater Fishes of Coastal New South Wales and the Murray-Darling Basin*. Prepared for: Commonwealth Government's Fisheries Action Program//World Wide Fund for Nature. NSW Fisheries Office of Conservation, NSW.

New South Wales National Parks and Wildlife Service (NPWS) (1998). *Seven Mile Beach National Park and Comerong Island Nature Reserve: Plan of Management*. Report prepared by Planning Unit and Nowra District of NSW National Parks and Wildlife Service.

RTA (2005). Guidelines for the Management of Acid Sulphate Materials: Acid Sulfate Soils, Acid Sulphate Rock and Monosulfidic Black Ooze. Roads and Traffic Authority NSW.

RTA (2008). Gerringong to Bomaderry Princes Highway Upgrade – Preferred Option Report. Prepared for RTA by Maunsell Australia Pty Ltd.

RTA (2010). Princes Highway Upgrade. Foxground and Berry Bypass. Preliminary Environmental Assessment. Prepared for RTA by AECOM Australia Pty Ltd.

RMS (2012). Princes Highway Upgrade. Concept Design Report – Foxground and Berry Bypass. Prepared for RTA by AECOM Australia Pty Ltd.

Smith, A. K. and Pollard, D. A. (1999). *Policy and Guidelines Aquatic Habitat Management and Fish Conservation: 1999 Update*. NSW Fisheries, Port Stephens Research Centre.

The Ecology Lab (1995). *Shoalhaven River Effluent Release Assessment Marine Ecological Considerations.* Prepared for: Manly Hydraulics Laboratory. The Ecology Lab Pty Ltd, Sydney, NSW.

The Ecology Lab (1999). *Gerringong Gerroa Sewerage Scheme Baseline Ecological Monitoring Aquatic Ecology.* Prepared for: Sydney Water Corporation. The Ecology Lab Pty Ltd, Sydney, NSW.

The Ecology Lab (2007). *Gerringong to Bomaderry Princes Highway Upgrade. Preliminary Aquatic Ecology and Water Quality Assessment*. Prepared for Maunsell. The Ecology Lab Pty Ltd, Sydney, NSW.

Umwelt Pty Ltd (2005). *Shoalhaven River Estuary Data Compilation Study*. Prepared for: Shoalhaven City Council. Umwelt Pty Ltd, Australia. Accessed on Shoalhaven City Council website: http://www.shoalhaven.nsw.gov.au/council/pubdocs/LandManagement/ShoalRiverStudy/default.htm

West, R., Thorogood, C., Walford, T. and Williams, R. (1985). *An Estuarine Inventory for New South* Wales, Australia. Division of Fisheries, NSW Department of Agriculture, Sydney, NSW.

Wheeler, A.P., Angermeier, P.L. and Rosenberger, A.E. (2005). Impacts of New Highways and Subsequent Landscape Urbanization on Stream Habitat and Biota. *Reviews in Fisheries Science*, **13**: 141 – 164.

Williams, R.J., West, G., Morrison, D. and Creese, R.G. (2006). *Estuarine Resources of New South Wales*., Prepared for the Comprehensive Coastal Assessment (DPI) by the NSW Department of Primary Industries, Port Stephens.

Witheridge, G. (2002). Fish Passage Requirements for Waterway Crossings – Engineering Guidelines. Institute of Public Works Engineering, Brisbane.

Terms and acronyms used in this assessment

Term	Definition
AHD	Australian Height Datum
ANZECC	Australia and New Zealand Environment and Conservation Council
ASL	Above sea level
ASS	Acid sulfate soils
AusRivAS	Australian River Assessment System (http://ausrivas.canberra.edu.au)
CEL	Cardno Ecology Lab Pty. Ltd.
CEMP	Construction environmental management plan
CMZ	Core Riparian Zone
DEC	NSW Department of Environment and Conservation
DECCW	NSW Department of Environment, Climate Change and Water
DGRs	Department of Planning and Infrastructure Director-General's requirements
Diadromous (fish)	A migratory fish that travels between salt and fresh water
DIPNR	NSW Department of Infrastructure, Planning and Natural Resources
DLWC	Department of Land and Water Conservation
DP&I	NSW Department of Planning and Infrastructure
DPC	NSW Department of Premier and Cabinet
DPI	NSW Department of Primary Industries
DSEWPaC	Commonwealth Department of Sustainability, Environment, Water, Population and Communities (formerly DEWHA)
DTIRIS	Department of Investment, Regional Infrastructure and Services
EEC	Endangered ecological community
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). Provides for the protection of the environment, especially matters of national environmental significance, and provides a national assessment and approvals process
ESCP	Erosion and Sediment Control Plan
FM Act	*Fisheries Management Act 1994*
FMA Act	*Fisheries Management Amendment Act 1997*
GDE	Groundwater Dependent Ecosystem
I&I NSW	Industry and Investment NSW
KTP	Key threatening process
LEP	Local Environmental Plan
LGA	Local government area

Term	Definition
Macroinvertebrate (aquatic)	An animal without a backbone that spends all or part of its life in water that can be seen with the naked eye
Mg/L	Milligrams per litre
MNES	Matters of national environmental significance. Refers to the seven matters
NPWS	NSW National Parks and Wildlife Service
ntu	Turbidity
OEH	NSW Department of Environment and Heritage
ORP	Oxygen Reduction Potential
PASS	Potential acid sulfate soils
pH	A measure of the activity of the (solvated) hydrogen ion (acidic/alkaline)
ppt	Parts per thousand. Measure of salinity
RAM	Rapid assessment method
RCE	Riparian, Channel and Environmental inventory
RCMS	Riparian Corridor Management Study
RCP	Regional Conservation Plan
RMS	NSW Roads and Maritime Services -known as RTA prior to 2011
RTA	NSW Roads and Traffic Authority
SEPP	State Environmental Planning Policy. A type of planning instrument made under Part 3 of the EP&A Act.
SEPP 14	State Environmental Planning Policy No.14 – Coastal Wetlands
SEPP 71	State Environmental Planning Policy No. 71 – Coastal Protection
SIGNAL	Stream Invertebrate Grade Number Average Level
SIS	Species impact statement
SPM	Suspended particulate matter
Study Area	The subject site and any additional areas which are likely to be affected by the project, either directly or indirectly. In the case of the project, the study area includes the subject site and a 50 metre buffer to account for any indirect impacts
Subject Area	The area to be directly affected by the project (ie the development "footprint"
Taxon (singular) Taxa (plural)	A taxonomic category or group, such as a family or a species
TN	Total Nitrogen
TP	Total Phosphorus
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
TSS	Total suspended solids
WM Act	*Water Management Act 2000*
YOY	Young-of-year

Appendix A

River descriptors, associated categories and values used in the modified riparian, channel and environmental inventory (RCE) from Chessman *et al.* (1997)

Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone	
Undisturbed native vegetation	4
Mixed native vegetation and pasture/exotics	3
Mainly pasture, crops or pine plantation	2
Urban	1
2. Width of riparian strip of woody vegetation	
More than 30 m	4
Between 5 and 30 m	3
Less than 5 m	2
No woody vegetation	1
3. Completeness of riparian strip of woody vegetation	
Riparian strip without breaks in vegetation	4
Breaks at intervals of more than 50 m	3
Breaks at intervals of 10 - 50 m	2
Breaks at intervals of less than 10 m	1
4. Vegetation of riparian zone within 10 m of channel	
Native tree and shrub species	4
Mixed native and exotic trees and shrubs	3
Exotic trees and shrubs	2
Exotic grasses / weeds only	1
5. Stream bank structure	
Banks fully stabilised by trees, shrubs etc	4
Banks firm but held mainly by grass and herbs	3
Banks loose, partly held by sparse grass etc	2
Banks unstable, mainly loose sand or soil	1

Descriptor and category	Score
8. Riffle / pool sequence	
Frequent alternation of riffles and pools	4
Long pools with infrequent short riffles	3
Natural channel without riffle / pool sequence	2
Artificial channel; no riffle / pool sequence	1
9. Retention devices in stream	
Many large boulders and/or debris dams	4
Rocks / logs present; limited damming effect	3
Rocks / logs present, but unstable, no damming	2
Stream with few or no rocks / logs	1
10. Channel sediment accumulations	
Little or no accumulation of loose sediments	4
Some gravel bars but little sand or silt	3
Bars of sand and silt common	2
Braiding by loose sediment	1
11. Stream bottom	
Mainly clean stones with obvious interstices	4
Mainly stones with some cover of algae / silt	3
Bottom heavily silted but stable	2
Bottom mainly loose and mobile sediment	1
12. Stream detritus	
Mainly unsilted wood, bark, leaves	4
Some wood, leaves etc. with much fine detritus	3
Mainly fine detritus mixed with sediment	2
Little or no organic detritus	1

Descriptor and category	Score
6. Bank undercutting	
None, or restricted by tree roots	4
Only on curves and at constrictions	3
Frequent along all parts of stream	2
Severe, bank collapses common	1
7. Channel form	
Deep: width / depth ratio < 7:1	4
Medium: width / depth ratio 8:1 to 15:1	3
Shallow: width / depth ratio > 15:1	2
Artificial: concrete or excavated channel	1

Descriptor and category	Score
13. Aquatic vegetation	
Little or no macrophyte or algal growth	4
Substantial algal growth; few macrophytes	3
Substantial macrophyte growth; little algae	2
Substantial macrophyte and algal growth	1

Appendix B

Fish habitat classification criteria for watercourses and recommended crossings types

Appendix B

Fish habitat classification criteria for watercourses and recommended crossings types (Source: Fairfull and Witheridge, 2003)

Classification	Characteristics of waterway type	Minimum recommended crossing type
Class 1 – major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.	Bridge, arch structure or tunnel
Class 2 – moderate fish habitat	Named permanently or intermittent stream, creek or waterway with clearly defined bed and banks and with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge, arch structure, culvert or ford
Class 3 – minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert or ford
Class 4 – unlikely fish habitat	Named or unnamed watercourse with intermittent flow during rain events only, little or no defined drainage channel, little or no free standing water or pools after rain event (e.g. dry gullies or shallow floodplain depression with no permanent wetland aquatic flora present).	Culvert, causeway or ford

Appendix C

Raw data for water quality measured *in situ* in the study area

Appendix C

Raw data for water quality measured *in situ* in the study area. Recorded by Cardno Ecology Lab 15 April 2009 to 17 April 2009

Site	13		16		17		25		27	
Watercourse	Broughton Creek		Broughton Creek		Broughton Creek		Broughton Mill Creek		Bundewallah Creek	
Replicate	1	2	1	2	1	2	1	2	1	2
Temperature (°C)	17.69	17.69	18.23	18.24	19.25	19.3	19.62	19.6	18.25	18.25
Conductivity (ms/cm)	0.06	0.06	0.06	0.06	0.06	0.06	0	0.05	0.12	0.06
Conductivity (us/cm)	97	61	105	104	102	102	16	25	166	96
Salinity (ppt)	0.05	0.05	0.03	0.03	0.03	0.03	0	0.03	0.06	0.03
pH	7.17	7.17	7.05	7.05	6.91	6.9	6.67	6.65	6.57	6.54
ORP (mV)	419	423	398	404	379	381	498	496	313	326
Dissolved oxygen (% sat.)	109.3	109.8	108.9	109.8	157.8	156	122	125.1	108.9	109.4
Dissolved oxygen (mg/L)	10.5	10.5	10.2	10.4	14.6	14.4	11.1	11.4	10.3	10.4
Turbidity (NTU)	0	0	0	0	0	0	1.5	5.1	1.1	0.6
Turbidity (NTU)	0	0	0	0	0	0	2.1	4.6	1.7	1.1
Turbidity (NTU)	0	0	0	0	0	0	1.2	5.3	2.2	1.4

Appendix D

Field data for fish and mobile macroinvertebrate sampling

Appendix D

Field data for fish and mobile macroinvertebrate sampling. See Figure 2.1 for site locations. Recorded by the Ecology Lab 15 April 2009 to 17 April 2009

Family name	Species name	Common name	Site 13	Site 22	Site 25	Site 27
			Broughton Creek	Unnamed watercourse	Broughton Mill Creek	Bundewallah Creek
Anguillidae	*Anguilla reinhardtii*	Longfinned Eel	✓		✓	✓
Galaxiidae	*Galaxias maculatus*	Common Jollytail	✓			✓
Retropinnidae	*Retropinna semoni*	Australian Smelt	✓		✓	✓
Poeciliidae	*Gambusia holbrooki*	Mosquito Fish#		✓		
Scorpaenidae	*Notesthes robusta*	Bullrout	✓			
Percichthyidae	*Macquaria novemaculeata*	Australian Bass	✓		✓	✓
Gobiidae	*Philypnodon grandiceps*	Flathead Gudgeon	✓			
Gobiidae	*Gobiomorphus australis*	Striped Gudgeon	✓			
Atyidae	-	Freshwater Shrimp	✓			

 # = alien species

Appendix E

Assessments of significance

Appendix E – Assessments of significance

Assessments of significance were conducted for the potential impact of the project on three threatened species and two endangered ecological communities (EECs): Macquarie Perch, Australian Grayling, Black Cod, Coastal Saltmarsh and Freshwater Wetlands on Coastal Floodplains. Where relevant, assessments were made in accordance with the EPBC Act *Significant Impact Guidelines 1.1* (DEWHA 2009), the *Guidelines for Threatened Species Assessment* (DEC/DPI 2005) for Part 3A development applications and referral guidelines for specific species (where applicable).

EPBC Act impact assessments

Macquarie Perch, *Macquaria australasica*

The Macquarie Perch (*Macquaria australasica*) is currently listed as endangered under the national EPBC Act. The assessment below was undertaken with reference to *Draft referral guidelines for the endangered Macquarie Perch, Macquaria australasica* (DSEWPaC 2011).

Macquarie Perch was not recorded during field survey nor are there any formal records of it occurring within the study area. Perch are usually found at higher elevations than are generally present in the study area (DPI 2005a); however some researchers have suggested that the Macquarie Perch was possibly a historic inhabitant of low elevation reaches of the Shoalhaven River system (Bishop 1979, Gehrke *et al*. 2001). However, the Broughton catchment is relatively small, competitive Australian Bass are abundant in the lower reaches and habitat is ephemeral at higher elevations. As such the study area is considered unlikely to sustain a viable population of Macquarie Perch.

Is the action likely to lead to a long-term decrease in the size of a species?

Causes of the decline of the Macquarie Perch include; barriers to spawning migrations, overfishing, habitat degradation and fragmentation, impacts on invertebrate food fauna and infection by the epizootic haematopoietic necrosis virus (EHN) (Morris *et al*. 2001, McDowall 1996).

Threatening processes potentially associated with the project include the creation of barriers to fish passage created by the installation of inappropriate channel crossings. Macquarie Perch migrate upstream in spring to spawn and barriers to this migration would create a reduction in available spawning habitat that could lead to subsequent reductions in recruitment and population size.

Earthworks associated with the construction of roads and channel crossing structures may mobilise sediments into waterways that could result in the downstream smothering habitat and deep holes. Due to the low elevation of the upper reaches of waterways in the project area it is unlikely that sufficient spawning habitat exists for perch reproduction. Given that perch migrate upstream to reproduce it is uncertain if any reach within the study area is of sufficient elevation to constitute potential spawning habitat.

These potential impacts can be minimised or eliminated by implementing the suggested recommendations, and as such it is considered unlikely that the project would lead to a long-term decrease in populations of *M. australasica*.

Would the action reduce the area of occupancy of the species?

Barriers to passage created by inappropriate channel crossings could conceivably reduce the area of occupancy downstream of the structure if there was little or no spawning habitat available (especially as perch migrate a distance upstream to spawn). Recruitment failure would ensure the eventual local extinction of the downstream population. If Macquarie Perch did occupy lower reaches of the Shoalhaven catchment this might explain the failure to record any fish in the catchment beneath Tallowa Dam in the last 25 years.

A temporary reduction in occupancy is possible in downstream areas during construction if there is an increase in the volume of suspended sediments. Large volumes of suspended sediments can be a direct cause of mortality due to the inability of the fish to respire through clogged gills. However this is also unlikely to cause long-term declines in populations as the incidents would only last as long as the duration of the high sediment loads.

These potential impacts can be minimised or eliminated by implementing the suggested recommendations (Section 5.1), and as such it is considered unlikely that the project would lead to a reduction in the area of occupancy of *M. australasica*.

Would the action fragment an existing important population into two or more populations?

Populations of the western catchment form of the Macquarie Perch have become fragmented across much of their previous range due to the creation of barriers such as dams and weirs (Morris *et al*. 2001). In instances where regulated flows have inhibited spawning cues or barriers have prevented access to spawning habitat, these isolated populations have declined (Morris *et al*. 2001).

If Gehrke *et al*. (2001) are correct in their observations that historically fish in the Shoalhaven formed a continuous community from 500 metres AHD to tidal level, then populations of Macquarie perch were fragmented by the construction of the Tallowa Dam. It is possible that the construction of inappropriate channel crossings that create a barrier to fish passage could similarly fragment populations should they be present in the study area.

Loss of spawning habitat to sedimentation is unlikely to fragment a population unless a considerable length of a watercourse has been affected such that even migrating groups of fish became reproductively isolated. This is even less plausible in the project area given that the majority of watercourses downstream of the alignment are at fairly low elevations and are therefore unlikely to contain perch spawning grounds.

It is possible that increased siltation could cause shallow sections of a channel to become more effective barriers to fish movement during periods of low flow and similarly diminish the frequency and/or effectiveness of deeper holes to provide refuge. However, variable flow and the resulting periodic fragmentation of populations are natural phenomena in Australian freshwater systems.

If suggested recommendations are implemented to minimise sediment loads and install drainage structures that allow fish passage it is unlikely that the isolation of currently interconnecting areas of habitat would be greater than is currently experienced.

Would the action adversely affect habitat critical to the survival of a species?

Macquarie Perch are generally found in freshwater reaches with low sediment loads that contain sequences of pools and riffle habitat with occasional deep holes with snags. Failure to adequately control sediments could result in the infilling of deep holes and the smothering of shallow riffle habitat found downstream of construction sites.

These potential impacts can be minimised if the recommended mitigation measures are implemented.

Would the action disrupt the breeding cycle of a population?

Macquarie Perch begin a migration upstream during spring when water temperatures reach 16^0C and form spawning aggregations in pools at the head of riffles (Morris *et al*. 2001). Their eggs are carried downstream and lodge among pebbles and gravel in riffles, usually about 0.50 metres to 0.75 metres deep with a flow rate of ~one metre per second (McDowall 1996). Barriers to passage created by crossings can prevent the perch reaching this spawning habitat.

Increased sedimentation from earthworks during construction (and unprotected spoil piles after) can result in smothering the riffle habitat of cobble and gravel where the perch's adhesive eggs would normally become lodged. Studies have also demonstrated that suspended sediments can negatively impact egg and fry development and disrupt the ability of some freshwater fish to migrate to spawning sites. However, given the relatively low elevation of the study area it is considered unlikely that there would be any perch spawning sites downstream of a construction site placed anywhere along the project corridor.

These potential impacts from barriers to passage can be avoided by the selection of appropriate channel crossing for the class of watercourse.

Would the action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

Channel crossing structures that create barriers to fish passage can potentially isolate downstream populations from refuge, foraging and spawning habitat above the crossing although these would still be accessible to populations above the structure (and vice versa).

High sediment loads can degrade foraging and refuge habitat below the construction site and a loss of riparian vegetation may result in a decline in the abundance of aquatic macroinvertebrate prey.

However it is unlikely these impacts would occur if the proposed safeguards are adopted.

Would the action result in invasive species that are harmful to an endangered species becoming established in the endangered species' habitat?

There is a possibility that the distribution of Alligator Weed would be increased locally by construction activities associated with the project. Alligator Weed is an environmental pest that can choke waterways and severely degrade habitat.

Alligator Weed grows vegetatively and can be spread from fragments attached to machinery. It is therefore possible that fragments might be transported on machinery from an area of infestation to an area where it is not yet established.

However, whilst Alligator Weed was reported by the EPBC Environmental Reporting Tool, no other records could be found for its presence within the study area.

The project is considered unlikely to result in an invasive species becoming established if the suggested recommendations are implemented (Section 5.1). Examples include training workers how to identify and dispose of Alligator Weed and to conduct regular inspections of machinery used on site.

Would the action introduce disease that may cause the species to decline?

Acid sulfate soils (ASS) are known to occur within the low lying areas of the Broughton Creek catchment. The resulting low pH waters can damage the surface of fish's skin and gills. Skin damage can increase the susceptibility of fish to fungal infections which may lead to diseases such as epizootic ulcerative syndrome, also known as 'red spot' disease. The Macquarie Perch is particularly susceptible to the red spot disease (Morris *et al*. 2001, McDowall 1996).

The probability of ASS within the project corridor is low and measures to address potential runoff from acid sulfate soils would be implemented and hence the project is considered unlikely to introduce or enhance the risk of disease.

Would the action interfere substantially with the recovery of the species?

Recovery objectives for the Macquarie Perch relative to this region include the prevention of siltation, the preservation of natural flows and removal of existing barriers to fish passage (Morris *et al*. 2001). It is possible that the project could interfere with these objectives, for instance if soil and erosion were poorly managed, but this is considered unlikely if the suggested recommendations are adopted.

Conclusion

Macquarie Perch are unlikely to occur in the study area. If Macquarie Perch were present, potential impacts of the project can be effectively minimised or eliminated by the adoption of recommendations to design and construction methods, and hence no direct or indirect impacts on populations or habitat are predicted. Referral of this project in relation to this species to DSEWPaC is therefore not required (DSEWPaC 2011).

Australian Grayling, *Prototroctes maraena*

The Australian Grayling is listed as a Vulnerable Species under the EPBC Act. No grayling were recorded during the current survey but previous Australian Museum collections have identified the Australian Grayling within the adjacent Broughton Creek catchment. However, the study area catchment is relatively small, freshwater habitat is degraded and is considered unlikely to sustain a viable population of grayling. The assessment of significance for the potential impact of the project was carried out as a precautionary measure.

Is the action likely to lead to a long-term decrease in the size of an important population of a species?

The Australian Grayling is believed to have suffered a severe decline during the latter half of the 20th Century throughout most of its range (Morris *et al*. 2001). It has not been recorded in the northernmost extent of its range (the Grose River) since the 1950s and only one specimen has been found in the Shoalhaven River catchment since the completion of the Tallowa Dam in 1976 (Morris *et al*. 2001). Subsequent significant sampling in the Shoalhaven River by the NSW Rivers Survey (Harris and Gehrke 1997) and the Tallowa Fishway study (Gehrke *et al*. 2001) failed to find any grayling. Similarly, Faragher (1999) found no grayling in Broughton Creek or the Shoalhaven River but was responsible for the sole capture of an individual from the Shoalhaven system (in the last 30 years) in Yalwal Creek to the south.

The major cause of this decline is river regulation and barriers to fish passage created by dams, weirs and inappropriate channel crossings. Barriers disrupt the diadromous life cycle of *P. maraena*, preventing larvae being swept downstream to estuarine and marine waters and juveniles migrating back upstream to adult freshwater habitat (Morris *et al*. 2001). Tallowa Dam has been estimated to restrict the access of migrating fish to 80 per cent of the Shoalhaven River (Harris 1984). Adult grayling suffer heavy post-spawning mortality so local extirpation is possible after only a few years without juvenile recruitment (Morris *et al*. 2001).

The construction of instream structures can also directly cause mortality events. During the construction of the Tallowa Dam the flow of the Shoalhaven River was completely blocked on a number of occasions for associated work to take place (Bishop and Bell 1978). During one such stoppage in 1976, 312 grayling were killed after being stranded when water levels beneath the dam dropped so rapidly that much of the river bed became dry (Bishop and Bell 1978). Only one grayling has been captured in the entire Shoalhaven catchment since.

Increased siltation and the loss of riparian vegetation are also believed to have contributed to the grayling's decline (Morris *et al*. 2001). Increased volumes of suspended sediment can smother gravel on the streambed which the grayling use for the development of their eggs and the loss of riparian vegetation can negatively affect macroinvertebrate communities which the grayling feed upon.

Threatening processes associated with the project could potentially cause a decrease in local populations of grayling (should they be present). The installation of inappropriate waterway crossings may alter natural flows and/or restrict fish passage. The construction of these structures could mobilise sediments into the watercourse that results in the loss of spawning habitat or expose acid sulfate soils that would reduce the water quality in lowland reaches inhabited by larvae and juveniles.

The project is considered unlikely to cause a long-term decrease in Australian grayling populations if the suggested recommendations are implemented (Section 5.1). These include the construction of crossing structures that maintain fish passage and effective control measures to mitigate the mobilisation of sediments.

Would the action reduce the area of occupancy of an important population?

The installation of crossings that create a barrier to fish passage could potentially reduce occupancy in areas upstream of the structure and possibly downstream (depending on the adequacy of remaining habitat beneath the barrier). For example, given that the grayling can be found in elevations up to 1000 metres ASL (McDowall 1996), the construction of the Tallowa Dam restricted access to ~80 per cent of the Shoalhaven River (Harris 1984). The dam represents an absolute barrier to the grayling and because grayling migrate between fresh and salt water (diadromous lifecycle), populations above the dam have completely disappeared. Despite rigorous sampling (Harris and Gehrke 1997, Faragher 1999, Gehrke *et al*. 2001) only one individual has been collected in the catchment beneath the dam since 1976, suggesting that populations downstream of the barrier have declined dramatically.

A temporary reduction in occupancy is possible in downstream areas during construction if there is an increase in the volume of suspended sediments. Large volumes of suspended sediments can be a direct cause of mortality due to the inability of the fish to respire through clogged gills. This is unlikely to cause long-term declines in populations as the incidents would only last as long as the duration of the high sediment loads. Increased sedimentation can also smother available spawning habitat downstream of the construction. This may affect downstream occupancy if there is little alternative spawning habitat.

The project is considered unlikely to reduce the Australian Grayling's area of occupancy if the suggested recommendations are implemented (Section 5.1). These include the construction of crossing structures that maintain fish passage and effective control measures to mitigate the mobilisation of sediments.

Would the action fragment an existing important population into two or more populations?

It is unlikely that the construction or operation of the project would lead to the fragmentation of grayling populations. Because grayling migrate between fresh and salt water (diadromous), a crossing that created a barrier to passage would lead to the local extinction of the species upstream of the structure, not the creation of two separate populations.

The degradation of possible spawning habitat downstream of the construction site from sedimentation may reduce recruitment but would not separate populations as juveniles could still recolonise upstream and adults would be able to move freely. Increased siltation could cause existing shallow sections of the channel to become more effective barriers to fish movement during periods of low flow perhaps increasing the temporary or seasonal fragmentation of populations. However variable flow and the resulting seasonal fragmentation of populations are natural phenomena in Australian freshwater systems.

If suggested recommendations to minimise sediment mobilisation are implemented it is unlikely that the isolation of currently interconnecting areas of habitat would be greater than is currently experienced.

Would the action adversely affect habitat critical to the survival of a species?

Channel crossing structures that impede fish passage would not physically harm critical habitat upstream but would restrict or remove access to it.

Increased sedimentation during construction could lead to loss of downstream spawning habitat from smothering. The extent of possible spawning habitat in Class 2 watercourses within the study area is expected to be limited.

The project is considered unlikely adversely affect critical habitat if the suggested recommendations are implemented (Section 5.1).

Would the action disrupt the breeding cycle of an important population?

Adult grayling do not migrate to breed but spawn in the same general area they normally inhabit. Grayling prefer watercourses with moderate flows and gravel beds (McDowall 1996). After spawning the eggs settle into the gravel substrate where they develop and the larvae hatch (Morris *et al*. 2001). Newly hatched larvae are positively photo tactic and swim to the surface where they are swept downstream to estuarine or marine waters and only migrate back to adult freshwater habitats at the age of six months (Morris *et al*. 2001). Channel crossing structures that create barriers to passage would prevent the downstream flow of grayling larvae in autumn and the upstream migration of juveniles in spring. The recruitment failure in the population above the barrier and high post-spawning mortality of adults would likely cause extirpation after a few years.

Increased sedimentation would also affect the availability of spawning habitat downstream of construction with concomitant reductions in recruitment.

The project is considered unlikely to disrupt the breeding cycle of the Australian Grayling's area if the suggested recommendations are implemented (Section 5.1). These include; the construction of crossing structures that maintain fish passage and effective control measures to mitigate the mobilisation of sediments.

Would the action modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline?

There are a number of Class 1 and Class 2 watercourses in the catchment providing major to moderate fish habitat. Inappropriate road crossings could prevent grayling passage upstream to refuge, foraging and spawning habitat. High sediment loads from construction earthworks could also potentially degrade downstream spawning habitat.

The project is considered unlikely to affect grayling habitat if the suggested recommendations are implemented (Section 5.1).

Would the action result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat?

There is a possibility that the distribution of Alligator Weed would be increased locally by construction activities associated with the project. Alligator Weed is an environmental pest that can choke waterways and severely degrade habitat.

Alligator Weed grows vegetatively and can be spread from fragments attached to machinery. It is therefore possible that fragments might be transported on machinery from an area of infestation to an area where it is not yet established.

However, whilst Alligator Weed was reported by the EPBC Environmental Reporting Tool, no other records could be found for its presence within the study area.

The project is considered unlikely to result in an invasive species becoming established if the suggested recommendations are implemented (Section 5.1). Examples include training workers how to identify and dispose of Alligator Weed and to conduct regular inspections of machinery used on site.

Would the action introduce disease that may cause the species to decline?

Acid sulfate soils (ASS) are known to occur within the low lying areas of the Broughton Creek catchment. The resulting low pH waters can damage the surface of fish's skin and gills. Skin damage can increase the susceptibility of fish to fungal infections which may lead to diseases such as epizootic ulcerative syndrome, also known as 'red spot' disease.

The probability of ASS within the project corridor is low and measures to address potential runoff from acid sulfate soils would be implemented and hence the project is considered unlikely to introduce or enhance the risk of disease.

Would the action interfere substantially with the recovery of the species?

Priority recovery objectives for the Australian Grayling that are relevant to the project include improving fish passage, ensuring navigable migration corridors during construction, reducing erosion and siltation, and the rehabilitation of degraded riparian vegetation (Morris *et al*. 2001).

Key components of the National Recovery Plan for Australian Grayling include identification of important populations and catchment management to restore and protect habitat (Backhouse *et al. 2008a).* It is unlikely that the threatening processes associated with the project would affect the potential recovery of the Australian grayling providing the suggested recommendations are implemented. Restoration of riparian habitat (as recommended in the Biodiversity Offset Strategy, Section 5.2) is consistent with key strategies of the national recovery plan for Australian Grayling (Backhouse *et al. 2008b)*

Conclusion

The key threats that the project poses to the Australian Grayling include disruption to the grayling's diadromous life cycle where it migrates between fresh and salt water and the loss of spawning habitat. These potential impacts can be minimised or eliminated by implementing the suggested recommendations. Referral of this project in relation to this species to DSEWPaC is therefore not required.

Part 3A Assessment of Threatened Species, Populations and Ecological Communities

The potential impacts of the project on aquatic species, populations and EECs listed in Schedules of the TSC Act and FM Act were assessed according to OEH and DTIRIS "*Guidelines for Threatened Species Assessment*" (DEC/DPI 2005). The guidelines identify important factors and/or heads of consideration that must be considered by proponents when assessing impacts on threatened species, populations, or ecological communities for development applications assessed under Part 3A of the EP&A Act.

Macquarie Perch, *Macquaria australasica*

The Macquarie Perch (*Macquaria australasica*) is currently listed as Vulnerable under the FM Act and as such it is necessary to assess the potential impacts of the project under the *Guidelines for Threatened Species Assessment*.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Macquarie Perch usually inhabit the upper reaches of clear, freshwater water courses containing deep, rocky pools with upstream riffle and pool sequences for spawning (Allen *et al*. 2003, DPI NSW 2005a). They migrate upstream to spawn in October to November and their eggs settle and develop in the gravel and cobble found in riffle habitat. The distribution of the eastern form can also be a function of interactions with other species. For example, if Australian Bass (*Macquaria novemaculeata*) are found in a watercourse then typically Macquarie Perch would only be found upstream of them (McDowall 1996).

Threatening processes potentially associated with the project include barriers to fish passage created by the installation of inappropriate channel crossings. During spring when water temperatures reach 16 degrees celcius, Macquarie Perch migrate upstream to spawn (Morris *et al*. 2001). They form spawning aggregations in pools at the head of riffles and their eggs are carried downstream and lodge among pebbles and gravel in riffles where they would develop (McDowall 1996). Barriers that impede this breeding migration can lead to a reduction in recruitment and eventual decline in population size. Earthworks required in the construction of roads and water crossings may mobilise sediments that results in the smothering of spawning habitat or deep holes. Studies have also demonstrated that suspended sediments can negatively impact egg and fry development and the survival of macroinvertebrate prey.

There have been no low-elevation records of Macquarie Perch in the region for nearly 30 years and none within the Broughton catchment and furthermore, it is unlikely that the project would have an adverse effect on the life cycle of the Macquarie Perch if the recommended mitigation measures to address sedimentation and siltation are adopted.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

Macquarie Perch are generally found to inhabit freshwater reaches with low sediment loads that contain deep holes with snags and adjacent riffle habitat.

Earthworks associated with the construction of roads and crossings can result in the mobilisation of sediments into the waterway. Given that Macquarie Perch are generally found in clear waters a temporary reduction in occupancy is possible in downstream areas during construction if there is a large increase in the volume of suspended sediments. Furthermore, increased sedimentation can potentially degrade habitat utilised for refuge, foraging and spawning. Refugia such as deep holes can infill and riffle habitat, where fertilised eggs lodge and develop, can become smothered. However given the low elevation of most watercourses within the study area it is considered unlikely that they contain spawning sites.

It is considered unlikely the project would substantially affect perch habitat if the recommended mitigation measures are implemented.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

There are no records of Macquarie Perch from within the study area, which has a low coastal elevation. Macquarie Perch preferentially inhabit and migrate to spawn in relatively undisturbed higher elevation reaches, such as those found in the Mongarlowe River. The reaches upstream of the bass distribution in Broughton Creek are considered unlikely to provide appropriate habitat for the persistence of a Macquarie Perch population. In addition there have been no low-elevation records of Macquarie Perch in the region for nearly 30 years and none within the Broughton catchment. In the unlikely event that Macquarie Perch did occur within the study area it could be possible that it was at the limit of its eastern, lowland distribution. As there is no evidence to suggest that Macquarie Perch occurs within the study area, it is not considered that the proposal would affect a proposal at the limit of its distribution.

How is the proposal likely to affect current disturbance regimes?

Freshwater habitat within the study area is considered to be variable, ranging from relatively healthy to significantly degraded. The riparian vegetation was extremely degraded or absent along most waterways that intersect the project. Similarly, there was little large woody debris present. Therefore, it is unlikely that the project could further degrade riparian areas such that it would cause a significant impact on Macquarie Perch.

Water quality in the catchment is typical of aquatic ecosystems that have been disturbed by agricultural practices. Downstream of the study area, in the low-lying floodplain, the tributaries of Broughton Creek have been highly modified by flood mitigation works.

The threatening processes listed under the FM Act relevant to the project that require consideration include:

- The removal of large woody debris.
- The degradation of riparian vegetation.
- The installation of instream structures (ie bridges and culverts) and other mechanisms that alter natural flow regimes of rivers and streams.

The operation of instream drainage structures constructed during the project should have little or no impact on Macquarie Perch given they also conform to ‘minimum’ recommended crossing types outlined in ‘*Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings*’ (Fairfull and Witheridge 2003).

It is possible that the project could have a cumulative impact on the current disturbance regime although this is considered unlikely if the recommended mitigation measures are implemented.

How is the proposal likely to affect habitat connectivity?

Of the habitats potentially affected by the project, access to upstream spawning sites would be the most critical. Without suitable breeding habitat beneath a barrier to passage, which appears to be the case given the low elevation of the study area, the continuous recruitment failure would quickly lead to the collapse of the downstream population.

Barriers to passage created by inappropriate water crossings can reduce access to upstream spawning, refuge and foraging habitat for perch populations beneath the barrier and downstream refuge and foraging habitat for perch above it. The degree to which a channel crossing acts as a barrier would vary with the type of structure and flow conditions. The effect it has on status of perch would depend on the fragmented population's access to remaining habitat. If there was little remaining spawning habitat for the downstream fish, recruitment failure and local extinction could result. If Macquarie Perch did historically occupy lower reaches of the Shoalhaven River this could explain the failure to record any beneath the dam in the last 25 years. Upstream populations although isolated could persist if there were adequate habitat and resources, as they have done above the Tallowa Dam.

How is the proposal likely to affect critical habitat?

No sites of Critical Habitat have been listed for Macquarie Perch

Conclusion:

The key threats that the project poses to the Macquarie Perch include the creation of barriers to perch spawning migrations and the smothering of spawning habitat by siltation. Potential impacts on local populations can, however, be effectively minimised or eliminated by the implementation of the recommended mitigation measures, such that the proposal is unlikely to have a significant impact on this species.

Black Cod *Epinephelus daemelii*

The Black Cod (*Epinephelus daemelii*) is currently listed as Vulnerable under the FM Act and as such it is necessary to assess the potential impacts of the proposal under the NSW Guidelines for Threatened Species Assessment. Black Cod was not recorded during field survey nor are there any formal records of it occurring within the study area.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Large juvenile Black Cod inhabit estuaries along coastal NSW. Within estuarine systems they are often caught in association with rocky reefs but it is possible that they also utilise seagrass habitat (I&I NSW 2009). There are records of Black Cod from the region and potential seagrass habitat in the lower reaches of the estuary.

Threats to Black Cod include the loss or degradation of nursery habitat (DPI 2007a). Potential impacts on Black Cod nursery habitat from the proposal relate to pollution and increased sediment loads. However, assuming the use of effective sediment controls and proper handling of hazardous substances, it is considered unlikely that the proposal would generate downstream impacts that might significantly degrade Black Cod nursery habitat and hence affect the life cycle of the species.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

The Crooked River lagoon and Shoalhaven/Crookhaven estuary are Potential habitat for large juvenile Black Cod. This area would not, however, be removed, modified, fragmented or isolated providing the recommended mitigation measures are adopted and properly implemented.

The proposal is consistent with the objectives of the Black Cod draft recovery plan (I&I NSW 2011) providing recommendations relating to sediment and pollution control are implemented.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

The distribution of Black Cod is known to extend across the NSW coastal zone and the proposal is not likely to affect a population at the limit of this distribution.

How is the proposal likely to affect current disturbance regimes?

The existing level of disturbance in the lower estuary is variable but may include surface runoff from urbanisation and development. Provided that measures to mitigate sedimentation and erosion in relation to the construction works are implemented, the proposal is not likely to affect existing levels of disturbance.

How is the proposal likely to affect habitat connectivity?

The proposal is unlikely to affect the connectivity of Black Cod habitat as it would not modify, fragment or isolate known populations.

How is the proposal likely to affect critical habitat?

Black Cod are listed as a vulnerable species and as such their habitat is not eligible to be listed as critical habitat.

Conclusion:

The key threat that the proposal poses to the Black Cod is the potential degradation of estuarine nursery habitat caused by sedimentation and pollution. Potential impacts can be effectively minimised or eliminated by the adoption of the recommended mitigation measures such that the proposal is unlikely to have a significant impact on this species.

Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions

Freshwater wetlands are listed as an EEC under the TSC Act and as such, it is necessary to assess the potential impacts of the proposal under the Guidelines for Threatened Species Assessment.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Freshwater wetlands are not a listed threatened species or population.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

Two small freshwater wetlands areas were identified by Chafer (1997) within the Crooked River catchment; the Willow Vale wetlands west of the Princes Highway and the Gerringong Wetlands east of the Princes Highway. Coomonderry Swamp lies outside of the catchment potentially impacted by the proposed works. Potential threats to freshwater wetlands on coastal floodplains relevant to the proposal include; pollution, changes to hydrology and infilling from sedimentation.

The Willow Vale wetlands are highly degraded and are found at the upper elevation limits of what has been defined as Freshwater Wetlands of Coastal Floodplains. They are upstream of the proposal and are therefore unlikely to be affected by potential threats associated with the proposal which would only affect downstream reaches.

The small Gerringong Wetlands are a highly degraded series of pondages and swamp associated with degraded creeks that pass through and near south-west Gerringong. These creeks are considered unlikely to provide fish habitat and are infested with exotic weeds. This habitat is also at the upper elevations limits of for Freshwater Wetlands of Coastal Floodplains.

Proper handling, storage, transport and disposal of hazardous substances used on site would minimise the chance of a spill during construction causing downstream pollution. The proposal is unlikely to cause significant changes to the hydrology of waterways within the Crooked River catchment if recommendations to (i) maintain the natural form of Crooked River realignment (ii) install appropriate drainage structures at road crossings are implemented. Implementation of recommended sediment controls would minimise mobilisation of sediments into waterways and downstream aquatic habitats.

It is considered unlikely that the proposal would affect the habitat of a threatened species, population or ecological community associated with freshwater wetlands downstream of the study area.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

Freshwater wetlands are not a listed threatened species or population.

How is the proposal likely to affect current disturbance regimes?

The freshwater wetlands potentially affected by the proposed works are already moderately to highly disturbed. Provided that the proposed works are carried out in accordance with the mitigation methods outlined during the construction phase of works, the proposal would not be expected to have any long term impact on the current disturbance regime.

How is the proposal likely to affect habitat connectivity?

Freshwater wetlands on coastal floodplains within the Crooked River catchment are unlikely to be removed, modified, fragmented or isolated as a result of the proposal. It is not therefore expected that the proposal would impact upon habitat connectivity.

How is the proposal likely to affect critical habitat?

No sites of Critical Habitat have been listed for freshwater wetlands on coastal floodplains.

Conclusion:

Potential threats to freshwater wetlands on coastal floodplains relevant to the proposal include; pollution, changes to hydrology and infilling from sedimentation. Potential impacts can be effectively minimised or eliminated by the adoption of the recommended mitigation measures such that the proposal is unlikely to have a significant impact on this threatened ecological community.

Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions

Coastal Saltmarsh is listed as an EEC under the TSC Act and as such it is necessary to assess the potential impacts of the proposal under the Guidelines for Threatened Species Assessment.

How is the proposal likely to affect the lifecycle of a threatened species and/or population?

Coastal saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions is not a listed as a threatened species or population.

How is the proposal likely to affect the habitat of a threatened species, population or ecological community?

There is no significant saltmarsh habitat within Werri Lagoon (Williams et al. 2006). Saltmarsh is present within the Crooked River estuary and covers an estimated area of 0.017 square kilometres (West et al. 1985, The Ecology Lab 1999, Williams et al. 2006).

Potential threats to coastal saltmarsh relevant to the proposal include pollution, changes to salinity from stormwater discharge and invasion by mangroves. However, geotechnical studies have indicated that the proposal is unlikely to cause significant changes to hydrology and therefore patterns in salinity downstream in the Crooked River estuary would remain unaffected. Proper handling, storage, transport and disposal of hazardous substances used on site would minimise the chance of a spill during construction causing downstream pollution (Recommendations, Section 5). Similarly, appropriate design of stormwater runoff structures would minimise possibilities of contamination of aquatic habitats from highway runoff. Increased sedimentation can facilitate the invasion of mangroves but the implementation of recommended sediment controls (Section 5) would minimise mobilisation of sediments into waterways and downstream aquatic habitats.

It is considered unlikely that the proposal would affect the habitat of a threatened species, population or ecological community associated with coastal saltmarsh downstream of the study area.

Does the proposal affect any threatened species or populations that are at the limit of its known distribution?

Coastal saltmarsh is not a threatened species or population.

How is the proposal likely to affect current disturbance regimes?

The proposal is unlikely to significantly affect the existing level of disturbance to coastal saltmarsh. Coastal saltmarsh habitat would not be directly affected by the proposal and no long term impacts to these habitats downstream of the proposed construction works would be affected.

How is the proposal likely to affect habitat connectivity?

Coastal saltmarsh within the vicinity of the study area is unlikely to be removed, modified, fragmented or isolated as a result of the proposal such that habitat connectivity would be affected.

How is the proposal likely to affect critical habitat?

No sites of Critical Habitat have been listed for coastal saltmarsh.

Conclusion:

Threats to coastal saltmarsh relevant to the proposal include pollution, changes to salinity from stormwater discharge and invasion by mangroves. Potential impacts can be effectively minimised or eliminated by the adoption of the recommended mitigation measures such that the proposal is unlikely to have a significant impact on this threatened ecological community.

Appendix F

Outline of surface water quality monitoring program

Appendix F – Outline of surface water quality monitoring program

Background

The following sampling program would be proposed to monitor water quality impacts of the project during both construction and operational phases. The program takes a similar approach to the Surface Water Monitoring Program that is currently being implemented by Cardno for the Tintenbar to Ewingsdale Pacific Highway upgrade within that sensitive receiving environment. This proposed approach underwent significant stakeholder consultation with Office of Environment and Heritage (OEH) and Department of Investment, Regional Infrastructure and Services (NOW and Fisheries) and has been approved by RMS and the Department of Planning and Infrastructure for the Tintenbar to Ewingsdale Pacific Highway upgrade.

The primary objective of the program would be to minimise the impacts to downstream surface water quality to protect aquatic ecology and ecosystem characteristics. During the construction phase of the project, the greatest risk to water quality would likely be from the mobilisation of exposed sediments. Potential impacts are more likely to be detected during wet weather as a result of exceedance/failure of the proposed control measures. During the operational phase, the greatest risk to water quality would likely be as a result of increased pollutant loads resulting from road surface runoff.

Performance standards

ANZECC guidelines

The ANZECC guidelines provide a management framework, guideline water quality triggers, protocols and strategies to assist water resource managers in assessing and maintaining aquatic ecosystems. The guidelines recommend numerical and descriptive water quality guidelines to help managers establish water quality objectives that would maintain the environmental values of water resources. They are not standards, and should not be regarded as such. Of particular importance is the approach for using the ANZECC guidelines of: '*protect environmental values by meeting management goals that focus on concerns or potential problems'* (ANZECC, 2000). That is, development of a water quality monitoring program should focus on site specific issues rather than on pre-determined guideline values.

Application of these values as triggers for management action associated with the project is not considered to be appropriate as they do not take into account the external influences of the catchment on water quality. The framework and principles of ANZECC guidelines would however be utilised in the development of a project specific approach to performance standards as outlined below.

Proposed project performance standards

The surrounding land use within the catchment has potential to impact the surface water quality. As such, this potential source of pollution should be recognised in the development of project performance standards. As such the assessment should be based on the impacts directly associated with the project, not on the health of the greater catchment. For many road upgrades, monitoring during construction involves sampling water quality upstream and downstream of the construction activity.

This approach would be utilised for the project as it allows for an assessment of impacts that can be attributed to the construction /operation activities rather than the impacts related to the catchment.

For each of the proposed monitoring sites, a site specific control chart would be developed to provide a suitable reference criteria and performance standard. The control chart would be produced by plotting the median concentration from the test site (ie downstream of the bypass) against the 80th percentile of the reference site (ie upstream of the bypass). The control chart would be based on the collection of baseline data and may be kept up-to-date by recalculating the 80th percentile each month with the most recent 24 monthly observations.

The trigger criteria recommended by the ANZECC guidelines for physio-chemical stressors would be adopted for this project, comprising:

- A trigger for further investigation would be deemed to have occurred when the median concentration of independent samples taken at a test site exceeds the eightieth percentile of the same indicator at a suitably chosen reference site.

The ANZECC guidelines also note that 'the statistical significance associated with a change in condition equal to or greater than a measurable perturbation (ie median of downstream sample exceeding 80th percentile of upstream sample] would require a separate analysis (ANZECC, 2000a)). This would be undertaken using a paired t-Test or Sign Test to determine whether the observed difference is statistically significant. Where a statistically significant difference is observed, the trigger criteria is deemed to be exceeded and further mitigation and management actions would be implemented.

Monitoring sites and parameters

The selection of monitoring sites would be prioritised using a risk based approach where the areas with the highest potential to impact on aquatic ecosystems would be identified and selected for monitoring. Selection of sites would represent a downstream gradient from the identified source to enable an estimation of the geographic extent of potential water quality exceedances.

The monitoring parameters proposed, as outlined below have been selected as these are considered the most likely pollutants to be generated as a result of the construction and operation of a major road.

Parameter	Unit	Monitoring approach
Dissolved Oxygen (DO)	mg/L	In-situ readings using portable probe
Electrical Conductivity (EC)	µs/cm	In-situ readings using portable probe
Oxygen Reduction Potential (ORP)	mv	In-situ readings using portable probe
pH		In-situ readings using portable probe
Temperature	^{o}C	In-situ readings using portable probe
Turbidity	NTU	In-situ readings using portable probe
Total Suspended Solids (TSS)	mg/L	Laboratory Analysis
Oils and grease	mg/L	Laboratory Analysis
Total Petroleum Hydrocarbons (TPH)	mg/L	Laboratory Analysis
Total Phosphorus (TP)	mg/L	Laboratory Analysis
Total Nitrogen (TN)	mg/L	Laboratory Analysis
Ammonia	mg/L	Laboratory Analysis
Metals (Aluminium, Cadmium, Copper, Lead, Zinc)	mg/L	Laboratory Analysis

Sampling frequency

The sampling program would focus on wet weather monitoring as this is when pollutants would most likely be mobilised and enter the receiving water environment. The following sampling frequency is proposed:

Construction monitoring

- Monthly sampling of minor wet weather events (ie where greater than 15 millimetres of rainfall is recorded in a 24 hour period). Three replicate samples would be taken every 15 minutes.
- Event based sampling of major wet weather events (ie where greater than 50 millimetres of rainfall is recorded in a 24 hour period). Three replicate samples would be taken every 15 minutes. A maximum of three major events would be sampled per year for the duration of the construction phase.

Operational monitoring

- Sampling of minor wet weather events (as defined above) above for one, or 12 sampling events, whichever is greater.

Appendix G

Outline of aquatic ecology monitoring program

Appendix G – Outline of aquatic ecology monitoring program

Background

The following sampling program would be proposed to monitor impacts of the project on aquatic biota. The program takes the "current best practice" approach of establishing baseline conditions, sampling before, during and after construction with comparisons of relevant indices to baseline indices, and incorporating replication within yearly periods to incorporate seasonality.

The primary objective of the program would be to detect any impacts on ecological receptors and estimate their geographical scale. During the construction phase of the project, the greatest risk to receptors such as aquatic macroinvertebrates would likely be from the mobilisation of exposed sediments. Potential impacts are more likely to be detected during wet weather as a result of exceedance/failure of the proposed control measures. During the operational phase, the greatest risk to aquatic assemblages would likely be as a result of increased pollutant loads resulting from road surface runoff.

Performance standards

AusRivAS assessment

The ecological health of rivers and their catchments can be assessed by using tools based on biological indicators. One such tool is "AusRivAS", an interactive software package that provides an assessment of the condition of freshwater macroinvertebrate assemblages in a stream by comparing them to those from reference (undisturbed) streams of the same type (Davies, 1994). The AusRivAS model uses information collected for 'predictor variables' to predict the assemblage of macroinvertebrates that could be expected to occur at a particular location. The expected assemblage is then compared to the actual observed assemblage of taxa providing a basis to assess health of the stream. Predictor variables are variables that are considered unlikely to be affected by anthropogenic impacts (Norris, 1997).

Physico-chemical water quality parameters would be recorded using a portable multi-head probe prior to each sampling event to record background conditions that may help interpret biological results. Properties recorded would include:

- Conductivity (Ωs/cm).
- Salinity (ppt).
- Temperature (^{o}C).
- Turbidity (ntu).
- Dissolved oxygen (mg/L and % saturation).
- pH.
- ORP (oxidation reduction potential)(mV).

Proposed project performance standards

Application of the AusRivAS model is based on collection of field data from specific aquatic habitats using standardised, semi-quantitative techniques within two timeframes: Spring (15 September to 15 December) and Autumn (15 March to 15 June). Macroinvertebrates are identified to established levels of taxonomic resolution and, along with physico-chemical site data mainly recorded in the field, entered into the model and compared to appropriate reference streams. The following changes in AusRivAs indices for macroinvertebrate assemblages would identify impacts from road construction or operation (refer Section 2.3.2 for details of model outputs):

Index	Change required to identify impact due to road construction /operation
OE50 taxa	Reduction by one or more bands (X, A, B, C, D) relative to index established during baseline monitoring based on model output using two seasons (Spring and Autumn) for the site.
SIGNAL2	Reduction by one or more grades: • SIGNAL > 6 = Healthy habitat. • SIGNAL 5 – 6 = Mild pollution. • SIGNAL 4 – 5 = Moderate pollution. • SIGNAL < 4 = Severe pollution. relative to grade established during baseline monitoring based on model output using two seasons (Spring and Autumn) for the site.

This approach would identify the impacts directly associated with the bypass, not on the health of the greater catchment, by comparison to baseline conditions.

Monitoring sites and frequency

The selection of monitoring sites would be based on sites where construction activities are likely to have the highest potential to impact on aquatic ecosystems. Selection of sites would represent a downstream gradient from the identified sources to enable an estimation of the geographic extent of potential water quality exceedances. Site selection should include the created creek channel between Town and Bundewallah creeks with the aim of providing an indication of the time taken for the new aquatic habitat to develop natural populations of macroinvertebrates.

Sampling frequency

The sampling program relies on the establishment of sufficient baseline data against which during and post construction conditions can be compared. The following sampling frequency is proposed:

- Pre-construction: Two sampling events in Spring (15 September to 15 December) and two sampling events in Autumn (15 March to 15 June).
- During construction: Two sampling events in Spring (15 September to 15 December) and two sampling events in Autumn (15 March to 15 June), beginning as soon as riparian habitat clearing/disturbance is initiated.
- Post-construction: Two sampling events in each of two seasons Spring (15 September to 15 December) and Autumn (15 March to 15 June) for a minimum of one year after commencement of road operation.

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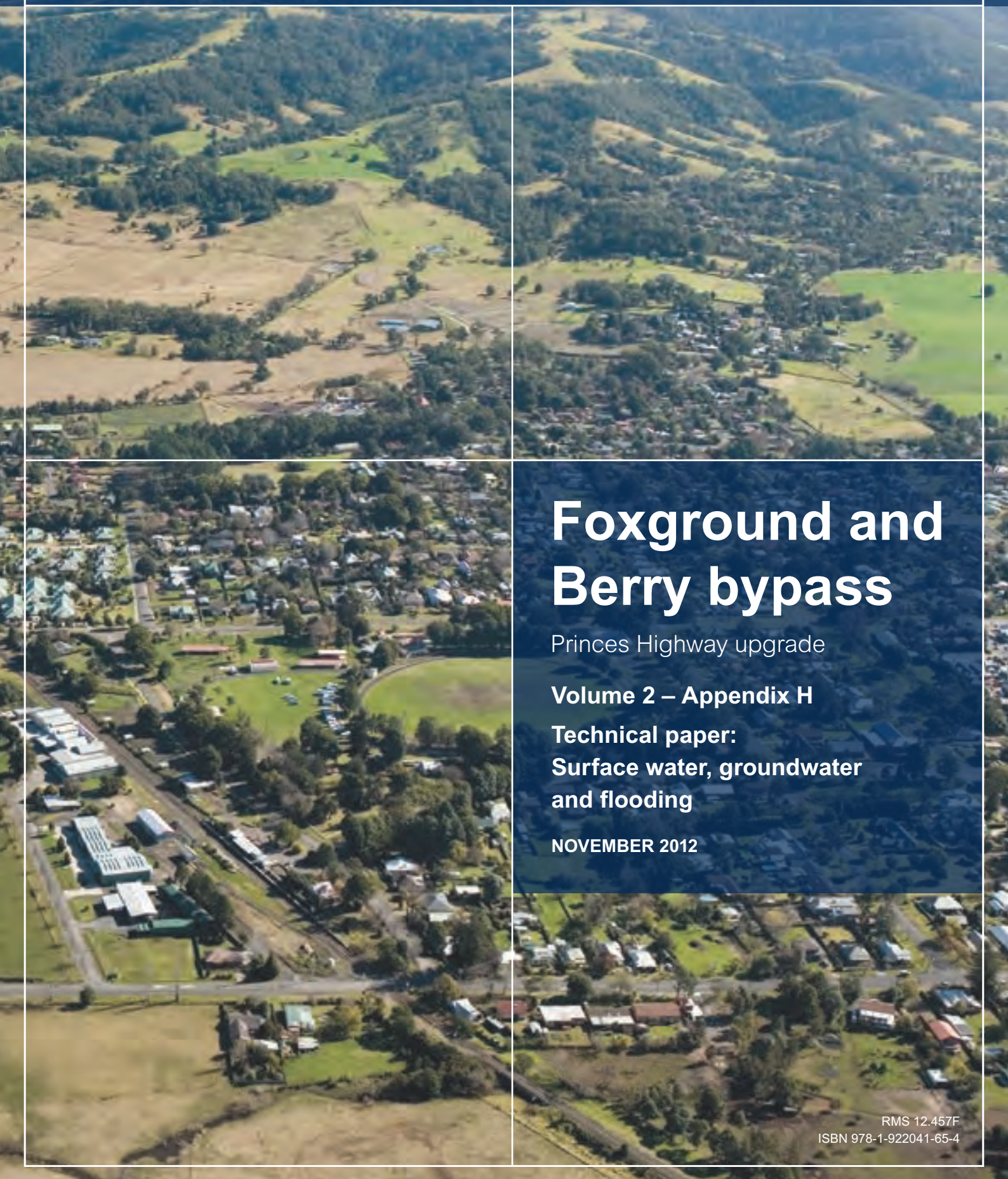

Foxground and Berry bypass

Princes Highway upgrade

Volume 2 – Appendix H

Technical paper: Surface water, groundwater and flooding

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Princes Highway upgrade

Prepared for

Roads and Maritime Services

Prepared by

AECOM Australia Pty Ltd
Level 21, 420 George Street, Sydney NSW 2000, Australia

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Executive summary

The Roads and Maritime Services (RMS) is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway, to achieve a four lane divided highway (two lanes in each direction) with median separation between Toolijooa Road north of Foxground and Schofields Lane, south of Berry (the project). The project would include bypasses of Foxground and Berry. The key features of the project are shown in **Figure 1-1**.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

This report discusses surface water, groundwater and flooding issues associated with the project.

Surface water

Existing environment

The project would begin at Toolijooa Road, pass through a large cutting and onto the Broughton Creek floodplain. It would then cross Broughton Creek three times before joining the existing Princes Highway alignment, following a ridgeline east of Berry. The project alignment would cross the confluence of Broughton Mill Creek, Connollys and Bundewallah Creek via the proposed bridge at Berry. It would then pass north of the Berry township, crossing a number of smaller catchments from the surrounding foothills, before finishing south of Schofields Lane. The project would also include the diversion of Town Creek to the north of the upgrade into Bundewallah Creek upstream of its confluence with Connollys Creek.

Water quality studies (refer to the *Aquatic Ecology and Water Quality Management Technical Paper* (Cardno, 2012) at Appendix G to this environmental assessment) determined that most waterways in the study area were considered typical of aquatic ecosystems that have been impacted due to agricultural and grazing practices, and that the existing pollution levels exceed those considered to be sustainable for maintaining ecosystem integrity. The values of total phosphorus within the Crooked River and Broughton Creek catchments are regularly above the Australia and New Zealand Environment Conservation Council (ANZECC) guidelines due to runoff containing manure and fertilisers from neighbouring pasture lands. In addition, the existing highway does not have any water quality controls and is likely to be contributing pollutant loads especially at or near creek crossing locations.

Broughton Creek is a Class 1 waterway providing major fish habitat. Broughton Mill Creek and Bundewallah Creek are Class 2 waterways providing moderate fish habitat and Connollys Creek is a Class 3 waterway with minimal fish habitat. Most of the higher elevation tributaries are ephemeral and are unlikely to provide fish habitat.

Downstream of the project, Town Creek is a relatively degraded stream having been cleared, urbanised and is thick with introduced vegetation. The vegetation creates the potential for blockage at a number of small culverts within Berry. These reaches are unlikely to provide fish habitat, have few standing pools and are largely disturbed.

No areas along the alignment have been identified as having high risk of containing acid sulfate soils.

Potential impacts

The primary risk to the surface waters during construction would be the increased potential for sediment release and transportation through runoff during clearing, cut and fill operations.

The primary risks to surface waters during operation would be an increase in surface runoff due to an increase in impervious surfaces and concentration of road runoff through drainage infrastructure, and the pollutants associated with road runoff, including sediments, oil and grease, heavy metals, chemicals and nutrients.

The proposal would include the diversion of Town Creek from its current alignment through Berry, to a new alignment that joins Bundewallah Creek to the east of Berry. This would increase flows in Bundewallah Creek, potentially increasing scour and erosion at the new confluence of Town and Bundewallah Creeks.

The proposed earthworks and associated changes to drainage would change the natural flow of water into some existing farm dams and potentially affect their yield.

Proposed mitigation measures

During the construction phase of the project, the overall erosion and sediment control strategy would be to first reduce erosion then capture sediment as close to the source as possible. Sediment basins are proposed to be utilised in a number of locations, however these would form only one part of the overall strategy. The sequencing of construction works would also form a key component of the erosion and sediment control strategy.

For the operational phase of the project, the strategy for the treatment of runoff includes using either swales and/or water quality basins designed to satisfy the target reduction in phosphorous and sediment pollutant loadings. Additional runoff treatment measures for outlets discharging directly to Broughton Creek, Broughton Mill Creek and Bundewallah Creek in the form of bioretention systems would be considered, space and grade permitting, to reduce nitrogen loads prior to discharge to sensitive receiving environments.

Bank stabilisation works, to mitigate scour would be incorporated at the new confluence of Town and Bundewallah Creeks.

Groundwater

Existing environment

There are two main aquifer systems present along the project alignment including unconsolidated and unconfined alluvial/colluvial aquifers, and Shoalhaven Group sediments.

Deep aquifers are accessed by the majority of licensed bores in the area extracting groundwater from depths between 30 and 50 metres below ground level. Groundwater quality data is limited. Groundwater level monitoring indicated the watertable naturally oscillates in response to climatic variation and topography.

A review of water bores registered with the NSW Office of Water (NOW) indicates there are 16 registered bores within 0.5 kilometres of the study area. Groundwater in this area is used for stock, domestic and agricultural purposes to supplement surface water supplies collected in dams and pumped from creeks.

Riparian vegetation associated with Broughton Creek is likely to be dependent upon groundwater to some extent. Groundwater discharge via springs, seeps or spring fed dams may also sustain local small communities.

Potential impacts

Potential impacts to groundwater due to the proposed construction works include the risk of hydrocarbon contamination via fuel spills, and potential changes in groundwater pH levels associated with the disturbance of acid sulfate soils. In addition, changes to groundwater flow patterns, recharge and discharge characteristics may be altered due to the intersection of the aquifer by artificial barriers such as road cuts and localised dewatering. It is not expected that groundwater extraction for water supply would be required during construction. If this need is identified during detailed design, further investigation would be undertaken.

Impacts occurring during the operational phase include road cuttings intercepting groundwater and locally lowering the water table, and the possibility that pollutants in road runoff may infiltrate to groundwater. There is a potential risk that groundwater dependent ecosystems (GDEs) may be impacted due to the development.

Proposed mitigation measures

Groundwater impacts during the construction phase would be managed through construction design and by management measures contained in a construction environmental management plan (CEMP) which includes a groundwater management plan for addressing issues during and after construction. Management measures would include:

- Minimising the depth of excavations in areas of alluvium.
- Limiting the need to dewater during construction.
- Limiting the need to excavate in areas if acid sulfate soils are identified.
- Using water treatment devices to treat runoff water quality before it has the opportunity to infiltrate to the water table.

Dewatering may be required during the excavation and construction of the Toolijooa Ridge cut and other deep cuts where the watertable would be intersected, and during the construction of infrastructure such as piles within the floodplain alluvium east of Berry. Discharge of the extracted groundwater would be to creeks or temporary storage in water quality basins to reduce turbidity prior to discharge.

During the operational phase potential on-going impacts to groundwater levels and groundwater quality would be addressed. Groundwater seepage into deep road cuts would be directed towards spoon drains that would flow by gravity into the road drainage system. Groundwater monitoring would be required to monitor potential impacts to groundwater quality. Included in the groundwater management plan would be emergency response plans to address spillages as a result of accidents that may impact on groundwater quality.

Flooding

Existing environment

The project traverses the Broughton Creek floodplain in the north, crosses a number of local ephemeral drainage lines through the hills between Tomlins Road and Tindalls Lane, then crosses the floodplain a second time near the confluence of Bundewallah, Connollys and Broughton Mill Creeks. It passes to the north of Berry before crossing a series of ephemeral creek lines between Berry and Jaspers Brush.

Named creeks and tributaries in the vicinity of the project include (from east to west):

- Broughton Creek.
- Broughton Mill Creek.
- Connollys Creek.
- Bundewallah Creek.
- Town Creek.
- Hitchcocks Lane Creek.

Connollys Creek, Bundewallah Creek, Broughton Mill Creek and Town Creek are the main sources of flooding in Berry. Town Creek in particular presents a flood risk to a significant number of properties within Berry. Cardno (2012) indicates the existing Princes Highway is overtopped during 100 year ARI event at the crossings of Broughton Mill Creek, Town Creek, Hitchcocks Lane Creek and Hitchcocks Lane Tributary.

Potential impacts

Where the alignment crosses the Broughton Creek floodplain there would be some localised increase in peak flood levels during the 100 year ARI event. This is due to changes in the overbank flow distribution patterns, particularly at Broughton Creek Bridge 2 where the proposed embankment has the potential to split flows along the east and west side of the embankment. These impacts would generally be limited to agricultural land use areas and would not impact structures or access, except for the existing Princes Highway crossing over Broughton Creek at Broughton Village.

The embankment between Broughton Creek bridge 2 and Broughton Creek bridge 3 may be subject to floodwaters flowing parallel to the alignment, along the toe of the embankment. This would increase the risk of scour of the embankment.

The project would cross the confluence of Connollys, Broughton Mill and Bundewallah Creeks at the bridge at Berry. While the bridge deck is located above the 100 year ARI flood level, the southern abutment extends out, into the existing 100 year ARI flood extent.

As a result of the highway works across the floodplain at Berry (including the embankment, piers and water quality basins) the available waterway area would be reduced and the 100 year ARI flood levels upstream of bridge at Berry would be affected. Areas downstream of the bridge would also experience increases in flood levels in the 100 year ARI event as a result of a combination of flows diverted from Town Creek together with a greater concentration of flow through the constricted bridge opening. There would be minimal flood level impacts along the Town Creek diversion route

Floor level survey has been used to undertake a review of those properties within Berry that may experience adverse flood impacts as a result of the proposed highway upgrade as well as those that will be better off.

Eleven properties near the bridge at Berry would be affected by changes in flood level as a result of the highway upgrade. For the three properties upstream of the bridge at Berry, the increase in 100 year ARI flood level would correspond to a reduction in freeboard as the properties do not currently experience flooding above floor level. One of the properties downstream of the bridge is far above the existing and proposed design flood levels and therefore not affected. The remainder of the properties currently experience flooding during the 100 year ARI event and the increase in flood levels at these properties is considered relatively minor in the context of the existing level of above floor inundation.

The proposed diversion of Town Creek would provide a significant benefit to properties within Berry township that currently experience flooding during large events. The existing portion of Town Creek flowing through the town of Berry (south of the proposed highway) will experience a lowering of 100 year ARI flood levels. Floor survey has been provided for 113 properties in the area around Town Creek, south of the proposed highway. Flood levels at these 113 properties would be reduced by a minimum of 0.01 metres to a maximum of 1.04 metres. Twelve houses currently have floor levels below the 100 year ARI flood level. Of these, nine would no longer experience above floor inundation. None of the properties in Berry would experience an increase in flood levels from Town Creek.

Climate change is expected to have adverse impacts on sea levels and rainfall intensities, both of which may have a significant influence on flood behaviour. Provision has been made in the design of the drainage structures for an increase in rainfall intensities of six per cent. Should rainfall intensities increase by more than six per cent there is the potential risk that the flood immunity of the highway would be reduced, that the capacity of drainage infrastructure would be exceeded and that flood extents would increase. An adaptive management approach to climate change is being taken by the RMS to manage these uncertainties.

Proposed mitigation measures

The alignment would be designed to be immune for flood events up to the 100 year ARI.

To minimise impacts on flow culverts would be located and sized to adequately convey the 100 year ARI runoff event (if on the main alignment) and designed to meet the design velocity criteria.

Bridge configurations would be designed to maintain existing flow patterns as far as possible to minimise increases in flood levels and velocities around the bridge structures. Upgraded highway levels would be set to provide the required 100 year ARI flood immunity with adequate freeboard to the underside of the bridge structure. Appropriate scour protection would be provided to the bridge abutments and piers where velocities have the potential to cause scour. Suitable batter treatment along the toe of the embankment between Broughton Creek bridges 2 and 3 would be designed to minimise damage or failure of the embankment due to scour.

Various options are available to reduce the impact of the on flood levels upstream and downstream of the bridge at Berry, including:

- Removal of the water quality basins that are located in the floodplain beneath the bridge at Berry.
- Modification of the retaining wall at the east abutment of the bridge to maintain the existing flowpath from the billabong at property 3.
- Creation of an opening at the western abutment of the bridge.

In addition to the above arrangements, all basins in the floodplain should be constructed at or close to ground level or replaced with bunded swales.

Provision would be made for adequate scour protection where velocities are high at the culvert outlets, in the Town Creek diversion channel and at the confluence of the Town Creek diversion channel and Bundewallah Creek.

Other mitigation options include local measures at individual properties such as diversion swales, local bunding or flood proofing.

The development of the proposed has been planned with an awareness of the potential for climate change impacts. The recommended measures to manage potential impacts would involve:

- The provision of an appropriate freeboard of around 0.5 metres minimum for major bridge waterway crossings on Broughton Creek and Berry.
- The provision of a six per cent allowance for increased rainfall intensities. For minor waterway crossing culverts, additional impacts could feasibly be accommodated (if required) through future local adaptive measures such as culvert amplification and/or lifting the level of the highway.

Further detailed modelling would be carried out as part of the detailed design process to confirm and minimise any flood level impacts.

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Glossary of terms and abbreviations

Term	Meaning
A	
Acid sulfate soils	Waterlogged soils that are rich in iron sulphides (primarily pyrite). If the sediments are exposed to air, the pyrite could be oxidised and generate sulfuric acid.
Afflux	The increase in upstream flood levels due to the restriction of flows.
ANZECC	The Australian and New Zealand Environment Conservation Council.
Aquifer	An underground waterlogged layer of permeable rock.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
ASSMP	An acid sulfate soil management plan.
Attenuation	Reduction of flows by providing flood storage.
Australian Height Datum (AHD)	A national standard level at approximately mean sea level.
Average Recurrence Interval (ARI)	A statistically derived estimate of the average time between rainfall and/or flooding events.
AWBM	The Australian Water Balance Model, which is a catchment scale rainfall/runoff numerical model.
AWS	Automatic weather station.
B	
Batter	A controlled sloping surface.
Bund	A small embankment designed to retain water.
C	
Catchment	A specific area where rainfall collects and drains to a known outlet.
CEMP	Construction environmental management plan.
Conveyance	The transportation of flow through a river or creek.
Critical storm	A storm that occurs for a precise time over a catchment of specific size to produce the greatest runoff and flow.
Culvert	A round or rectangular pipe that transports flow under a road or an embankment.
Cut	Excavation of the existing terrain to accommodate for new road levels.
Confluence	Joining of rivers or creeks.
Colluvial soils	Soils that have been formed by the deposition of particles due to gravity.
D	
DECCW	NSW Department of Environment, Climate Change and Water. Now part of the Office of Environment and Heritage.

Term	Meaning
DGRs	Director-General's requirements. Requirements and specifications for an environmental assessment prepared by the Director-General of the Department of Planning under section 75F of the *Environmental Planning & Assessment Act 1979*.
Discharge	Also known as flow which is the volume of water moving per time. Often measured in litres per second or cubic metres per second.
DLWC	The former NSW Department of Land and Water Conservation.
DNR	The former NSW Department of Natural Resources.
DSEWPAC	The Commonwealth Department of Sustainability, Environment, Water, Population and Communities.
DTIRIS	The NSW Department of Trade and Investment, Regional Infrastructure and Services
E	
EMC	Event mean concentration. A method for characterising pollutant concentrations in receiving water from a runoff event.
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).
EPL	Environment Protection Licence.
EPA	NSW Environment Protection Authority.
ESCP	Erosion and sediment control plan.
F	
Fill	Addition of selected material to the existing terrain to accommodate for new road levels.
Flood	When flows in a creek or river are large enough to overtop the side banks.
Flood Frequency Analysis	The use of statistics to determine how large floods would be at specific periods in time.
Flood fringe	Remaining area of flood prone land after floodway and flood storage have been identified.
Flood storage	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodplain	An area of low lying land adjacent to a river or creek that becomes inundated when the creek floods.
Flow diversions	Intentionally redirecting water flow from its natural path.
FM Act	NSW *Fisheries Management Act 1994*.
Fraction impervious	The percentage area of catchment that consists of an impermeable surface such as roads or houses.
Freeboard	The vertical distance from the top water level of a flood or creek to a specific location such as a road surface level or a ground level of a house.

Term	Meaning
G	
GDE	Groundwater Dependent Ecosystems.
Groundwater	Water that passes underground through seams of rock and/or soil.
H	
HEC-RAS	Hydraulic Engineering Centre River Analysis System, developed by the US Army Corps of Engineers. Models the hydraulics of water flow through natural channels.
HRC	The Healthy Rivers Commission.
Hydraulic	The broad name used in defining characteristics of flow that travels through rivers, channels or pipes.
Hydrograph	A graph showing the seasonal variation in the level of a body of water, from which its velocity and discharge can be calculated.
Hydrology (hydrologic)	The broad name used in defining the characteristics of flow that develop from rainfall.
I	
Impervious	Not permeable or penetrable. Often refers to a surface that does not allow for water to be absorbed, like a road or a roof.
Inlet control	Where the flow through a pipe is controlled by the geometric characteristics of the upstream end of the pipe.
J	
-	-
K	
-	-
L	
-	-
M	
Manning's 'n'	Parameter relating to surface roughness.
MHRDC	Calculation of the Maximum Harvestable Right Dam Capacity. Dams used for erosion and sedimentation control are exempt from MHRDC.
MUSIC	The model for urban stormwater improvement conceptualisation (MUSIC) - developed by the Co-operative Research Centre for Catchment Hydrology to predict the effectiveness of various stormwater treatment techniques. Used to simulate the impact of a change in land use, by an estimate of the performance of a stormwater treatment train put in place to retain pollutants. Best used as a comparative assessment tool, ie to compare predevelopment with post development or to measure the effectiveness of treatment measures.
N	
NOW	NSW Office of Water.

Term	Meaning
NWQMS	The National Water Quality Management Strategy, a joint initiative of the Federal and State Governments.
O	
OEH	NSW Office of Environment and Heritage.
P	
PASS	Potential acid sulfate soil.
Peak flow	The maximum flow that results from a specific rainfall event.
Pervious	Permeable. Often refers to a surface that allows for water to be absorbed like a grassed field.
Pluviograph	An automated instrument that measures rainfall.
POEO	NSW *Protection of the Environment Operations Act 1997.*
Probable maximum flood	The PMF is the largest flood that could conceivably occur at a particular location.
Probabilistic rational method	A method defined in the *Australian Rainfall and Runoff* that estimates the peak flow in a catchment under a certain storm.
Pavement drainage	The broad term used to define flow and its corresponding structures that travel along a road. This is generally referred to a dirty flow as is contains many vehicular pollutants.
Q	
-	-
R	
Rainfall intensity	The amount of rainfall that fall per time usually measured in millimetres per hour.
RCP	Reinforced concrete pipe.
Receiving environment	A river, ocean, stream or other watercourse into which treated water is discharged.
Runoff	Rainfall that eventually converges to make flow often in a creek or river.
Riparian vegetation	Plants that grow on the fringe of land and rivers.
S	
SAQP	A Sampling Analysis and Quality Plan, which would be prepared for the purposes of groundwater monitoring.
Scuppers	Designed orifices or holes in a bridge deck that allow for drainage.
Sediment basin	A pond like structure that captures runoff and promotes sediment particles to drop out of the flow thus improving water quality.
Sensitive receiving environment	Receiving environment with high conservation value or supporting human uses of water that are sensitive to degradation.
SEPP	A State Environmental Planning Policy.

Term	Meaning
Sheet flow	Runoff that has not yet converged in a low point. It has uniform depth due to the relatively even planar surface it flows over. Flow over a smooth road is said to be sheet flow before it collects into a gutter or kerb.
SO gutter	An RMS standard “vee” shaped kerb type.
SPM	Suspended particulate matter.
Storm duration	The time that a storm produces rainfall. These are often recorded in specific standardised intervals which aid continuity in design.
STP	Sewage treatment plant
Suspended solids	Small particles that remain mixed in flow due to the motion and turbulence of the water.
Swale	Type of flow channel that is heavily vegetated to promote water quality.
SWMP	A soil and water management plan.
T	
TN	Total Nitrogen.
TP	Total Phosphorus.
Transverse drainage	The broad term used to define flow and its corresponding structures that travel under a road or an embankment. This is generally referred to a clean flow as is does not contain many vehicular pollutants.
TSS	Total Suspended Solids.
U	
-	-
V	
-	-
W	
Water quality basins	A pond like structure that captures runoff and promotes water quality through the use of plants and micro-organisms.
Weir	Structure used to regulate flow in a river or stream.
WM Act	The *NSW Water Management Act 2000*.
WQO	Water Quality Objectives (WQO), adopted by the NSW Government for local waterways as part of the *Drinking Water Catchments Regional Environment Plan No. 1.*
X, Y, Z	
-	-

1 Introduction

1.1 The project

Roads and Maritime Services (RMS) propose to upgrade 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project comprises the following key features:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.

- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.

Eight underpasses including roads, drainage structures and fauna underpasses:

  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Gembrook Road, Tindalls Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent stockpiling site for general road maintenance.

During detailed design, refinements could be made to the design features and construction methods (refer to Chapter 4 of the environmental assessment).

This report provides an assessment of the key surface, groundwater and flooding related issues for the project as nominated by the Director-General's requirements (DGRs) as set out in **Table 1-1**.

For each key issue, the existing environment is described, the potential impacts (both direct and indirect) during construction and operation are assessed, the influence of relevant planning matters are considered and proposed management and mitigation measures are described. The proposed management measures have influenced the development of the draft Statement of Commitments in Chapter 11 of the environmental assessment.

1.2 Agency consultation

In relation to surface, groundwater and flooding management, this document addresses the relevant DGRs as indicated in **Table 1-1**.

Agency letters accompany and inform part of the DGRs. These originate from Shoalhaven City Council, the Department of Environment and Climate Change and Water (DECCW) now known as the Office of Environment and Heritage (OEH), the Department of Industry and Investment now known as the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) and the NSW Office of Water (NOW). Relevant agency issues are outlined in **Table 1-2**.

Table 1-1: Director-General's requirements for surface, groundwater and flooding

Director-General's requirements	Section reference
Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000'. The assessment must describe measures to control erosion and sedimentation during construction activities and measures to capture and treat runoff from the site during the operational phase.	Sections 1.3.1, 2.1.2, 2.2.1, 2.2.3 and 2.3
Identify potential risks of the project on groundwater resources including: characterising existing local and regional hydrology; potential risks of drawdown; impacts to groundwater quality; discharge requirements; and implications for groundwater-dependent surface flows (including springs and drinking water catchments), groundwater-dependent ecological communities, and groundwater users.	Section 3
Identifying potential impacts of the project on existing flood regimes, consistent with the 'Floodplain Development Manual' (Department of Natural Resources, 2005), including impacts to existing receivers and infrastructure and the future development potential of affected land, demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the project. The assessment shall demonstrate due consideration of flood risks in the project design.	Section 4
Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better.	Sections 2.1, 2.3, 3.2, 3.3, 4.2 and 4.3 Appendix G of the environmental assessment

Director-General's requirements	Section reference
An assessment of the key issues, including an assessment of the worst case and representative impact for each issue for all aspects of the project (including the proposed locations of and/or options for the ancillary facilities) with the following aspects addressed for each key issue (where relevant):	Sections 2.2.6, 3.3.3 and 4.2.9
• Describe the existing environment.	Sections 2.1, 3.2 and 4.1
• Assess the potential impacts of the project at both construction and operation stages, in accordance with relevant policies and guidelines. Both direct and indirect impacts must be considered including potential interactions with the existing Princes Highway (as relevant).	Sections 2.2, 3.3 and 4.2
• Identify how relevant planning, land use and development matters, (including relevant strategic and statutory matters), have been considered in the impact assessment and/or in developing management/mitigation measures.	Sections 2.3, 3.4 and 4.3
• Describe measures to be implemented to avoid, minimise, manage, mitigate, offset and/or monitor the impacts of the project and the residual impacts.	Sections 2.3, 3.4 and 4.3

Table 1-2: Surface, groundwater and flooding issues raised by local and State Government agencies

Agency issues	Section reference
Office of Environment and Heritage (OEH)	
The environmental outcomes for the project in relation to water should be: • No pollution of waters (including surface and groundwater) during construction or occupation of the site by the final users. • Acceptable in terms of the achievement or protection of the River Flow Objectives and Water Quality Objectives. The EA should document the measures that would achieve the above outcomes.	Sections 2.2 and 2.3
The source of water for dust control is a major issue for this project. The RMS should clearly demonstrate where the water would be sourced and quantities required for dust control and other activities.	Section 2.3.1
Other water issues include erosion and sediment control during construction activities including pipelines, stormwater runoff control and chemical storage during operation.	Section 2.3.1
If an offsite discharge is proposed for any or all wastewater streams, then the EA must address potential impacts and demonstrate that the discharges would not prejudice attainment of water quality objectives for the receiving water course. The NSW government has adopted Water Quality Objectives (WQO) for local waterways as part of the *Drinking Water Catchments Regional Environment Plan No. 1* and its supporting policies and guidelines, as a guide for the assessment of environmental impacts on aquatic ecosystems. These WQOs were developed from community consultation and the Healthy Rivers Commission (HRC) Inquiry into the Hawkesbury Nepean River System.	Sections 1.3 and 2.3

Agency issues	Section reference
Describe measures for dealing with the following water pollution issues: • Measures to control erosion and sedimentation during construction activities. Further guidance is available in the guideline 'Managing Urban Stormwater - Soils and Construction' (Landcom, 2004). • Measures to capture and treat runoff from the site during the operational phase. • Sealing areas of the site to prevent soil erosion. • Spillage controls and bunding for materials used onsite. • The environmental assessment should specify and assess all monitoring programs for measuring noise, air quality and water quality monitoring during the construction phase and on-going operation of the facility. These monitoring programs should be capable of assessing whether or not the development achieves a satisfactory level of environmental performance. The evaluation should include a detailed description of the monitoring strategies, sample analysis methods and the level of reporting proposed.	Sections 2.3.1 and 2.3.2
The key issues of concern to DTIRIS in relation to development are: • Direct impacts on aquatic environments and key fish habitat (including riparian vegetation, instream aquatic vegetation and large woody debris) from road construction. • Impacts on water quality during all road construction activities and from stormwater runoff and road drainage during the ongoing use of the upgraded highway. • Impacts on recreational fishing access and opportunities in Broughton Creek, Broughton Mill Creek and Bundewallah Creek.	Sections 2.3.1 and 2.3.2 Appendix G of the environmental assessment
Proposed measures to mitigate, rehabilitate or compensate for such impacts are to be detailed in accordance with the Department's Policy and Guidelines to ensure that there is 'no net loss' of aquatic habitats. Consider and provide information on the following specific issues: • Description of aquatic and riparian environments in the vicinity of the development - particularly extent and condition of riparian vegetation and instream aquatic vegetation, water depth, and permanence of water flow and snags (large woody debris) within the footprint of the project. • Analysis of any interactions of the proposed roadworks with aquatic and riparian environments and predictions of any impacts upon aquatic and riparian environments (including fish and aquatic and riparian vegetation) from the roadworks (both temporary and permanent). This should include assessment of both direct impacts (removal, disturbance, smothering) and indirect impacts (eg shading, permanent loss of habitat). • Description of proposed environmental compensation measures to offset the permanent loss of riparian habitats in Broughton Creek, Broughton Mill Creek and Bundewallah Creek (eg funding for aquatic rehabilitation works, such as removal of fish passage barriers, elsewhere in the catchment as recommended by DTIRIS). • Description of potential impediments to fish passage as a result of the works (eg temporary coffer dams, instream bunds or work platforms) and possible mitigation measures to be employed to negate these impacts.	Sections 2.1, 2.2, 2.3 and section 7.3 of the environmental assessment Appendix G of the environmental assessment

Agency issues	Section reference
• Predictions of impacts upon water quality of the proposed road development, including in Broughton Creek, Broughton Mill Creek and Bundewallah Creek, both during the construction and operational phases. • Safeguards to mitigate any impacts upon aquatic species and environments and water quality during construction and operation of the highway upgrade. In particular, provide details on proposed revegetation of riparian areas, projects for erosion and sediment control (to be incorporated into a construction environmental management plan (CEMP)) and proposed stormwater and road drainage management measures (eg sediment basins). Water quality management for the highway upgrade should be designed to achieve no nett increase in pollutant runoff to Broughton Creek, Broughton Mill Creek and Bundewallah Creek. • An assessment of any impacts of the proposed development and construction works on recreational fishing in the area, especially in relation to fishing access arrangements (foreshore and boat based).	
Office of Water (NOW)	
The EA needs to provide sufficient details for the NOW to assess any water licensing requirements under the *Water Act 1912*, including: • Water supply source(s) for the proposal. • Any proposed surface water extraction, including purpose, location of any existing and proposed pumps or storage ponds/ dams. • Any proposed groundwater extraction. • Volumes of water to be used. • The function and location of all existing and proposed storages/ponds for the project. If the proposal includes water management structures/dams, the EA needs to provide details on the following: • Any existing structures (date of construction, location, purpose, size and capacity, the legal status/approval for existing structures). • Any proposal to change the purpose of existing structure/s. • If any remedial work is required to maintain the integrity of the existing structure/s. • The purpose, location and design specifications for any proposed structure/s. • Size and storage capacity of the structure/s. • Calculation of the Maximum Harvestable Right Dam Capacity (MHRDC). • If the structure/s is affected by flood flows. • Any proposal for shared use, rights and entitlement of the structure/s. • If the proposed development has the potential to bisect the structure/s. The proposal needs to demonstrate that it is consistent with NSW State groundwater policy, does not impact on groundwater quality or the health of groundwater dependent ecosystems (GDEs).	Sections 2.1, 2.2, 2.3 and section 7.3 of the environmental assessment

Agency issues	Section reference
The EA should consider and provide the following details: • The predicted highest groundwater table at the site. • Any works likely to intercept, connect with or infiltrate the groundwater sources. • Any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes. • A description of the flow directions and rates and physical and chemical characteristics of the groundwater source. • The predicted impacts of any final landform on the groundwater regime. • The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts. • An assessment of the quality of the groundwater for the local groundwater catchment. • How the proposed development would not potentially diminish the current quality of groundwater, both in the short and long-term. • Measures for preventing groundwater pollution so that remediation is not required. • Protective measures for any groundwater dependent ecosystems (GDEs). • Proposed methods for the disposal of waste water and requirement for approval from the relevant authority. • The results of any models or predictive tools used. Where potential impact/s are identified the EA would need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on: • Any proposed monitoring programs, including water levels and quality data. • Reporting procedures for any monitoring program including mechanism for transfer of information. • An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal. • Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category). • Description of the remedial measures or contingency plans proposed. Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.	

Agency issues	Section reference
Shoalhaven City Council	
No relevant issues relating to ground and surface water.	N/A
Kiama Municipal Council	
No relevant issues relating to ground and surface water.	N/A

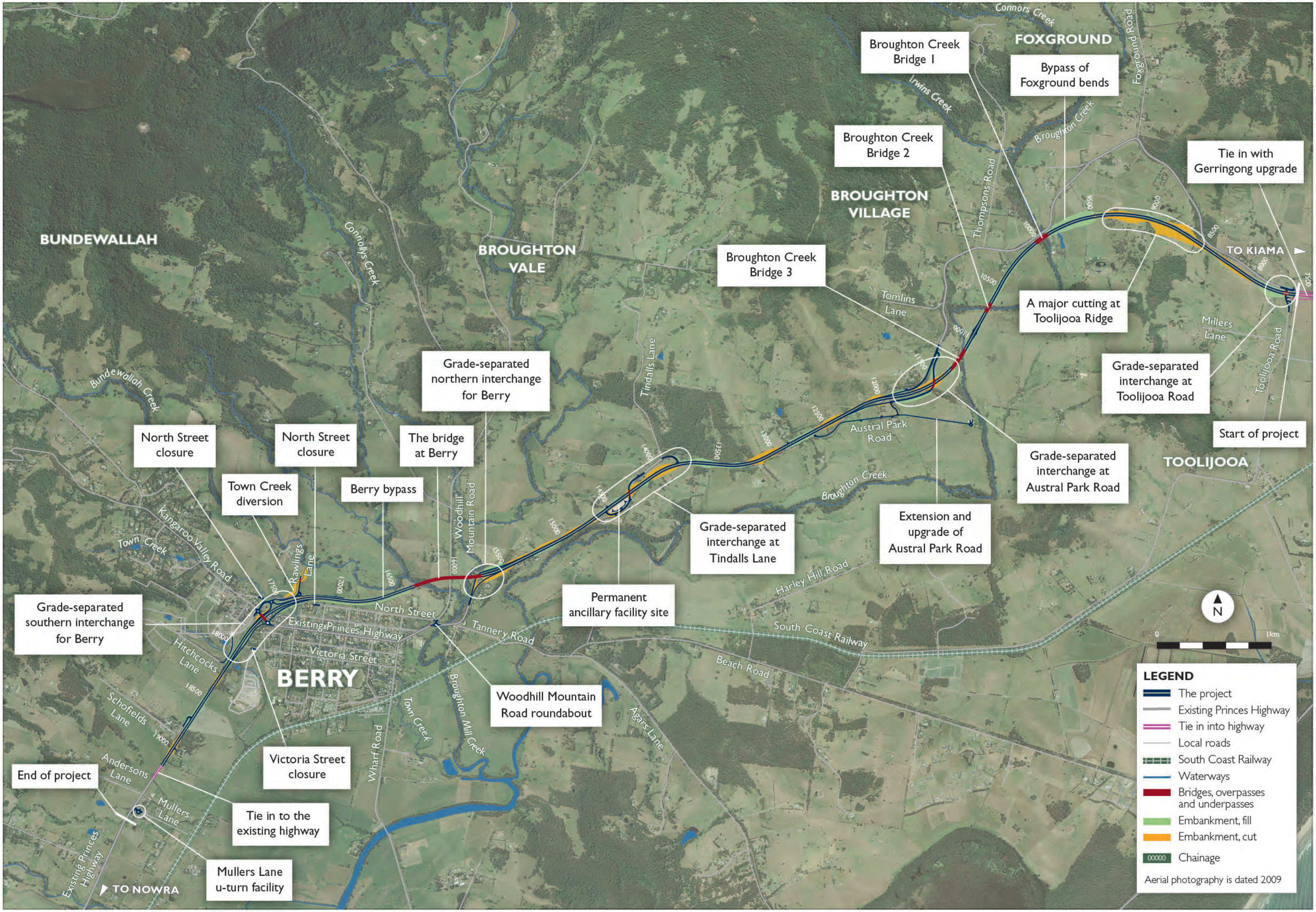


Figure 1-1: Foxground and Berry bypass project area

1.3 Policy context and legislative framework

A brief summary of the strategic policy and guidelines that have been considered as part of this assessment is provided below.

1.3.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), (referred to as the ANZECC water quality guidelines) form part of the National Water Quality Management Strategy and list a range of environmental values for water bodies. Different water quality criteria are set for the water bodies based on environmental values assigned to that water body. These values include consideration as to whether the water is to be used for drinking, recreation or according to ecological values. The ANZECC water quality guidelines provide water quality criteria (scientifically-based benchmark values) for a wide range of parameters for each of these values. The ANZECC guidelines state that "The Guidelines should not be used as mandatory standards because there is significant uncertainty associated with the derivation and application of water quality guidelines" (ANZECC, 2000, Chapter 1 Introduction). However the guidelines provide a useful measure of risks to aquatic ecosystem health.

ANZECC guidelines are ambient water quality guidelines, appropriate for the monitoring of baseflows or water bodies and have therefore been used in the assessment of the existing water quality of creeks in proximity to the project as discussed in **Section 2**. ANZECC criteria would also be used in future monitoring of ambient conditions (base flow) of the downstream waterways to assess the impacts of the proposal on these ecosystems.

It is not appropriate to use the guidelines for the assessment of stormwater runoff from urbanised or natural catchments, since the concentrations of pollutants in runoff may at times exceed the guidelines recommended for ambient water quality in both natural and urbanised catchments. There are guidelines specifically derived for the management of stormwater runoff such as Managing Urban Stormwater: Council Handbook (Environment Protection Authority (EPA), 1998a) as discussed below.

ANZECC guidelines are also applicable to groundwater quality and have been used in the groundwater quality assessment detailed in **Section 3** of this report.

1.3.2 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) is a joint initiative of the Federal and State Governments. The policy objective of the strategy is "to achieve sustainable use of the nation's water resources by protecting and enhancing their quality whilst maintaining economic and social development" (Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), 1994).

1.3.3 NSW Water Quality and River Flow Objectives

The NSW Water Quality and River Flow Objectives are consistent with the agreed national framework and are primarily aimed at maintaining and improving water quality, thereby supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities (DECCW, 2006).

NSW Water Quality and River Flow Objectives have been developed for most river catchments in the state, though not for the Shoalhaven River catchment. The catchments immediately upstream and downstream of the Shoalhaven catchment are the Illawarra catchment and the Clyde River and Jervis Bay catchment. The water quality and river flow objectives that were determined for these catchments which could be applied to the

Shoalhaven catchment are shown in **Table 1-3** along with cross references to sections of this report where discussion relating to each objective is located.

Table 1-3: NSW water quality and river flow objectives

Objective	Section reference
Water quality objectives:	
Protect aquatic ecosystems.	Sections 2.1, 2.2, 2.3
Protect livestock water supply.	Section 2.2.5
Protect irrigation water supply.	Section 2.2.5
River flow objectives:	
Protect natural low flows.	Sections 2.2.3, and 4
Protect pools in dry times.	Sections 2.2.3, and 4
Protect important rises in water levels.	Section 4
Maintain wetland and floodplain inundation.	Section 4
Mimic natural drying in temporary waterways.	Section 4
Maintain natural flow variability.	Section 4
Maintain natural rates of change in water levels.	Section 4
Manage groundwater for ecosystems.	Section 3
Minimise effects of weirs and other structures.	Section 4

1.3.4 Managing Urban Stormwater: Council Handbook, Draft (EPA, 1998a)

The Managing Urban Stormwater: Council Handbook (EPA, 1998a) is part of a package of documents addressing the management of urban stormwater published by NSW Government agencies. The aim of this document is to provide guidance on the preparation and meeting of requirements of catchment-based stormwater management plans.

These guidelines have been developed for urban catchments and as such are not strictly applicable to the rural environment along the project route. However, the recommended treatment objectives have been used as a basis for developing appropriate design criteria for water quality treatment for this project. The development of these design criteria is discussed in **Section 2.3**.

1.3.5 Protection of the Environment Operations Act 1997

Clause 48 of the *Protection of the Environment Operations Act 1997* (POEO Act) applies to scheduled activities where Schedule 1 indicates that a licence is required for premises at which the activity is carried on.

Clause 35 of Schedule 1 states that:

"(2) The activity to which this clause applies is declared to be a scheduled activity if it results in the existence of 4 or more traffic lanes (other than bicycle lanes or lanes used for entry or exit) for at least:

(b) where the road is classified, or proposed to be classified, as a main road (but not a freeway or tollway) under the Roads Act 1993:

(i) 3 kilometres of their length in the metropolitan area, or
(ii) 5 kilometres of their length in any other area."

As the proposed road would be classified as a main road with four traffic lanes, is located outside the metropolitan area and is greater than five kilometres is length, an Environmental Protection Licence (EPL) would be required to be obtained for the construction of the project.

Section 120 of the POEO Act prohibits the pollution of any waters. Standard conditions of the EPL would require compliance with the POEO Act and this has been taken into consideration in the design of the project. Mitigation measures would be implemented to prevent pollution of waters as discussed in **Section 2.3** and **Section 2.4**.

1.3.6 Other policies and guidelines

The following guidelines were also considered in the assessment:

- Managing Urban Stormwater - Soils and Construction, Volume 1 (Landcom, 2004); Volume 2D – Main Road Construction (NSW DECCW, 2008) colloquially known as the Blue Book).
- RMS Road Design Guideline: Section 8 Erosion and Sedimentation (Roads and Traffic Authority (RTA), 2003).
- RMS Guideline for Construction Phase Water Quality Monitoring (RTA, n.d.).
- RMS Erosion and Sedimentation Management Procedure (RTA, 2009).
- Procedures for Selecting Treatment Strategies to Control Road Runoff (RTA, 2003a).
- RMS Code of Practice for Water Management (RTA, 1999).
- RMS Water Policy (RTA, 1997).
- Road Runoff and Drainage: Environmental Impacts and Management Options, AP-R180 (Austroads, 2001).
- Guidelines for Treatment of Stormwater Runoff from Road Infrastructure, AP-R232 (Austroads, 2003).
- Floodplain Development Manual (Department of Natural Resources (DNR), 2005).
- RMS Technical Guideline: Environmental Management of Construction Site Dewatering (RTA, 2011).
- Coastal Lakes: Independent Inquiry into Coastal Lakes and Statement of Joint Intent (Healthy Rivers Commission of NSW, 2002)
- The relevant targets within the State Water Management Outcomes Plan (NOW, 2003).
- Managing Urban Stormwater: Council Handbook (EPA, 1998a).
- Managing Urban Stormwater: Source Control (EPA, 1998b).
- Managing Urban Stormwater: Treatment Techniques (EPA, 1998c).
- State Groundwater Policy Framework Document (Department of Land and Water Conservation (DLWC), 1997).
- The NSW State Groundwater Quality Protection Policy (DLWC, 1998).
- (Draft) NSW State Groundwater Quantity Management Policy (DLWC, n.d.).
- NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002).
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and ANZECC, 1995).

2 Surface water

2.1 Existing environment

2.1.1 Overview

A brief description of the project alignment is provided below (refer also to **Figure 1-1**):

- The project would begin at Toolijooa Road, and pass through a large cutting and onto the Broughton Creek floodplain.
- It would cross Broughton Creek three times before moving out of the floodplain and through the foothills north of Broughton Creek.
- It would then join the existing Princes Highway alignment, following a ridgeline east of Berry.
- It would cross the confluence of Broughton Mill Creek, Connollys Creek and Bundewallah Creek at the bridge at Berry.
- It would then pass north of the Berry township, crossing a number of smaller catchments from the surrounding foothills, before finishing south of Schofields Lane.

The project would also include the diversion of Town Creek into Bundewallah Creek to the north of the project (upstream of its confluence with Connollys Creek).

Broughton Creek (upstream of Berry) traverses the proposed route in a southerly then westerly direction before meandering south again and finally flowing into the Shoalhaven River approximately five kilometres west of Shoalhaven Heads. The Broughton Creek catchment (refer **Figure 4-2**) consists predominately of rural pastures below steeper forested hillsides.

Bundewallah Creek, located to the north of Berry, flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. From the confluence with Bundewallah Creek, Broughton Mill Creek flows southwards under an existing bridge at the Princes Highway, then under a second bridge at the South Coast Railway Line before flowing to the south of Berry. Broughton Mill Creek then flows into Broughton Creek downstream and to the east of Berry,

Connollys Creek enters Bundewallah Creek upstream of the confluence with Broughton Mill Creek. Two unnamed creeks flow through Berry before joining Broughton Mill Creek.

Town Creek (or Princess Creek) is a small ephemeral watercourse that passes directly through the Berry township. It has a catchment area of 70 hectares upstream of Berry. Town Creek meanders southeast through the Berry town centre, adjacent to Princess Street, before joining Broughton Mill Creek near its confluence with Broughton Creek. The reach of Town Creek through Berry is in poor condition.

Broughton Creek, Broughton Mill Creek, Bundewallah Creek and Connollys Creek are considered sensitive receiving environments in the study area.

2.1.2 Water quality studies

A number of water quality studies have been undertaken as part of the route selection process for the project. These included field investigations, sampling and testing undertaken by Cardno Ecology Lab in June 2011, April 2009 and January/February 2007.

Water quality analyses were undertaken at a range of waterway locations associated with the project including potential crossing locations. This information was used to assess water quality within the study area in terms of health of aquatic ecosystems by comparison with ANZECC (2000) guidelines for low-land and estuarine watercourses (as appropriate) in south–eastern Australia (The Ecology Lab, 2007).

In-situ water testing determined that most waterways had pH, salinity levels and to a lesser extent, turbidity within acceptable limits and all sites had levels of organochlorine pesticides and trace elements that were below ANZECC thresholds.

Values of total phosphorus generally exceeded the ANZECC guidelines. As nearly all creeks lie adjacent to land cleared for agricultural purposes, the application of fertilisers and manure from stock are the likely sources of the high nutrient levels. Dissolved oxygen values were almost universally less than the ANZECC lower threshold for the protection of ecosystems.

Overall the water quality results were considered typical of aquatic ecosystems that have been impacted by agricultural and grazing practices. The study found that the long-term agricultural land use in the region has ultimately resulted in significant pollution that exceeds levels considered to be sustainable for maintaining ecosystem integrity.

In addition, the existing highway does not have any water quality controls and is likely to be contributing pollutant loads especially at or near creek crossing locations.

2.1.3 Biodiversity

The maintenance of water quality to the receiving waterways is important, in order to support downstream ecosystems. As flora and fauna all depend on water quality, an understanding of the existing habitats for flora and fauna in the study area is central to understanding potential impacts the project may have.

Existing aquatic habitats

Broughton Creek is a Class 1 waterway providing major fish habitat, Broughton Mill Creek and Bundewallah Creek are Class 2 waterways providing moderate fish habitat and Connollys Creek is a Class 3 waterway with minimal fish habitat (Cardno Ecology Lab, 2012).

The above creeks are considered sensitive receiving environments with respect to this project.

Town Creek is a Class 4 waterway unlikely to provide fish habitat. The waterway is ephemeral at the proposed route crossing and much of the watercourse channel is undefined and has been colonised by pasture grasses and annual weeds (Cardno Ecology Lab, 2012).

The patches of vegetation present within the urbanised reaches of Town Creek were characterised as disturbed riparian open woodland. South of the urban centre, Town Creek flows through pasture land with riparian vegetation consisting of closed grassland. It then flows through a constructed wetland adjacent to the Berry Sewage Treatment Works (STP) and subsequently through disturbed riparian open woodland habitat before its confluence with Broughton Mill Creek (Cardno Ecology Lab, 2012).

Downstream of the project at the confluence of Broughton Creek and the Shoalhaven River there are a variety of important estuarine wetland habitats such as seagrass beds, tidal flats, saltmarsh and mangroves which are important for seabirds and migratory waders. There are a number of State Environmental Planning Policy No.14 Coastal Wetlands (SEPP 14 wetlands) in this locality, including the Comerong Island Nature Reserve, which are sensitive receiving environments.

Coomonderry Swamp, to the southeast of the study area near the coast, is a freshwater coastal wetland and sensitive receiving environment that is also protected under SEPP14 and represents one third of all semi-permanent coastal freshwater wetland habitat in NSW (NPWS, 1998). It provides habitat for a diverse array of flora and fauna, including many threatened species such as the Green and Golden Bell Frog, *Litoria aurea*.

For further information on wetland habitats in the locality of the study area refer to the *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012) which is provided at Appendix G to the environmental assessment.

Aquatic fauna

A previous study undertaken to inform route selection (The Ecology Lab, 2007) identified 36 fish species that could potentially exist within the study area, of which 33 are native. Of these, the Macquarie Perch, *Macquarie australasica* is listed as endangered and vulnerable (*Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) respectively) and the Australian Grayling, *Prototroctes maraena* is listed as vulnerable (EPBC Act). However, the study noted that given the relatively small size and low elevation of the drainage systems and the degraded nature of the habitat, it is unlikely that viable populations of either Macquarie Perch or Australian Grayling are present within the study area (The Ecology Lab, 2007).

Further the Aquatic Ecology and Water Quality Management Assessment (Cardno Ecology Lab, 2011) for the project noted that it is probable that not all 36 species occur within the study area. The Broughton Creek catchment supports an estuarine floodplain and freshwater reach, but the catchment is still relatively small and most of the higher elevation tributaries are ephemeral and are unlikely to provide fish habitat. It is possible that some species, particularly the larger and more sensitive, may not be present (Cardno Ecology Lab, 2011).

Aquatic flora

The reach of Broughton Creek upstream of Berry is surrounded by cleared agricultural land although there are significant sections with relatively intact native riparian vegetation dominated by river oak (*Casuarina cunninghamiana* subsp. *Cunninghamiana* and *Eucalyptus* spp.) (Cardno Ecology Lab, 2011).

The land surrounding Broughton Mill Creek has largely been cleared for agricultural use, with existing riparian vegetation containing a mixture of native and exotic trees and shrubs. Similarly, the land surrounding Bundewallah Creek had been cleared for agricultural use and recreation. Riparian vegetation is relatively continuous and composed of native trees (river oak) and exotic shrubs, climbers and annuals (Cardno Ecology Lab, 2011).

Broughton Creek, Broughton Mill Creek and Bundewallah Creek were all classed as Category 1 Riparian Habitats (Environmental Corridor), this classification representing the objective to provide biodiversity linkages by maintaining connectivity for the movement of aquatic species along the riparian corridor and between key destinations (for example, the bottom and the top of the catchment) (Cardno Ecology Lab, 2011).

2.1.4 Acid sulfate soils

Acid sulfate soil (ASS) is a naturally occurring soil and sediment containing iron sulphides which when exposed to oxygen can generate sulphuric acid. ASS generally occurs in marine or estuarine sediments of recent geological age (holocene), within soil horizons typically less than five metres above Australian Height Datum (AHD) (Coffey, 2007).

The study area is covered by three acid sulfate risk maps - Kiama, Burrier / Berry and Gerroa (DLWC, 1997a-c). Reference to these risk maps indicate that no areas along the alignment have been identified as being at risk. Geotechnical investigations for the project (Coffey, 2010) included field and laboratory investigations to identify ASS. No soils were identified as being of potential ASS (PASS) risk within the study area. ASS may still be present in the floodplain sediments around Berry and Broughton Creek although the risk is considered low.

2.2 Assessment of potential surface water impacts

A water quality impact assessment has been undertaken to identify potential impacts and provide appropriate management controls within the project (refer Section 2.3 for a discussion on environmental management measures).

Surface water impacts have been considered in terms of the NSW Water Quality and Flow Objectives as listed in Section 1.3.3.

Further assessment of impacts to water quality is presented in the *Aquatic Ecology and Water Quality Management Technical Paper* at Appendix G of the environmental assessment.

2.2.1 Construction potential impacts

The primary risk to surface water quality during construction would be the increased potential for sediment release and transportation through runoff during and following clearing and cut and fill operations, as bare soil would be exposed to erosion during the construction works. Transportation of sediment could also occur through vehicular movements such as tracking onto roads. Increased sedimentation of watercourses can smother aquatic habitats and organisms, and can increase levels of nutrients, metals and other potential toxicants that attach to sediment particles.

Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads (Cardno Ecology Lab, 2012). Therefore without appropriate management controls the potential construction impact of sediment release may increase turbidity levels within waterways associated with the project.

Noting previous water studies indicate several of these waterway's turbidity levels are narrowly outside the ANZECC lower thresholds (Cardno Ecology Lab, 2012) an increase could place additional physical stress on aquatic biota.

Other potential risks to surface water during the construction phase include:

- Sediment release from stockpile sites and earthmoving activities.
- Increased surface runoff due to an increase in cleared and impervious surfaces.
- Exposure of ASS resulting in acidic runoff that could have environmental impacts on the water quality of receiving creeks.
- Oil/fuel leakage from construction equipment.
- Contaminated runoff or spills (for example caused by accidental chemical spills, or damage to chemical storage areas) that could pollute receiving waterbodies.
- General waste generation from construction materials and activities that could enter waterbodies.
- Dust generation during excavation that could settle in waterbodies.
- Changes to existing farm dam catchments and therefore a disruption of water supply for livestock and irrigation, resulting from the diversion of existing runoff due to cut or fill (see discussion in Section 2.2.5 below).
- Damage to ancillary facilities, such as stockpile sites and chemical storages that could result in an export of pollutants to receiving water bodies.
- Flood damage to chemical storage or stockpile areas.
- Tannins leachate from vegetation stockpiles.
- Riparian vegetation removal resulting in increased sedimentation and erosion into waterbodies.
- Hydrologic and water quality impacts as a result of the proposed Town Creek diversion channel.
- Decreased health of aquatic ecosystems due to increased sediment and contaminants in waterbodies.

2.2.2 Operational potential impacts

The primary risk to surface waters during operation would be an increase in surface runoff due to the increase in impervious surfaces potentially resulting in an:

- Increase in pollutant loads reaching waterways.
- Increase in the volume, frequency and velocity of flows in receiving waterways, leading to or exacerbating erosion and the mobilisation of sediments.

With respect to the ANZECC guidelines the pollutants of interest associated with road runoff are primarily sediments (as noted in the potential construction impacts increased sediments are likely to impact on turbidity levels) nutrients (namely nitrogen and phosphorus), heavy metals, hydrocarbons and organics.

Studies undertaken in the Broughton Creek catchment generally show that turbidity levels are narrowly outside the ANZECC lower thresholds and values of total phosphorus generally exceeded the ANZECC guidelines (Cardno Ecology Lab, 2012).

Without appropriate management controls the potential operational impacts may place further stress on waterways associated with the project.

The proposed design would require two piers within Bundewallah Creek. Typical bankfull average flow velocities are in the order of 1 to 3m/s. The piers would typically slow average velocities immediately upstream by 0.1 to 0.2m/s. As the flow passes around the piers there would be an increase in the velocities close to the piers, however this increase would not typically extend across the entire flow width at this cross section.

Other potential risks to surface water during the operational phase include:

- Sediment from the paved surface entering waterbodies.
- Heavy metals, attached to particles washed off the paved surfaces, entering waterbodies.
- Oil, grease and other hydrocarbon products from general vehicular use of the road reducing runoff water quality and entering water bodies.
- Anthropogenic litter entering waterways and reducing water quality.
- Permanent changes to existing catchments (primarily due to cuttings to create the alignment) that may result in reduced runoff to farm dams and therefore a disruption to water supply for livestock and irrigation.
- Chemical spills, resulting from road traffic crashes, entering waterbodies.
- Nutrients (nitrogen and phosphorus) found in road runoff due to atmospheric deposition entering waterbodies.
- Contaminants from erosion of roadway or road shoulder entering waterbodies.
- Flow regime and water quality impacts as a result of the proposed Town Creek diversion channel.
- Decreased health of aquatic ecosystems due to increased sediment and contaminants in waterbodies.

2.2.3 Town Creek diversion channel – Hydrologic and water quality impacts

As part of the proposed highway upgrade, runoff from the Town Creek catchment (approximately 70 hectares) to the north of the highway upgrade would be rerouted by a diversion channel passing under Rawlings Lane into Bundewallah Creek upstream of its confluence with Connollys Creek. It would then flow into Broughton Creek.

The diversion of Town Creek would alter flow regimes in parts of Bundewallah Creek, Connollys Creek, Broughton Mill Creek and Town Creek within Berry. Generally, Town Creek south of the alignment would receive less flow while Bundewallah, Connollys and Broughton Mill Creeks would receive higher flows.

The reduced flow regime for reaches downstream of the proposed diversion channel is not expected to have a significant impact as these reaches are typically colonised by pasture grasses with undefined flow paths, and are heavily urbanised or constructed. The impacts resulting from the stemming of flow from the upstream catchment (due to the proposed diversion channel) are considered negligible as these largely disturbed reaches are unlikely to provide fish habitat (Class 4 waterway) and have few standing pools. Refer to the *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012) provided at Appendix G of the environmental assessment for additional information.

Impacts on flow regime were assessed for the five river reaches shown in **Figure 2-1**.

The flow regimes would be affected by changes in the size of the catchments feeding into each creek. Bundewallah Creek, Connollys Creek, upstream Broughton Mill Creek, and downstream Broughton Mill Creek (B, C, D and F) would have less than five per cent change in catchment area due to the proposed development. The reach of Town Creek flowing through Berry would experience changes in catchment area of -100 per cent at the upstream end (A) and -47 per cent at the downstream end (E).

Table 2-1 indicates the changes in catchment areas as a result of the diversion.

Table 2-1: Catchment area changes as a result of the Town Creek diversion

River	Map location	Existing upstream catchment area (km^{2*})	Proposed upstream catchment area (km^2)	% change in catchment area
Town Creek- north end of Berry	A	0.7	0	-100
Bundewallah Creek - below diversion of Town Creek	B	14.1	14.8	5
Bundewallah Creek - below confluence with Connollys Creek	C	21.6	22.3	3
Broughton Mill Creek upstream	D	43.2	43.9	2
Town Creek- south end of Berry	E	1.5	0.80	-47
Broughton Mill Creek downstream	F	45.5	45.5	0

**Existing upstream catchment areas are shown in Figure 2-1*

An Australian Water Balance Model (AWBM) was created for the existing and proposed catchment areas. AWBM is a catchment scale rainfall/runoff numerical model that allows estimates of streamflow to be derived from rainfall by quantifying the volume and duration of rainfall storage prior to its discharge as runoff. The model was calibrated using daily streamflow data from the flow gauging station at Broughton Mill Creek, combined with daily rainfall data from Berry Masonic Village and monthly evapotranspiration (ET) data from Port Kembla.

A set of parameters were determined that could be used to approximate rainfall/runoff relationships throughout the ungauged catchments of Town, Bundewallah and Connollys Creeks.

The model was run for the existing and proposed catchment areas with results reported at the six locations (A-F) on the river reaches that would be affected by the diversion of Town Creek. The existing and proposed flow duration curves for each site are presented in **Figure 2-2**.

The flow duration curves represent the percentage of time that a given flowrate is equalled or exceeded at each of the assessed locations. '0 per cent time exceeded' corresponds to the highest possible flow, and '100 per cent time exceeded' corresponds to the lowest possible flow. If the portion of the curve above 80 per cent is relatively steep this indicates a low input from natural sources such as groundwater. Conversely, if this portion of the curve has a gentler slope, this indicates a significant baseflow in the waterway.

The results of the modelling indicate that as Bundewallah Creek, Connollys Creek, upstream Broughton Mill Creek, and downstream Broughton Mill Creek (B, C, D and F) would experience a minimal change in catchment areas due to the proposed development, the resulting impact on flow volumes in these reaches is negligible.

As Town Creek would be completely diverted upstream of the highway, there would be no flow at the upstream end of the reach through Berry (A), and the flow volume would be reduced to approximately one third of the existing flow at the downstream end of the reach through Berry (E). The diversion could lead to sediment accumulating in Town Creek downstream of the diversion as a result of reduced flushing efficiency.

There are potential water quality impacts (primarily erosion) associated with the creation of the diversion channel through excavation works but this will be dependent on the rehabilitation landscape works. In a worst case scenario this could lead to excess sediment loads into Bundewallah Creek resulting in mortality and decreased growth of aquatic species, degradation of habitat and reduced water quality.

There are also potential operational water quality impacts including the accumulation of sediment as a result of reduced flushing efficiency and erosion at the confluence of the diversion channel and Bundewallah Creek due to eddying.

The final diversion channel concept (which would be determined in consultation with directly impacted landowners, EPA/OEH and NOW) would include design measures to maintain flushing efficiency and mitigate potential erosive forces at the diversion's discharge location. Construction would be undertaken in a staged manner in conjunction with erosion control landscaping measures to reduce exposure of soils.

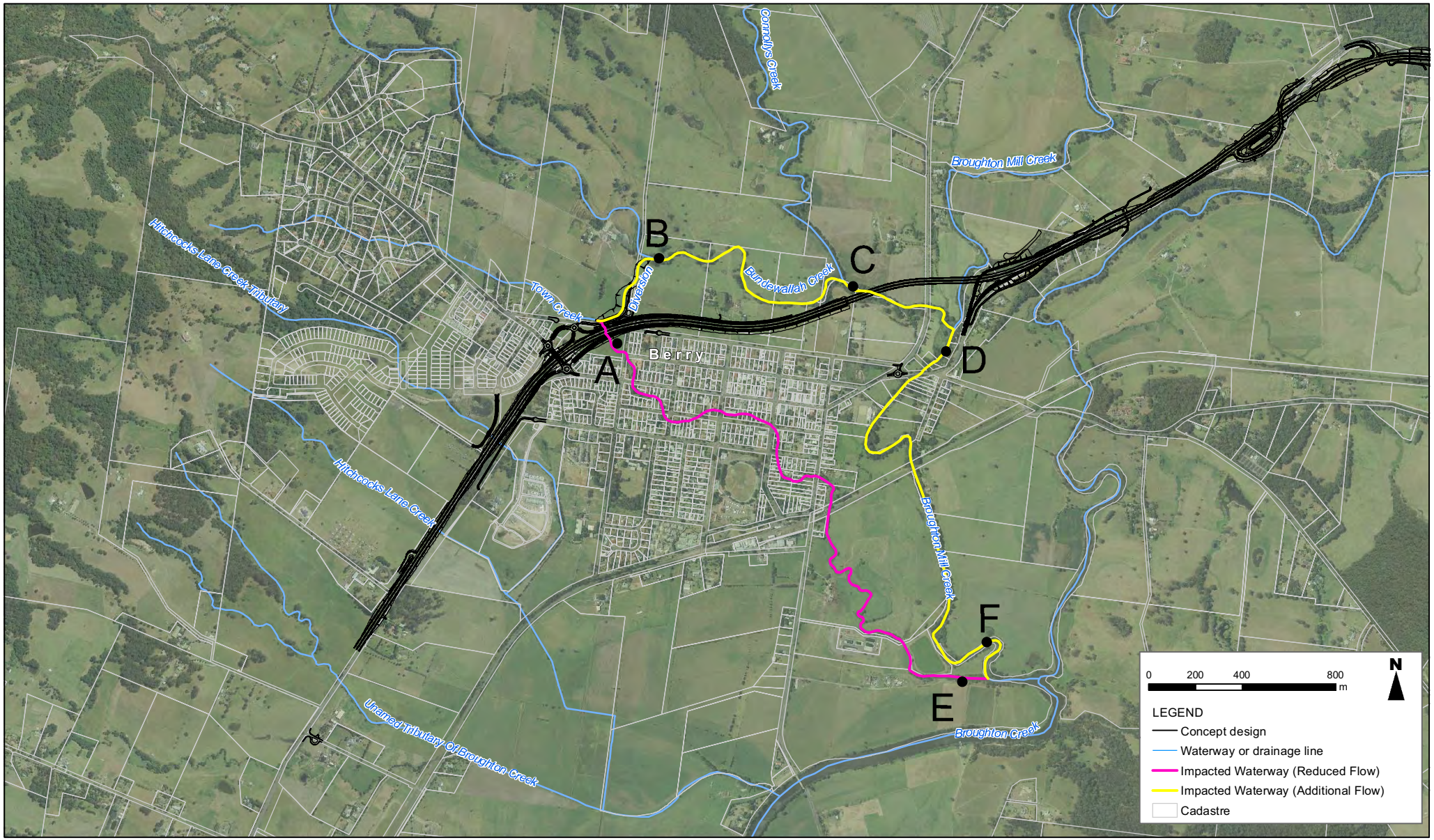
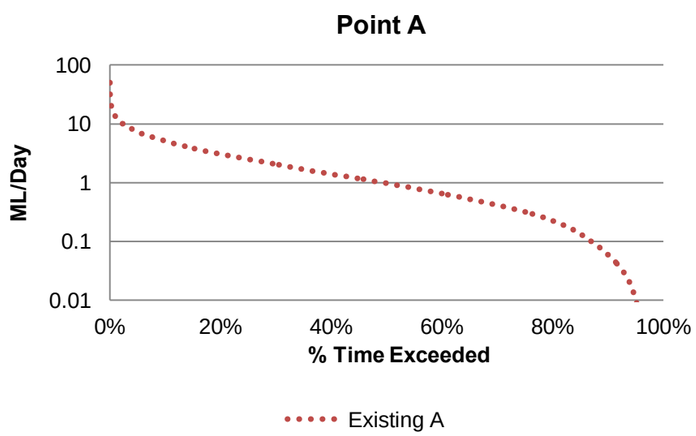
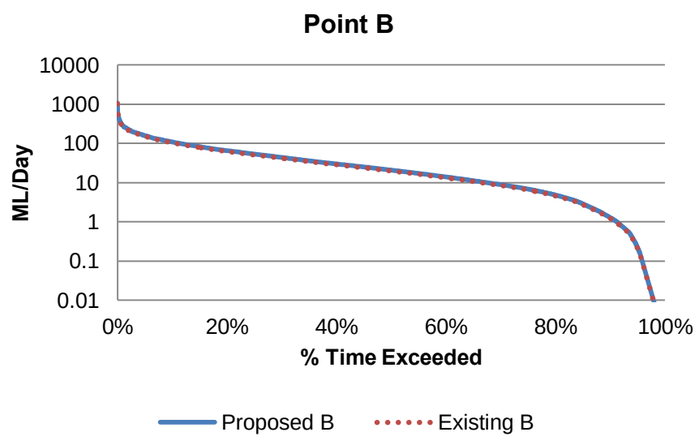


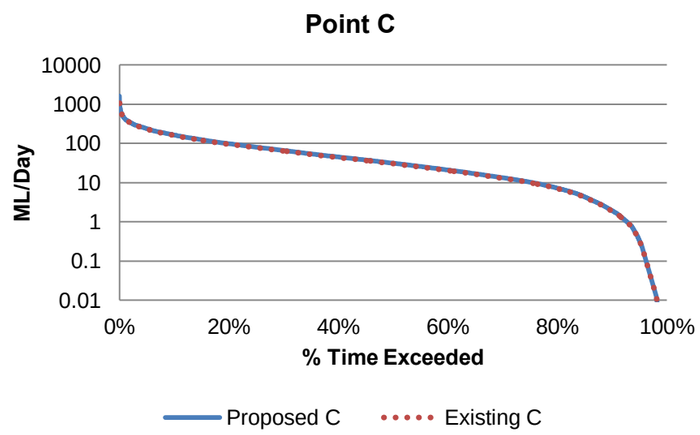
Figure 2-1 Town Creek Diversion - Impacted streamlines and flow reporting locations

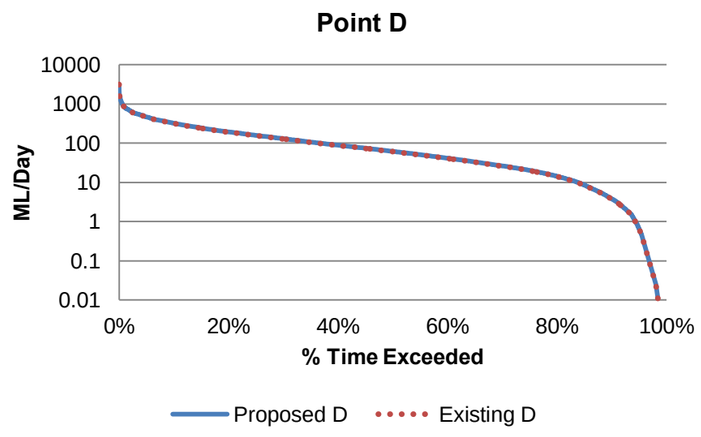
Source: AECOM (2012), LPMA (2011)

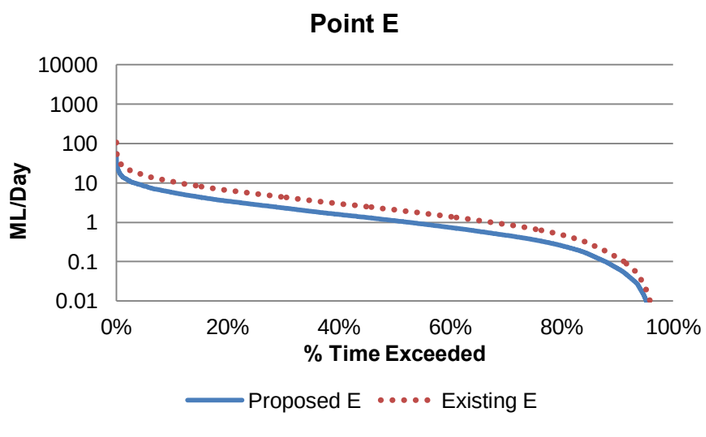
Note 1: Letters identify flow reporting locations. Refer to Table 2.1











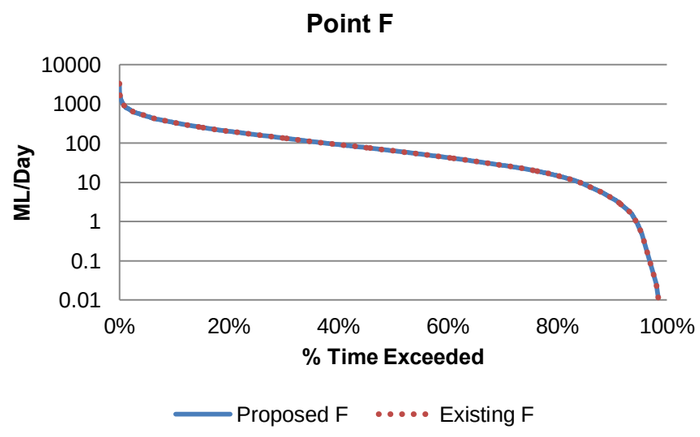


Figure2-2: Flow duration curves – existing and proposed conditions at reaches affected by the Town Creek diversion

2.2.4 Water quality impact assessment

In order to assess the impacts on the surface water quality for the operation phase, existing and proposed runoff was modelled in the MUSIC (Model for Urban Stormwater Improvement Conceptualisation) water quality modelling package (MUSIC Version 4).

The aim of this assessment was to ascertain and compare loads of pollutants generated from the existing environment (current highway) and the project (highway upgrade).

Further analysis was undertaken to test and refine mitigation measures in order to minimise surface water quality impacts of the project on receiving waterways, refer Section 2.3.2.

Rainfall from the Nowra RAN Air Station (number 068072) was adopted for the modelling as it was one of few pluviographs (providing six minute interval data) within close proximity to the project with a consecutive data set and relatively high annual rainfall. Data from 1969 to 1976 was used providing an annual mean rainfall of 1230 millimetres for the modelled period. These dates were used because they cover a period with minimal data gaps from a geographically relevant pluviograph and that is neither particularly wet or dry. The long-term mean annual rainfall for this station is 1133 millimetres.

Typical one hectare catchments were analysed for “pre-existing” (rural land only), “existing” (existing Princes Highway) and “proposed” (the project) pollutant loadings. Event Mean Concentrations (EMCs) for Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) were adopted based on typical pollutant load generation for rural and road catchments (Fletcher *et al.* 2004).

The “pre-existing” catchment was modelled as a single one hectare rural node.

In order to determine pollutant loadings of road runoff on a per hectare basis for the “proposed” catchment, the following assumptions were made with regards to road geometry:

- Three metre wide impervious outside shoulder.
- Two 3.5 metre impervious traffic lanes (pavement).
- One metre wide impervious inside shoulder.
- Five metre wide pervious central median.
- Twenty metre wide pervious batter on each side draining to the pavement.

The typical one hectare catchment breakdown modelled for the proposed catchment is illustrated in **Figure 2-3**.

The “existing” catchment was based on the same assumptions as the “proposed” catchment model, with the exception of a reduced pavement width to reflect the existing traffic lane area. This included a road and median node (41 per cent impervious) and a batter/fill node (zero per cent impervious). The “existing” catchment model did not include any water quality treatment measures.

The “proposed” catchment model was set up with two source nodes; a road and median node (82 per cent impervious) and a cut/fill batter node (zero per cent impervious).

In order to establish a baseline for comparison, the three one hectare catchments were analysed for generated pollutant loadings (kilogram per year), as summarised in **Table 2-2**.

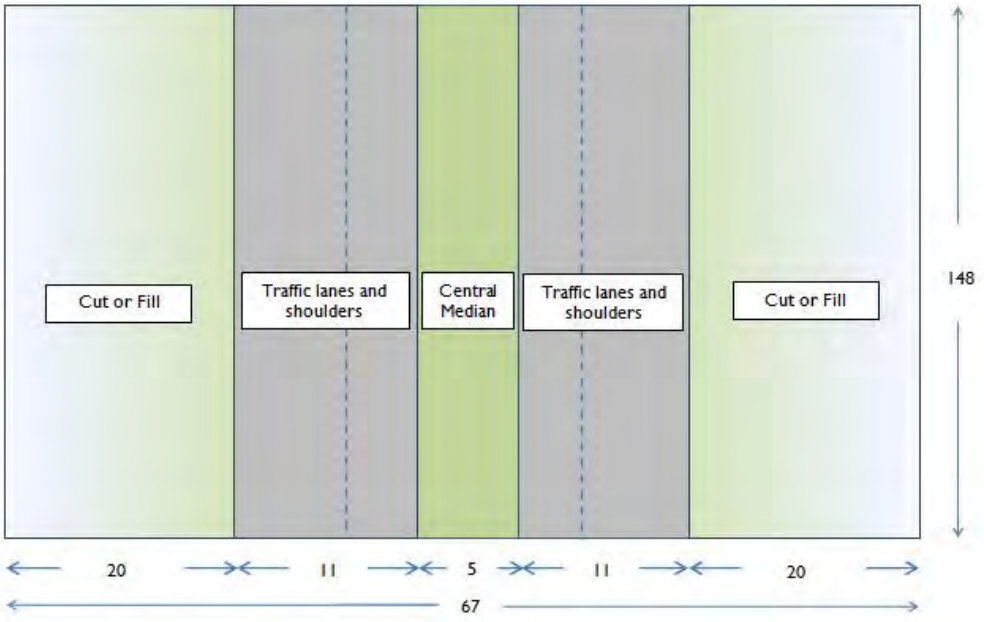


Figure 2-3: Typical 1 hectare of proposed highway upgrade (not to scale, distance in metres)

Table 2-2: MUSIC model residual pollutant loads (no treatment)

	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Pre-existing	235	0.62	6.36
Existing	1260	2.31	10.8
Proposed	1980	3.64	16.6

TSS – Total suspended solids, TP –Total phosphorous, TN – Total nitrogen.

Table 2-2 shows there is an increased pollutant generation from the existing highway compared to a pre-developed rural state. Modelling also shows the project is likely to generate loads in excess of the existing highway as the impervious areas (primarily pavement widths) would increase.

2.2.5 Farm drains/dam yield and downstream ecosystems

An assessment of farm dam catchments was undertaken to determine the likely impact of the construction and operation of the project on the yield of farm dams.

The road development and associated changes to drainage patterns would prevent the natural flow of water into some existing farm dams and potentially affect their yield. During construction and in some cases during operation (refer **Table 2-3**) surface water runoff that, under pre-development conditions, would have flowed downhill to farm dams may in some circumstances be diverted around road cuttings via catch drains and other drainage infrastructure. The water would then be conveyed via a culvert or catch drain, to discharge to a natural waterway.

Farm dams likely to be impacted by the project have been identified and their catchment areas determined. The assessment identified 29 farm dam catchments that are likely to be affected by the proposal. The pre- and post-construction catchment areas were compared to determine the likely impact for each affected farm dam. The changes in catchment area are presented in **Table 2-3**. The farm dam numbers correspond to the labels shown on **Figure 2–4**. Consultation with affected landowners would be carried out during detailed design.

Table 2-3: Changes in farm dam catchment area

Dam No.	Dam location		Pre development area (m^2)	Post development area (m^2)	Area lost / gained (m^2)	Change as % of original
	DP	Lot				
1	615284	6	143,590	141,551	-2040	-1%
2	615284	5	39,426	39,426	Nil	0%
3	1040653	8	16,926	13,615	-3311	-20%
4	563651	2	28,443	32,950	4508	16%
5	563651	2	39,368	39,368	-	0%
6	840646	31	60,628	60,628	-	0%
7	801177	1	58,591	43,227	15,364	-26%
8	1098617	11	204,129	206,156	2027	1%
9	1098617	13	100,100	91,836	-8264	-8%
10	1098617	13	2,900	2490	-411	-14%
11	620014	4	41,848	41,848	-	0%
12	801512	4	7636	7636	Nil	0%
13	628132	2	148,836	141,843	-6992	-5%
14	Unknown	Unknown	42,642	34,716	-7925	-19%
15	628132	3	73,624	71,297	-2327	-3%
16	628132	4	430,286	402,572	27,715	-6%
17	628132	2	716,027	711,489	-4537	-1%
18	653306	69	61,409	35,412	25,997	-42%
19	653306	69	15,803	7299	-8504	-54%
20	377518	A	248,846	248,846	Nil	0%
21	224377	2	13,358	13,470	112	1%
22	701647	22	334,290	304,700	29,591	-9%
23	607155	11	183,977	187,226	3250	2%
24	224377	2	14,271	1894	12,377	-87%
25	224377	2	70,511	48,841	21,669	-31%
26	224377	2	92,035	64,632	27,403	-30%
27	621894	151	99,655	81,688	17,967	-18%
28	255171	1	126,165	134,063	7898	6%
29	1014800	1	27,689	27,521	-168	-1%

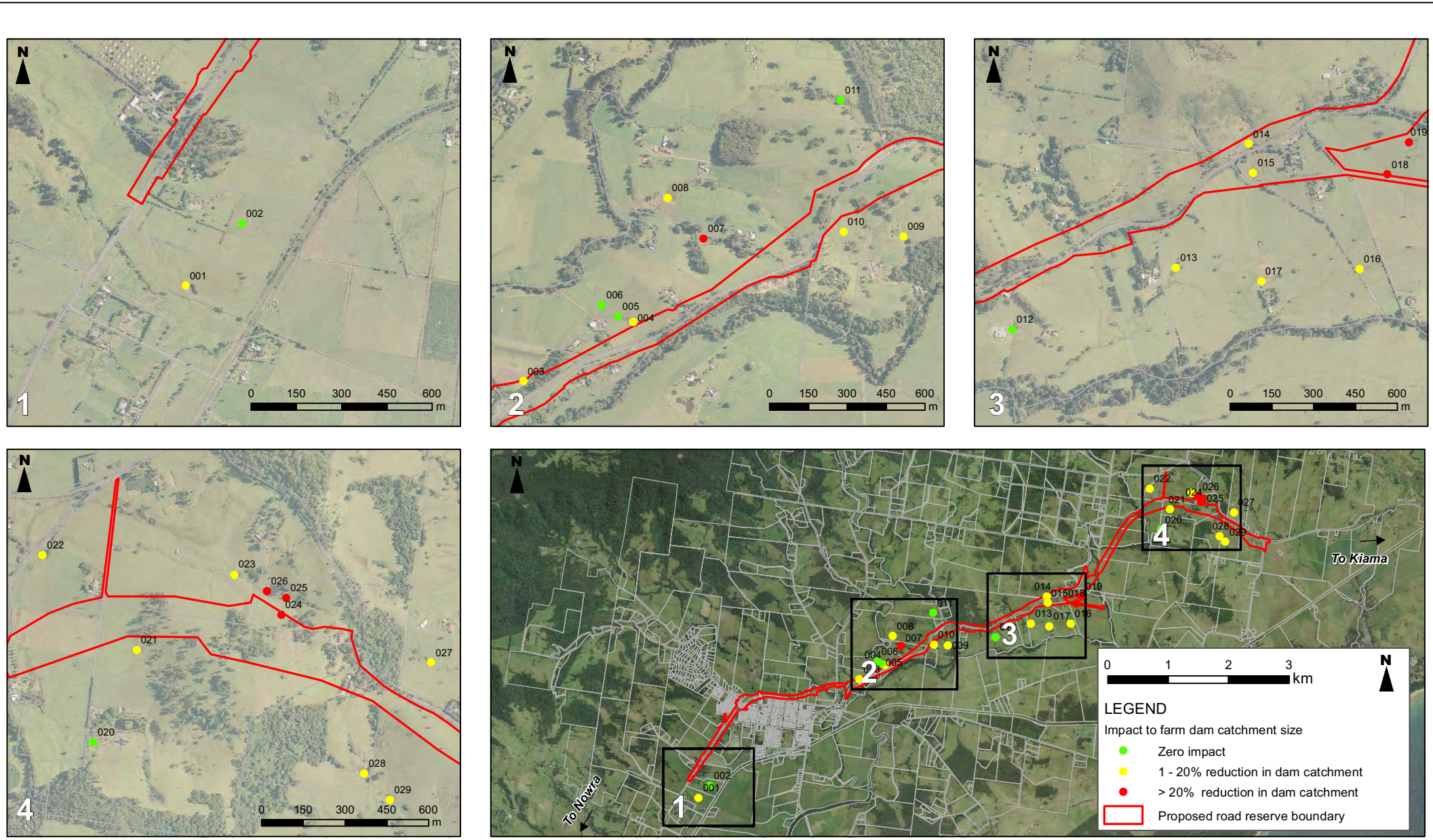


Figure 2-4 Location and impacts on farm dams in the project area

Source: LPMA (2011)

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2.2.6 "Worst case" surface water impacts

The DGRs for the project require that the "worst case" impacts be described. For the purpose of surface water impact assessment, this has been interpreted to represent a situation where no mitigation measures are incorporated in the design, or the mitigation measures have failed. Discussion has been provided below to improve understanding of issues that may arise if this case was realised.

Untreated runoff has hydrologic and water quality impacts. Hydrologically, impervious areas, such as road pavement, deliver an increased volume of water flowing at a faster rate. This could result in the receiving streams potentially eroding over say one to two decades (depending on the rainfall) to a new equilibrium. The new stream form would be wider and deeper than the existing stream and the geomorphic diversity of the stream could be impacted. Consequently, the biodiversity of the flora and fauna that has evolved to the stream geomorphology could be reduced.

These impacts can be mitigated if treatment is provided as part of the project or shortly after construction. The longer the stormwater runoff remains untreated, the less effective mitigation measures would be.

Untreated stormwater runoff can lead to an accumulation of pollutants in waterways over time. This creates ongoing pressures on the ecology of these waterways, leading to lower biodiversity. These water quality impacts would be difficult to remediate as it would take a considerable amount of time to remove pollutants and allow the ecosystems to recover.

2.3 Environmental management measures

2.3.1 Construction management measures

Appropriate management measures are to be implemented during construction to effectively reduce the generation of pollutants and minimise impacts on receiving waters.

Erosion and sediment controls

A soil and water management plan (SWMP) documenting the controls for capturing and removing sediment from runoff prior to reuse or discharge to receiving waters would be developed for the construction phase. Additionally, site specific erosion and sediment control plans (ESCP) would be developed to document the specific controls in place at that time for each area of the site. These would typically be a progressive series of plans to reflect changes to sediment and erosion controls implemented as construction progresses. The erosion and sediment controls across the site would be planned and implemented in accordance with Managing Urban Stormwater-Soils and Construction, Volume 2D (Landcom 2004), and the conditions of the EPL required for the project.

The overall erosion and sediment control strategy for the project would be to first prevent or reduce erosion then capture sediment as close to the source as possible using multiple small control devices rather than solely relying on large sediment basins downstream of construction works. Sediment basins are proposed to be utilised in a number of locations, however these would form only one part of the overall strategy. The sequencing of construction works would also form a key component of the erosion and sediment control strategy.

A proactive and committed approach to erosion control would minimise the sediment generated from the site and lessen the chance of offsite impacts on water quality. Erosion control strategies that would be considered and implemented include:

- Diverting non-site water around and/or through the construction site and the establishment of temporary cross drainage so that up gradient stormwater is not mixed with site stormwater.
- Minimising the extent of disturbed areas and rehabilitating disturbed areas as soon as practicable.
- Reducing the length of slopes through the use of temporary diversion drains to reduce water velocity, and therefore erosion potential, over exposed surfaces.
- Limiting the volume of water movement within the site by removing water from the site at regular intervals though multiple small scale sediment capture devices.
- Construction of operational drainage measures prior to construction, where possible, for use during the construction stage.

Sediment capture strategies

As stated above, sediment capture would be secondary to erosion control and would utilise multiple small capture devices such as check dams and construction sediment basins.

Sediment capture would be undertaken in accordance with Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004).

In some areas of the alignment, water quality swales are proposed to convey stormwater as part of the overall water quality management process during the operational phase. During construction in these locations, an increased focus would be placed on at-source erosion control with the footprint of the proposed operational swales utilised as a location to provide multiple water storage areas. This would be achieved by providing rock or sandbag check dams (or similar) along the footprint of the operational swale drain, or other methods in accordance with Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004). This construction footprint could also be over excavated if additional water storage volume is required, though a dewatering method statement would be required for each location.

Construction sediment basins

Preliminary basin sizing has been undertaken based on the concept design in order to provide an indication of how erosion and sediment control may be achieved.

Detailed sediment basin sizing would be undertaken by the construction contractor during the construction planning stage of the project. Basin volumes would be calculated for estimated catchment areas at both the clearing stage of the project and at the final earthworks levels, and would be based on the sensitivity of the receiving environments as per Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004). Basin volumes for all other stages of construction would be expected to be within this range. Cut batters have been included in the catchment area when sizing sediment basins as earthworks reach the final levels. Fill batters may be excluded as they can be progressively stabilised as they are constructed or can be managed as separate catchment areas.

The construction sediment basins have been sized using the required design criteria for Type D or F (dispersible and fine-grained) soils specified in Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004) and shown in **Figure 2-5**.

The sediment basins that do not drain directly to water bodies would be designed to capture and treat the 80th percentile five day rainfall event.

The sediment basins that would directly discharge to sensitive receiving environments such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek would have a higher capacity and capture all runoff from the 85th percentile five day rainfall event.

Typically, operational water quality basins would be constructed during the clearing stage, and utilised during construction to control sediment. A preliminary analysis of the project identified three locations where temporary sediment basins may be required for the construction period only (refer **Figure 2-5**). These basins have been indicatively sized based on the catchment required during the clearing stage. As earthworks progress, these basins would become redundant as construction water is directed to the operational basin locations.

The locations of these indicative temporary basins have been determined based on the concept design and would be subject to change during the detailed design phase. During construction planning, the construction contractor may also determine that more or less temporary construction basins are necessary. The final location of any temporary construction basins would take into account other site factors such as ecological constraints and the availability of land and the basins would not extend beyond the approved construction footprint without further assessment.

A number of locations exist along the alignment where operational basins are not proposed and temporary construction basins are not feasible due to topographical constraints or small catchment areas. These locations have been identified as high residual risk erosion and sedimentation areas (refer **Figure 2-6**) based on the RMS's Erosion and Sedimentation Management Procedure (RTA, 2009).

Generally, the areas identified as high risk are the major cuttings and areas close to the creek as they represent the largest disturbance, steepest slopes and closest proximity to the receiving environment. However these areas can be effectively managed by employing at-source erosion controls to limit the potential for erosion as well as multiple small scale sediment capture structures to trap sediment prior to water leaving the construction site.

As portions of the site have been identified as posing a high risk for erosion and sedimentation a soil conservationist would be engaged to provide advice throughout the construction period.

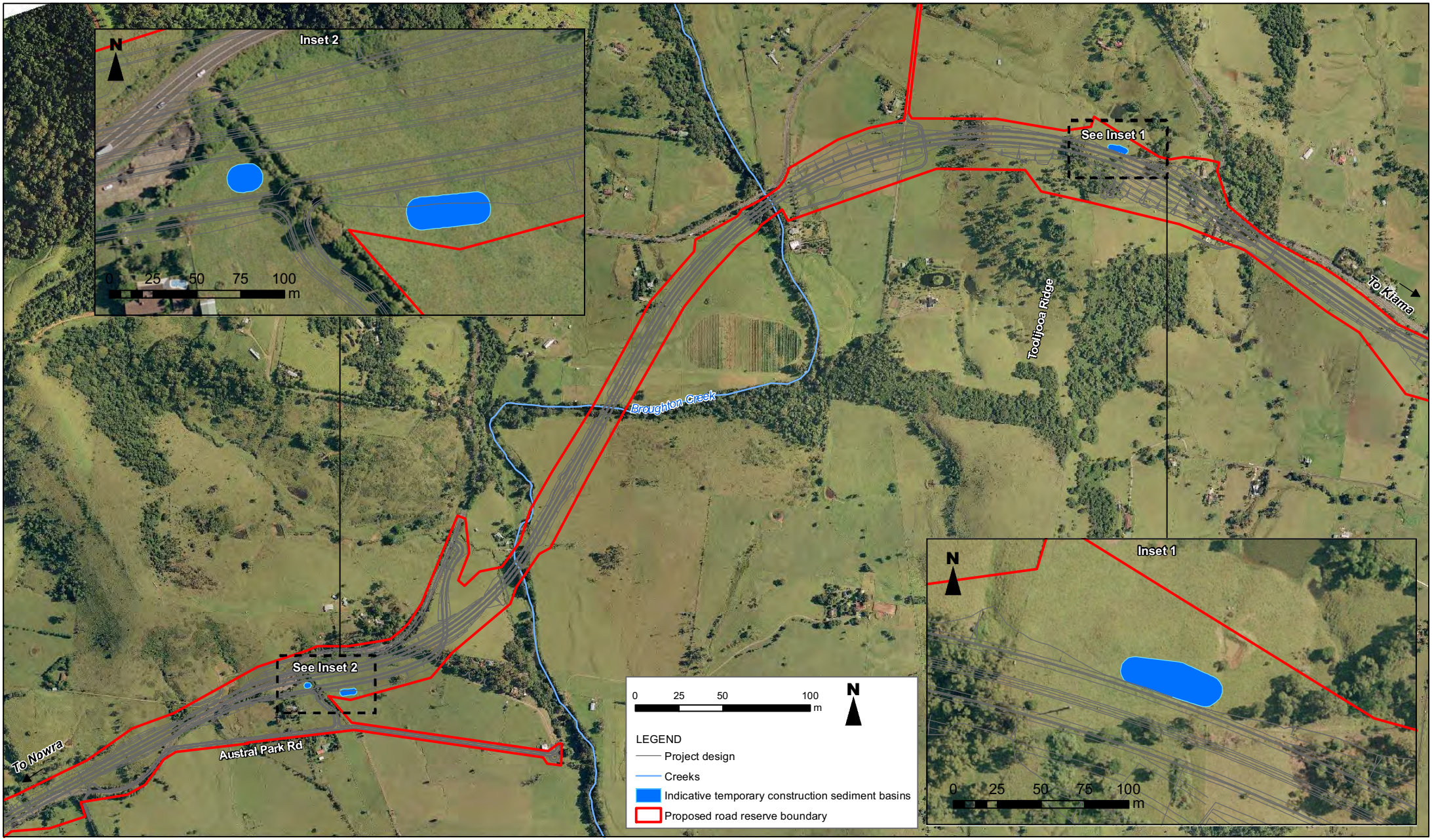

Figure 2-5 Location of indicative temporary construction sediment basins

Source: AECOM (2012), LPMA (2011)

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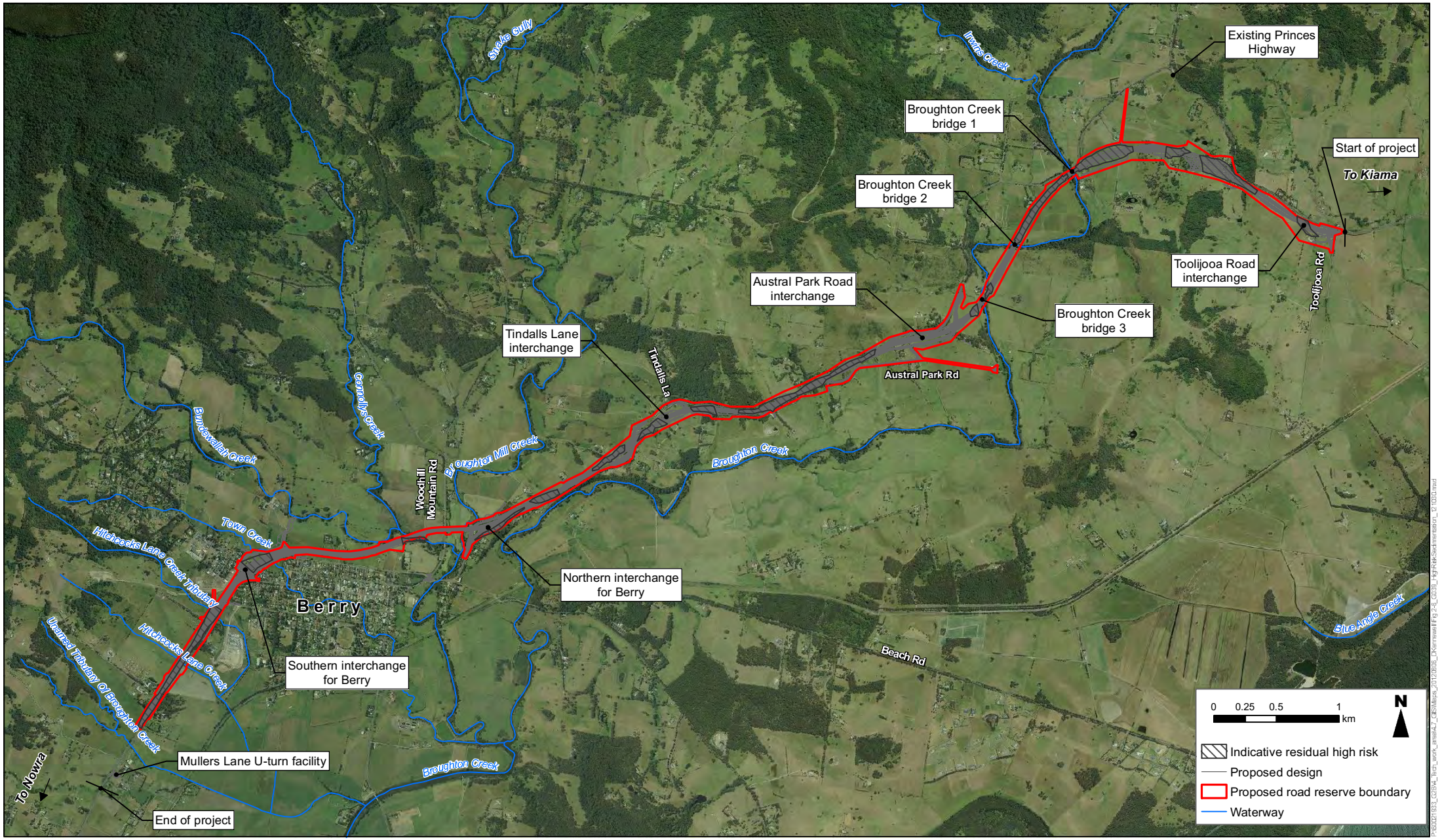

Figure 2-6 Residual high risk erosion and sedimentation area

Source: AECOM (2012), LPMA (2011)

Construction sequencing

Construction sequencing can play a significant role in the erosion and sediment control strategy. When planning construction sequencing, consideration would be made of the following:

- Detailed design and construction staging would be informed by the use of a qualified soil conservation specialist
- Construction works would be planned to minimise the extent of disturbed areas and to rehabilitate disturbed areas as soon as practicable after construction.
- Permanent clean water diversion and top of cut drains would be constructed at the commencement of construction to limit the volume of water on the construction site.
- Where possible, permanent transverse drainage would be installed early in the construction program to allow offsite water conveyance through the construction site. Where this is not possible, temporary drainage structures may be required.
- Sediment basins (both operational and temporary/construction) would be constructed prior to or concurrently with clearing activities.
- Where practical, the proposed operational water quality swales would be constructed prior to or concurrently with clearing activities to enable their use during the construction period.
- Fill batters would be stabilised progressively as they are constructed to limit the areas of disturbed land.
- The proposed diversion of Town Creek (refer to Section 4 for a discussion of the proposed Town Creek diversion) would largely be constructed off line until new beds and banks were stabilised before diverting flows from the upper Town Creek catchment.

Dewatering

Construction site dewatering would be managed through a work method statement prepared in accordance with the RMS technical guidelines for the Environmental Management of Construction Site Dewatering (RTA, 2011).

Acid sulfate soils

Although there is a low risk of ASS (refer Section 2.1.4), appropriate management measures would be implemented during construction to reduce the risk associated with disturbing ASS. Such measures would include an acid sulfate soil management plan (ASSMP) outlining the strategies to manage potential ASS (PASS) impacts. During the initial works onsite, further testing for ASS or PASS across the floodplains would be undertaken to quantify the risk of disturbing ASS, with a particular focus on any excavations. The ASSMP would be developed in accordance with the RMS Guidelines for the Management of Acid Sulfate materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulphidic Black Ooze (RMS, 2005).

The ASSMP would outline the following:

- How excavated material would be temporarily stored, treated and used.
- Specific leachate control procedures.
- Protocol measures should unexpected ASS related incidents occur.

To minimise PASS impacts where possible, construction should be planned to reduce the amount of deep trenching or soil replacement. Designers should also account for the potential acidic nature of the estuarine soils and the impact on engineered structures. Where ASS are found, soil specialists should be consulted to determine soil treatment requirements.

Mitigation measures may include the following:

- Avoidance of ASS.
- Minimising the disturbance of ASS.
- Avoiding activities that could lower the water table.
- Undertaking water quality monitoring downstream of ASS risk areas.
- Neutralising acidic runoff.
- Covering ASS with clean fill to prevent further disturbance.

Contaminated runoff and spills

Areas would be allocated for the storage of fuels, chemicals and other hazardous materials. These facilities would be secured and bunded. Any spills or contaminated runoff would be captured and disposed of at a licensed facility.

Activities such as refuelling, washdown and preparation of construction materials would be undertaken in bunded areas to mitigate risks in relation to spills or leaks of fuels/oils or other hazardous onsite construction material.

The application of good practice in the storage and handling of dangerous and hazardous goods would provide appropriate practical responses to manage impacts on occupational health and safety and minimise the risk of a spill occurring.

In addition, potential discharges from construction sites such as accidental construction spills or leaks would be managed through the installation of basins (primarily designed for sediment capture but with capacity to contain a significant spill volume) constructed in accordance with Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004). Captured contaminants resulting from spills or leaks would be treated and disposed of at a licensed facility.

Water required for dust control

Impacts from dust entering waterbodies would be managed using dust suppression techniques such as water spraying. The amount of water required would depend on a number of factors including rainfall, wind direction and intensity, soil type and area of ground disturbance at any one time.

It is estimated that approximately 12 litres/m^2 of water would be required for dust suppression daily. This is dependent on weather and surface exposure and would be variable over the course of the project.

Water for construction purposes including dust control would be sourced, where reasonable, from the following locations in order of preference:

- Recycled effluent from the Gerringong Gerroa Sewerage Scheme and the Berry Sewage Treatment Plant (in accordance with RMS policy and guidance for the use of reclaimed water)
- Surface water (sediment basin captured runoff).
- Surface water (watercourses).
- Potable water.
- Groundwater.

Farm dams

The assessment of existing farm dam catchments (refer Section 2.2.5) showed that for the majority of farm dams the loss of catchment area would be less than 20 per cent of the original catchment. The farm dams with the greatest proportion of catchment loss are those smaller dams which are located at higher elevations and have relatively small catchments. Several of these highly impacted dams are located on properties already acquired by RMS for the project. Residual impacts would be managed through consultation with individual stakeholders.

Water quality monitoring

An independent surface water quality monitoring program would be incorporated into the ESCP in accordance with the recommendations of the *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012), which is provided at Appendix G to the environmental assessment.

This program would use ANZECC trigger values for the protection of aquatic ecosystems as a starting point to develop locally appropriate thresholds that would trigger mitigating management responses. This would include monitoring parameters such as Turbidity (positively correlated with suspended sediment loads) and pH (to monitor ASS).

2.3.2 Operational management measures

The assessment of water quality has sought to identify potential impacts and provide appropriate management controls within the design (see Section 2.2.2). The water quality treatment system selected for the project aims to improve the quality of runoff compared to the existing highway and therefore have a net benefit to receiving waterways. This approach would protect sensitive receiving environments, in particular creeks of ecological importance including moderate and major fish habitat waterways.

The design of crossings over creeks and drainage lines has considered the sensitivity of these receiving environments and appropriate measures would be applied, including suitably spanned bridges to protect the riparian environments.

Town Creek diversion

The diversion channel would include the appropriate use of energy dissipators and/or batter treatment to ensure the diversion of flows from Town Creek into Bundewallah Creek does not cause scour and erosion.

The design of the diversion channel would include a revegetation component to stabilise banks and therefore mitigate erosion. Whilst enhancing the structural integrity of the channel, subsequent benefits of revegetation would include:

- Increased protection to the adjacent landowners land.
- Increased channel roughness thereby reducing velocities and erosive flows.
- Increased channel shear strength and soil binding.
- Provision of habitat, habitat corridor, nutrient assimilation and increased biodiversity.

The design and revegetation of the diversion channel would ensure there is no detrimental impact on water quality within the channel and therefore for flows into Bundewallah Creek.

Operational water quality basins and swales

In order to inform and develop an efficient water quality strategy for the operation phase, pavement runoff was modelled using the MUSIC model developed for the water quality impact assessment (see Section 2.2.2). A range of water quality treatment measures (Scenario 1 through to Scenario 4c) were included in the model. A description of each scenario is provided in **Table 2-4**.

The modelling included the treatment of runoff from a batter of five metres width on both sides of the roads. These "treated batter' nodes have EMC values for sediment loads based on typical agricultural catchments (as per Fletcher *et al.* 2004) as soils for the lower portion of total batter area may be incompletely protected by vegetation. For nutrients the "treated batter" nodes have rural catchment values rather than agricultural values as the fertilisers normally associated with agricultural practices would not be used.

The remaining batter areas (in excess of the five metres assumed draining to the pavement) were modelled as "untreated batter" nodes with typical rural EMC values to represent the vegetated state of the operational phase, allowing little mobilisation of pollutants. These "untreated batter" nodes would generally be diverted around treatment measures and therefore bypass treatment nodes in the MUSIC model.

Table 2-4: Operational pollutant reduction strategies – swales and basins

Scenario	Size (per hectare)	Description of water quality treatment
1	140 m^3 basin	Operational water quality basins include the following assumptions: • 2.5 m deep (including 0.5 m freeboard, 1.4 m extended detention and permanent pool depth of 0.6m). • 2H:1V internal batters. • 3H:1V external batters. • Notional detention time of six hours. • Energy dissipaters or scour protection methods would also be used to prevent erosion at outlets.
2	220 m^3 basin	
2a	300 m^3 basin	
3a	60 m x 1.0 m swale	Swales design would include the following assumptions: • 1% longitudinal grade. • 2H:1V batters. • Exfiltration set to zero. • Depth of 0.3 m. • 0.25 m vegetation height.
3b	100 m x 1.0 m swale	
3c	140 m x 1.0 m swale	
4a	60 m x 2.0 m swale	Swales design would include the following assumptions: • 1% longitudinal grade. • 2H:1V batters. • Exfiltration set to zero. • Depth of 0.3 m. • 0.25 m vegetation height.
4b	100 m x 2.0 m swale	
4c	140 m x 2.0 m swale	

In order to establish a baseline for comparison, the three one hectare catchments were analysed for generated pollutant loadings (kg/year) and the results are summarised in **Table 2-5**.

Table 2-5: Residual pollutant loads – swales and basins

No treatment	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Pre-existing	235	0.62	6.36
Existing	1260	2.31	10.8
Proposed	1980	3.64	16.6
Design with treatment			
Scenario 1	530	1.69	15.4
Scenario 2	433	1.53	14.9
Scenario 2a	376	1.44	14.5
Scenario 3a	413	1.60	16.0
Scenario 3b	298	1.41	15.4
Scenario 3c	240	1.31	15.0
Scenario 4a	316	1.44	15.5
Scenario 4b	226	1.29	14.8
Scenario 4c	184	1.22	14.4

Note: No pre-treatment "buffering" (sheet flow of water over grassed medians or batters) is accounted for in the above scenarios.
TSS – Total suspended solids, TP –Total phosphorous, TN – Total nitrogen.

It should be noted that modelling did not allow for any pavement water ingress through the swale base and sides. It is likely that some runoff would be exfiltrated therefore reducing pollutant loads further than stated in the above results. Similarly pollutant reduction percentages would increase where exfiltration occurs.

As shown in **Table 2-5**, incorporating treatment measures such as swales and permanent operational water quality basins can reduce pollutant loads to receiving environments below existing conditions for TSS and TP. The proportion of pollutant reduction attributable to different treatment devices is shown in **Table 2-6**.

Table 2-6: Pollutant reduction percentages – swales and basins

Water quality basins	TSS (% reduction)	TP (% reduction)	TN (% reduction)
Scenario 1	73.2	53.5	7.6
Scenario 2	78.1	57.8	10.1
Scenario 2a	81.0	60.4	12.8
Swales 1 m wide			
Scenario 3a	79.1	56.0	3.9
Scenario 3b	84.9	61.3	7.3
Scenario 3c	87.9	64.0	10.0
Swales 2 m wide			
Scenario 4a	84.0	60.3	6.9
Scenario 4b	88.6	64.5	10.8
Scenario 4c	90.7	66.5	13.6

The modelling suggests a water quality basin with 300 cubic metres of extended detention storage per hectare (Scenario 2a) can provide up to an 81 per cent average removal of TSS generated under proposed design conditions. A similar level of TSS removal could be provided with a vegetated swale of one metre base width and 60 metres length per hectare (Scenario 3a). However wider and longer swales per hectare are required to achieve TP and TN removal similar to sedimentation basins. Scenario 4c (Two metre base width and 140 metres length) is the swale that matches the basin in Scenario 2a most closely for TN reduction.

It is recommended that the water quality strategy includes a combination of swales and water quality basins to treat road runoff and protect downstream receiving environments, in accordance with the following:

- Swales: A range of swales of varying length are proposed both in the median and along outer road edges to convey and treat runoff. As a minimum these swale sizes would meet the total area requirements of Scenario 4c (ie 140 metres long by two metres wide, per hectare of upstream catchment).
- Basins: Proposed sizes for water quality basins along the upgrade are summarised in **Table 2-7** (based on Scenario 2A). Access in the form of a three metre wide access track would be incorporated in the basin berm for maintenance.

Based on the current concept design, **Table 2-7** indicates that water from the operational roadway would be treated in one of up to 18 operational water quality basins prior to discharging into the environment. An initial assessment of the positioning of the proposed operational water quality basins (refer **Figure 2-7**) indicated that the majority of these basins would also be suitable for use during the construction period. Water quality basins 12A and 13A were determined not to be suitable for use as they are designed to capture water from a bridge structure and the amount of earthworks in the vicinity of these basins would be minimal. The preliminary sizing indicates that one operational basin (3A) would be below the design criteria during the clearing stage and five operational basins (2A, 4A, 6A, 9B and 9C) would be below the design criteria at final construction levels (note: basins 3A and 6A discharge to sensitive receiving environments). The latter five basins were all associated with areas of cut. In these areas, other measures would be implemented during construction to compensate for this shortfall in the basin volume (such as staging of works, at-source erosion control and small sediment capture devices throughout the catchment).

Additionally, the cut batters could be managed as separate catchments with multiple small sediment capture devices to reduce reliance on the end of line sediment basin. It should be noted that the actual operational water quality requirements, including number and location of basins, would be refined and finalised during detailed design.

Table 2-7: Potential size requirements for operational water quality basins based on the Concept Design

Basin name	Catchment area (m^2)	Indicative volume required (m^3)
1A	8480	254
2A	38,661	1160
3A	12,990	390
4A	27,579	827
5A	16,850	505
6A	17,839	535
7A	19,165	575
8A	56,289	1689
8B	13,792	414
9A	6644	199
9B	19,040	571
9C	11,610	348
10A	19,033	571
11A	24,155	725
12A	5280	158
13A	4296	129
14A	36,738	1102
15A	24,465	734

*Note: see **Figure 2-7** for basin locations. Number of basins and volumes are subject to change during detail design*

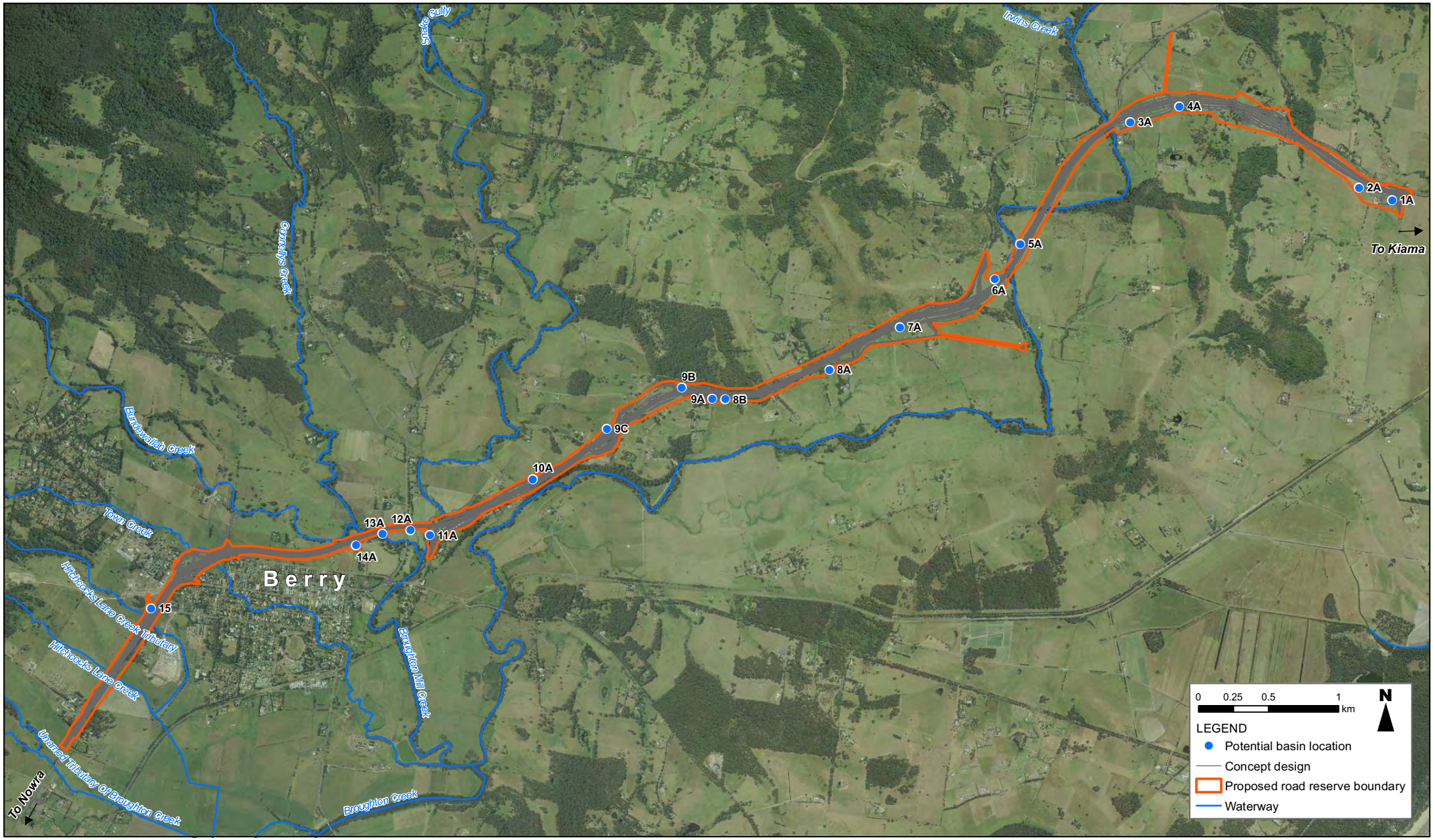

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Figure 2-7 Potential operational water quality basin locations

Source: LPMA (2011)

Capture and spills

The upgraded highway alignment would likely provide for safer transportation of vehicles compared with the existing alignment. This would reduce the total number of accidents along the upgraded section and therefore the potential of a spill of hazardous substances would also reduce.

Any spills that do occur would be directed to the permanent water quality basins and swales, all of which would have the capacity to receive a spill with a volume corresponding to that of a typical transport truck.

Both water quality basins and swales have potential for spillage control or containment. These water quality treatment measures provide capacity to treat first flush from the pavement surface and reduce the risk of spills discharging onto adjacent land or watercourses. The potential for spillage control or containment would be based on the hydrologic conditions prevailing at the time of the spill.

Additional treatment measures for sensitive receiving environments

Basins capturing runoff from pavements that drain to sensitive receiving environments would be designed with special outlet configurations to reduce the likelihood of overflow into the sensitive environment. For example:

- Water quality basins would have a permanent pool which a volume of spill would have to displace before passing through the entire basin.
- Bioretention systems would have extended detention depths that would have to be breached before overflowing into the downstream environment.

These simple yet effective arrangements would be incorporated into the design of water treatment systems as mentioned above with capacity to accommodate a typical transport truck.

In addition to swales and water quality basins, other treatment measures would be considered to further reduce nutrient loads from road runoff (primarily targeting nitrogen).

With regard to the runoff pollutants TSS, TP and TN, the latter is usually the most difficult pollutant to remove. This is because TSS and a large fraction of TP are associated with particulates, which are readily trapped by basins or swales. Only a small fraction of TN is particulate, the remainder being dissolved forms of nitrogen that can only be removed by biological processes such as a bioretention swale or trench (as shown in **Figure 2-8** and **Figure 2-9**).

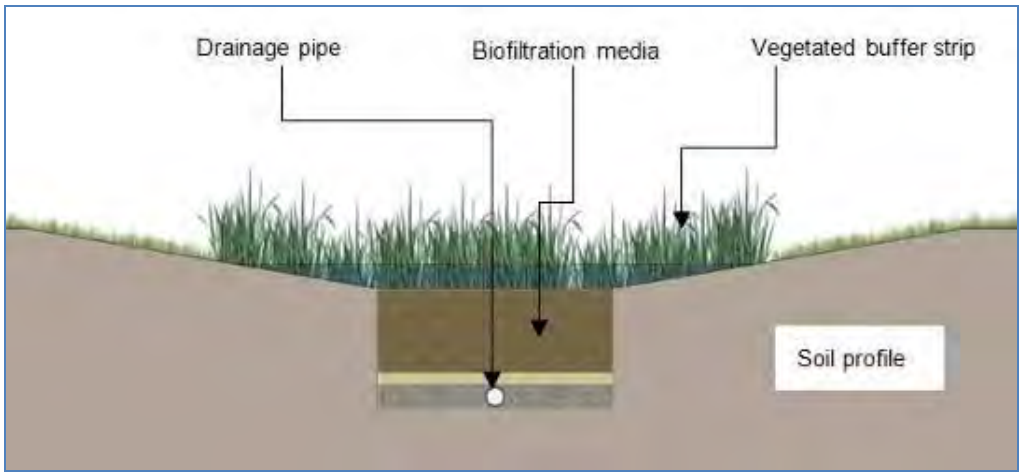

Figure 2-8: Typical cross section of a bioretention swale (note saturated zone not shown on this section)

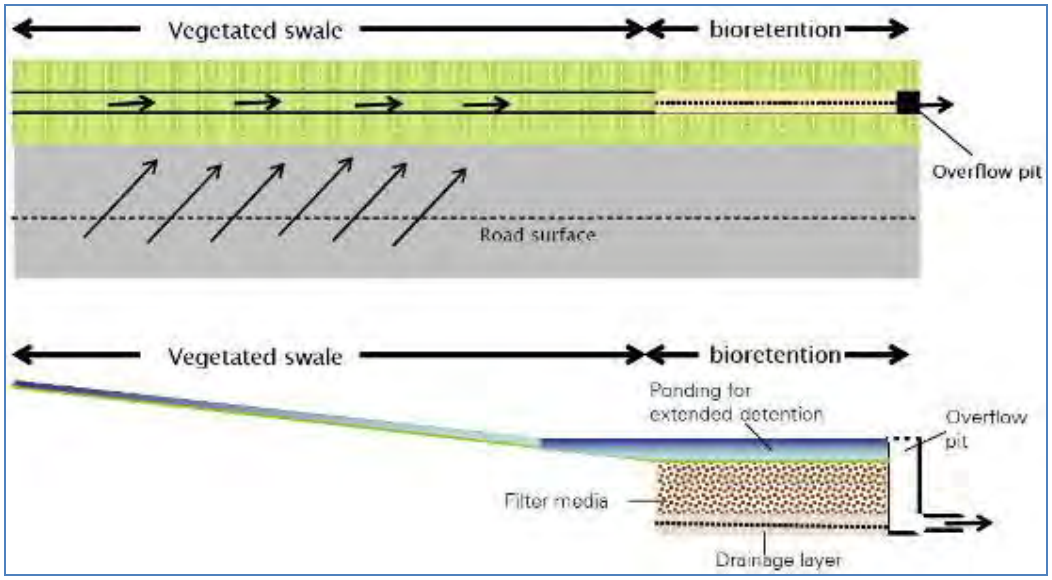

Figure 2-9: Conceptual layout for bioretention swale (WSUD Technical Design Guidelines, 2006)

Bioretention systems effectively remove fine suspended sediments, dissolved nutrients and heavy metals. Treatment of runoff occurs both on the surface of the bioretention system and within the filter media. When large storm inflows cause temporary ponding on the surface of the system (provided flat grades are achieved or check dams are installed to detain flows) pollutants are removed from the runoff through sedimentation and particulate adhesion onto the stems and leaves of the vegetation.

As stormwater percolates through the filter media, fine particulates and some soluble pollutants are removed through processes such as adhesion onto the surface of the filter media particles, biological transformation of pollutants by biofilms growing on the surface of the filter media particles, and biomass uptake of nutrients and metals through the root systems of the vegetation. The agitation of the surface layer of the soil caused by movement of the vegetation and the growth and death of roots helps maintain the permeability of the filter media.

Recent developments in bioretention system design have aimed to enhance the removal of dissolved nitrogen by enhancing anaerobic nitrogen removal processes such as denitrification. This has been done by modifying bioretention system designs to accommodate a submerged anoxic zone within the filter media and the addition of a carbon source to promote the denitrification bacterial activity. Studies of submerged zone bioretention systems have reported very high dissolved nitrogen removal from these adapted systems (Zinger *et al,* 2007).

Bioretention systems are typically planted with select species that are well adapted to the bioretention hydrology, are indigenous to the area, are hardy and would provide complementary habitat to the waterways into which they would drain. Dense and diverse plantings of such an ecological community provide excellent pollutant removal and require very little maintenance after establishment.

Effective removal of nitrogen requires that the footprint of the bioretention system be large enough to treat a sufficient volume of water from most storms (up to one year average recurrence interval (ARI)).

Targeted catchments

The catchments where additional nutrient removal treatment measures would be most effective are those that discharge directly to permanent waterways such as Broughton Mill Creek, Connollys Creek, Bundewallah Creek or Broughton Creek.

Bioretention construction involves trenching (up to one metre deep to accommodate filter depths and submerged zones) and it is possible that ASS (if present) may be exposed during this process. Bioretention also requires effective hydraulic operation to allow sub-surface collection drains to discharge downstream. This may be prohibitive for some areas within these floodplains.

Investigations would be undertaken to determine the presence of ASS at locations immediately upstream of road runoff discharge points to Broughton Mill Creek, Bundewallah Creek or Broughton Creek where bioretention would be most beneficial.

Where it is found that site conditions are suitable for bioretention, including an available area that does not contain ASS and where levels allow suitable hydraulic function, bioretention systems would be considered for implementation as part of the road runoff treatment.

Bioretention sizing

In order to determine suitable sizes for bioretention systems a range of scenarios were modelled using MUSIC. Modelling was undertaken as per the source catchment descriptions and EMC pollutant loads outlined above. A description of each scenario is provided in **Table 2-8**. Scenarios include swales as a pre-treatment to bioretention or a water quality basin preceded by a bioretention system. Note the scenarios described in **Table 2-8** could replace standalone swales and water quality basins, provided site conditions are suitable for bioretention.

The MUSIC modelling results outlined in **Table 2-9** and **Table 2-10** show a substantial reduction in TSS, TP and TN pollutant loads for all scenarios.

Table 2-8: Additional bioretention treatment measures for sensitive receiving environments (based on one hectare of road corridor)

Scenario	Description	Description of water quality treatment
5a	Swale and bioretention: 140 m swale + 60 m^2 bioretention system (ie 30 linear metres of bioretention swale)	Swales design would include the following assumptions: • 1 % longitudinal grade. • 2 m wide base. • 2H:1V batters. • Exfiltration set to zero. • 0.3 m depth. • 0.25 m vegetation height. Bioretention design would include the following assumptions: • 0.5 m deep filter depth. • 0.3 m extended detention depth. • 150 mm/h saturated hydraulic conductivity • 0.3 m submerged zone with carbon source.
5b	Swale and bioretention: 140 m swale + 70 m^2 bioretention system (ie 35 linear metres of bioretention swale)	
5c	Swale and bioretention: 140 m swale + 80 m^2 bioretention system (ie 40 linear metres of bioretention swale)	
6a	Sediment basin and bioretention: 25 m^3 sediment basin + 75 m^2 bioretention system	Sediment Basin design would include the following assumptions: • 2.0 m deep (including 0.5 m freeboard, 0.5 m extended detention and permanent pool depth of 1.0 m). • 2H:1V internal batters. • 3H:1V external batters. • Energy dissipaters or scour protection methods would also be used to prevent erosion at outlets. Bioretention design would include the following assumptions: • 0.5 m deep filter depth. • 0.3 m extended detention depth. • 150 mm/h saturated hydraulic conductivity • 0.3 m deep submerged zone with carbon source.
6b	Sediment basin and bioretention: 30 m^3 basin + 85 m^2 bioretention system	
6c	Sediment basin and bioretention: 35 m^3 basin + 95 m^2 bioretention system)	

Table 2-9: Residual pollutant residual loads - additional bioretention measures

No treatment	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Existing Princes Highway	1260	2.31	10.8
Design Princes Highway	1980	3.64	16.6
Design with treatment			
Scenario 5a	119	0.811	9.6
Scenario 5b	112	0.78	9.2
Scenario 5c	107	0.76	8.9
Scenario 6a	347	1.18	10
Scenario 6b	279	1.03	9.09
Scenario 6c	249	0.97	8.7

Table 2-10: Pollutant reduction percentages - additional bioretention measures

Scenario	TSS (% reduction)	TP (% reduction)	TN (% reduction)
Scenario 5a	94.0	77.7	42.3
Scenario 5b	94.3	78.5	44.4
Scenario 5c	94.6	79.1	46.3
Scenario 6a	82.4	67.7	39.8
Scenario 6b	85.9	71.6	45.3
Scenario 6c	87.4	73.3	47.6

Suitable bioretention scenarios for catchments that discharge directly to Broughton Mill Creek, Bundewallah Creek or Broughton Creek would include for example:

- Scenario 5c: 140 metre swale plus 80 square metres of bioretention (ie 40 linear metres of two metre wide bioretention swale).
- Scenario 6b: 30 cubic metres of water quality basin plus 85 square metres of bioretention.

These meet a 45[1] per cent TN reduction target as per the EPA guidelines (Managing Urban Stormwater: Council Handbook (refer **Table 2-10**).

[1] This indicates compliance is possible, under a "typical" section of highway, if these scenarios were adopted. The purpose of this analysis is to confirm a solution is possible, but maintain flexibility to provide site-specific solutions during detail design. The actual solution implemented would depend on factors such as the availability of engineered soils, the suitability of existing topsoils and the season/time of year during which revegetation would occur.

Maintenance

The typical maintenance requirements of the proposed stormwater treatment elements are described in **Table 2-11**.

Table 2-11: Maintenance requirements for typical stormwater treatment element

Treatment element	Typical maintenance requirements
Swales	• Check that vegetation is at suitable height to allow design flow capacity. • Clear obstructions or debris. • Check for erosion, weeds, plant condition, oil spills and the build-up of litter and sediment.
Sediment basins	• Check that pits, pipes, weirs and other structures are clear of any obstructions or debris. • Check for erosion, weeds, plant condition, oil spills and the build-up of litter and sediment. • Desilt approximately once every five years (or when half of the sediment storage capacity is full).
Bioretention systems	• Check that pits, pipes, weirs and other structures are clear of any obstructions or debris. • Check for erosion, weeds, plant condition, compaction of filter media, oil spills and the build-up of litter and sediment.

Generally, inspection of stormwater treatment devices is recommended every three months until the system has become established. After this time inspection is recommended after large storm events (minimum of one inspection per year). Additional maintenance is then only required if a problem is evident during the inspection. Maintenance requirements can be further reduced through appropriate considerations and provisions in the detailed design phase, for example:

- Adopting a bush regeneration approach (using native species) for the water treatment features of the landscape. This would reduce the frequency of maintenance compared to an exotic species based formal landscape. As the vegetation community in a native species based landscape establishes, it becomes increasingly self-sustaining or self-regenerating.
- By specifying very high and diverse planting densities in planting plans to make aquatic features resistant to weed establishment, for example, six to 12 plants per square metre, depending on the situation. Effective weed management would then be achieved through regular monitoring and the early removal of weed propagules during the establishment phase.

Water quality basins generally require cleaning out about every five years depending on the sizing of inlet ponds, while bioretention systems may need resetting every 25 years (MUSIC by eWater (2010)).

Management measures summary

In order to mitigate the impact on receiving waterways from runoff generated from the project, appropriate water quality treatment mechanisms would be adopted. This would include as a minimum swales and/or permanent water quality basins to target sediment and nutrient capture.

Suggested water quality treatment targets for the project are:

- An 80 per cent reduction in TSS load.
- A 60 per cent reduction in TP load.

Example treatment systems to meet this target would include:

- Swales 140 metres by two metres per hectare of road catchment (based on **Figure 2-3**).
- Water quality basins providing 300 cubic metres of working volume per hectare of road catchment (based on **Figure 2-3**).

These treatments would meet stormwater quality targets for TSS and TP and also reduce loads for these parameters below existing conditions.

Suggested water quality treatment targets for catchments that discharge directly to the more sensitive receiving environments of Broughton Mill Creek, Connollys Creek, Bundewallah Creek or Broughton Creek are:

- An 85 per cent reduction in TSS load.
- A 60 per cent reduction in TP load.
- A 40 per cent reduction in TN load.

Additional water quality treatment measures for outlets directly discharging to sensitive receivers would be considered in order to increase nitrogen removal. This requires the addition of bioretention systems to the treatment train. This would include swales and bioretention and/or water quality basins and bioretention in place of standalone swales or water quality basins. Example treatment systems to meet this target would include:

- 140 metre swale plus 80 square metres of bioretention per hectare of road catchment (based on **Figure 2-3**).
- 30 cubic metres of water quality basin plus 85 square metres of bioretention per hectare of road catchment (based on **Figure 2-3**).

In addition to meeting targets for TSS and TP, these treatments would meet stormwater quality targets for TN to reduce loads for nitrogen below existing conditions.

Note site conditions would be assessed at the detailed design phase to ensure bioretention is suitable. Site conditions such as the presence of PASS and minimum grades may prevent bioretention being feasible. In this case swales and/or water quality basins would be adopted to treat runoff.

In situations where it would not be possible to meet the nitrogen reduction target without compromising the hydraulic capacity of the system, or exposing PASS, the nitrogen reduction target would be waived in preference to hydraulic capacity and TSS removal.

Water quality monitoring

The water quality treatment system selected for the project aims to improve the quality of runoff compared to the existing highway and therefore have a net benefit to receiving waterways. Monitoring of surface waters upstream and downstream of site would be required In order to assess the performance of the system.

An independent surface water quality monitoring program is described in *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012) which is provided at Appendix G to the environmental assessment.

This program would use ANZECC trigger values for the protection of aquatic ecosystems as a starting point to develop locally appropriate thresholds that would trigger operational mitigating management responses. This would include monitoring parameters such as Turbidity (positively correlated with suspended sediment loads), pH (to monitor ASS), Nutrients (TP and TN), Metals (Aluminium, Cadmium, Copper, Lead, Zinc) and Total Petroleum Hydrocarbons.

3 Groundwater

This chapter describes the existing groundwater features in the locality of the project and assesses the potential impacts of the construction and operation of the project. It also outlines measures to mitigate these potential impacts. The chapter is based on the DGRs for the project and consideration of comments from the NOW (2011). Site specific groundwater information is derived from a geotechnical investigation (Coffey, 2010), in which 20 monitoring wells were constructed. Groundwater was encountered in all these monitoring wells along the route and groundwater levels were measured. However no groundwater quality data is available. The shallowest groundwater (0.96 metres below ground level) intersected along the route was within sandstone adjacent to Broughton Creek.

Groundwater management strategies outlined in this chapter have been compiled in accordance with NSW State policy as outlined by the OEH and NOW.

3.1 Groundwater regulation and management

Groundwater and surface water within the Sydney Basin is managed by NOW. The access, extraction and use of groundwater in NSW is currently managed and implemented under two key pieces of legislation - the *Water Management Act 2000* (WM Act) and the *Water Act 1912* (Water Act). The WM Act is gradually replacing the planning and management frameworks in the Water Act, although some provisions of the Water Act are still in force. The WM Act regulates water use for rivers and aquifers where Water Sharing Plans have commenced, while the Water Act continues to operate in the remaining areas of the State. The project area is located within the Sydney Basin Southern management zone of the Greater Metropolitan Region Water Sharing Plan which commenced on 1 July 2011 (NOW, 2011a).

The objective of the WM Act is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The Act requires approvals for activities that impact the aquifer(s) present. The approval is for activities that intersect groundwater other than water supply bores and may be issued for up to ten years. In accordance with Part 3A of the EP&A Act water use approval under Section 89, and a water management work approval under Section 90 or an activity approval under Section 91 of the WM Act is not required.

The NSW State Groundwater Policy Framework Document was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses (DLWC, 1997). The policy has three component parts:

- The NSW State Groundwater Quality Protection Policy (DLWC, 1998).
- The (Draft) NSW State Groundwater Quantity Management Policy (largely replaced by Water Sharing Plans) (DLWC, no date).
- The NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002).

While these policies set the principles and overarching goals for groundwater management, the Water Sharing Plans are legislated sets of rules for specific groundwater sources, placing volumetric limits on different categories of extractive use, and identifying minimum environmental water needs. Interference to environmental water requirements is governed by strict rules regarding the long-term average annual recharge. Thus construction activities would need to manage impacts within the prescribed limits.

The protection of groundwater from contamination is primarily governed by the POEO Act which makes it an offence to pollute waters, including groundwater. In accordance with Part 3A of the EP&A Act, under section 75v(1) an application for an EPL under the POEO Act cannot be refused if necessary for the carrying out of an approved project.

3.1.1 Groundwater quality

The NSW Groundwater Quality Protection Policy (DLWC, 1998) states that the objectives of the policy would be achieved by applying the management principals listed below:

- All groundwater systems should be managed so that the most sensitive identified beneficial use (or environmental value) is maintained.
- Town water supplies should be afforded special protection against contamination.
- Groundwater pollution should be prevented so that future remediation is not required.
- For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the resource.
- A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation or receiving waters.
- Groundwater dependent ecosystems would be afforded protection.
- Groundwater quality protection should be integrated with the management of groundwater quantity.
- The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.
- Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

3.1.2 Groundwater dependent ecosystems

The NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002) is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines GDEs, as “communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater.” A GDE may either be entirely dependent on groundwater for survival or it may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998). GDEs often occur in low lying areas with shallow groundwater close to the surface, however they are also associated with perched swamps, springs, karsts and base-flow to creeks and estuaries.

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles are as follows:

- GDEs have important values. Threats should be identified and action taken to protect them.
- Groundwater extractions should be managed within the sustainable yield of aquifers.
- Priority should be given to ensure that sufficient groundwater is available at all time to identified GDEs.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs.
- Planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater systems.

3.1.3 Groundwater quantity protection

The objectives of managing groundwater quantity in NSW are:

- To achieve the efficient, equitable and sustainable use of the State's groundwater.
- To prevent, halt and reverse degradation of the State's groundwater and/or its dependent ecosystems.
- To provide opportunities for development which generates the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability.
- To involve the community in the management of groundwater resources.

The policy for managing access to groundwater sources and relevant links with the Water Sharing Plan process and licensing conditions are outlined in NOW (2011b).

3.2 Existing environment

3.2.1 Aquifer characteristics

There are two main aquifer systems present along the project alignment including:

- Unconsolidated and unconfined alluvial/colluvial aquifers.
- Shoalhaven Group sediments.

The alluvial aquifer occurs as sand, silt clay and gravel flanking the creek systems and as more widespread floodplain deposits. Groundwater flow within the alluvial aquifer is via intergranular flow where sand and gravel lenses are interconnected providing preferential pathways of higher permeability. Within the flood plain sediments localised perched groundwater is expected above interbedded clay horizons. Little information is available within the NOW database for the alluvial aquifers suggesting the groundwater available for abstraction within the alluvial aquifer is limited and there are other water supply options available for local land holders. Groundwater movement within the alluvial aquifer and flood plain sediments is expected to flow towards low lying topographical features discharging into local creek systems or as springs.

Groundwater within the Shoalhaven Group sediments within the study area is present within the volcanoclastic Broughton Sandstone as well as within latite and underlying Berry Siltstone. Groundwater within the Shoalhaven Group sediments occurs in perched horizons within the weathered sandstone, siltstone and latite and within the deeper regional aquifer. Groundwater flow within the generally shallow perched horizon is limited and dominated by intergranular flow in the weathered sedimentary rocks. In contrast groundwater flow within the deeper aquifers is along both primary features, such as less well cemented zones within the rocks and secondary structural features such as joints, shear zones, faults and bedding plane partings. Groundwater flow within the tuff, basalt and latite of the Gerringong Volcanics is dominated by fracture flow but is also by interconnected vesicular zones.

Data obtained from the NOW database indicates that bores constructed in the Shoalhaven Group sediments in the area have variable yields. These deep aquifers are accessed by the majority of licensed bores in the area extracting groundwater from depths typically between 30 and 50 metres below ground level.

3.2.2 Groundwater levels

The depth of groundwater along the route is influenced by positioning in the landscape and proximity to discharge features. Typically the watertable is a subdued reflection of the topographic expression being deepest beneath hills and shallowest adjacent to creeks and wetlands. Shallow groundwater has been identified within the Broughton Creek floodplain immediately north of Berry where a number of water courses converge. Groundwater monitoring conducted between November 2009 and January 2010 confirms these general trends (Coffey, 2010).

Groundwater level monitoring (Coffey, 2010) also confirmed that groundwater along the route was shallow and typically less than ten metres below ground level for all lithologies. The elevation of groundwater was variable ranging from six metres AHD in low lying silts and gravels up to 100 metres AHD within latite in topographically elevated areas.

Time series groundwater level monitoring (Coffey, 2010) indicated the watertable naturally oscillates in response to climatic variation. As expected groundwater levels increased following significant rainfall and declined following periods of low rainfall. The amplitude of the groundwater response was variable and dependent upon landscape position and aquifer type. Low to moderate groundwater fluctuations of less than one metre were recorded in the siltstone and sandstone aquifers whereas larger fluctuations (between three and four metres) were typically measured in the sandstone and latite aquifers.

3.2.3 Groundwater quality

Groundwater quality data throughout the proposed route is limited. Some groundwater quality data has been obtained from the NOW groundwater database however the data is often incomplete. Background groundwater quality data in the existing groundwater monitoring network has yet to be collected, although this is likely to be undertaken in the early stages of the project.

Groundwater quality within the unconsolidated and unconfined alluvial/colluvial aquifers is expected to be of low salinity given low residence times and neutral pH. The high groundwater quality is due to local recharge via infiltration of rain and local runoff and low residence times within the predominately quartzose aquifers. In fact groundwater from these aquifers is often potable with appropriate water quality treatment.

In contrast groundwater quality within the Shoalhaven Group sediments is variable depending on the lithology intersected. Within shale lenses, groundwater quality is typically poor and saline due to connate salts within the marine shale units and low formation permeability. Groundwater within the sandstone and siltstone units is variable but typically of better quality than the shale units due to a high quartz content and higher groundwater flow, flushing the unit. Groundwater from the latite (Broughton Sandstone) is expected to be of better quality than groundwater derived from the Berry Siltstone due to poor quality groundwater within shale lenses leaking into the Berry Siltstone aquifer.

3.2.4 Groundwater users

A review of water bores registered with NOW indicates there are 16 registered bores within 0.5 kilometres of the project. Although the data within the database are limited, analysis indicates that groundwater along the alignment is a valuable resource used for stock, domestic and agricultural purposes to supplement surface water supplies collected in dams and pumped from creeks. Groundwater is extracted from a variety of aquifers including latite, gravels, sandstone, shale and fractured rock. The groundwater yield is variable but typically less than two litres per second.

There are no drinking water catchments in the project area. Groundwater has low use within the region because the area receives a relatively high rainfall and Shoalhaven Water provides a reticulated water supply to Berry. North of Berry water users are more reliant on tank water and groundwater.

3.2.5 Groundwater dependent ecosystems

See Section 3.1.2 for a definition of GDEs.

Groundwater from the alluvial aquifer systems associated with the Broughton Creek floodplain discharges into Broughton Creek. Riparian vegetation associated with Broughton Creek is likely to be dependent upon groundwater in some capacity. Local shallow groundwater flow systems also exist within elevated parts of the catchment within the Berry Sandstone and latite. Groundwater discharge via springs, seeps or spring fed dams may also sustain local small communities.

Coomonderry Swamp and Foys Swamp are coastal freshwater wetlands, located east of Broughton Creek. The Sydney Basin Southern management zone of the Greater Metropolitan Region Water Sharing Plan for the project area identifies Coomonderry Swamp as a high priority GDE in Schedule 4 of the Plan (NOW, 2011a). Coomonderry Swamp is a large (429 hectare) semi-permanent freshwater swamp, northeast of Nowra that is listed on the register of the National Estate. Foys Swamp is not listed in the Water Sharing Plan.

Floodplain swamp forest is a low, dense forest tolerant of brackish groundwater that was identified along Toolijooa Road and the railway line between Berry and Gerringong (Maunsell, 2007). This community may grade into estuarine fringe forest with increasing groundwater salinity.

Further information on GDEs can be found in the Aquatic Ecology and Water Quality Management Assessment Report (Cardno Ecology Lab, 2011). Water management plans that are to be prepared for this project are expected to minimise any impacts to GDEs.

3.3 Assessment of potential groundwater impacts

Several potential impacts to groundwater due to the proposed project have been identified. Impacts may occur during the construction phase or long-term operations phase.

3.3.1 Construction potential impacts and groundwater drawdown

Construction impacts may include potential changes to groundwater quality and groundwater levels. Potential groundwater quality risks include spills and accidents throughout construction. These risks consist of hydrocarbon contamination via fuel spills, and potential changes in groundwater pH levels associated with the disturbance of ASS, if present. In addition changes to groundwater flow patterns, recharge and discharge characteristics may be altered due to the intersection of the aquifer by artificial barriers such as road cuts and/or localised dewatering.

Deep excavations and cuttings may require temporary localised dewatering during the construction phase. Within the alluvial gravels identified north of Berry the groundwater is shallow and the foundations for cased bored piles associated with bridges or other major structures may have to be dewatered. Localised dewatering would temporarily alter groundwater flow conditions but after dewatering is completed original groundwater flows would be re-established.

It is not expected that groundwater extraction for water supply would be required during construction. If this need is identified during detailed design, further investigation would be undertaken.

Reduced groundwater recharge

The construction of access roads, tracks and the isolation of areas for stockpiling of construction materials can alter groundwater recharge and introduce pollutants. Compaction of shallow soils due to construction works may be caused in areas of unconsolidated alluvial sediments which can also result in reduced groundwater recharge.

Excavation of road cuttings beneath the watertable or intersecting perched groundwater causes groundwater to drain into culverts, creeks or rivers, locally reducing groundwater recharge and lowering the watertable.

Groundwater drawdown construction impacts

Temporary dewatering may be required during construction to artificially lower the watertable to maintain dry working conditions within excavations. Dewatering may be required in the cases of construction of bridge footings or road cuttings. Temporary dewatering is likely to draw down local groundwater levels in the immediate vicinity of the excavation. Should dewatering of the alluvial aquifer be required during the construction of bridge footings, groundwater drawdown will be limited to the base of the footing, and the zone of influence or induced cone of depression is expected to be limited due to the highly transmissive nature of an alluvial aquifer. Should dewatering be required during the construction of road cuttings, the impacts will depend on the local hydraulic conductivity of the aquifer matrix and secondary water bearing structural features.

In the event of temporary dewatering being required, modelling would be undertaken to assist in quantifying the amount of groundwater drawdown and any potential impacts. This would be included as a requirement in groundwater management plans for the project.

Groundwater quality impacts

Potential exists for fuel and chemical spills including petrol, diesel, hydraulic fluids, lubricants, and explosives residue to contaminate groundwater and GDEs, particularly if a leak or spill occurs on highly permeable sandy strata. Spills as a result of accidents can occur during construction activities, refuelling operations or from storage areas. Runoff from unpaved areas may be highly turbid. Accession of suspended solids to the groundwater however is likely to be retarded by filtering through the unsaturated zone, reducing the significance of impact.

There is a low risk that ASS may be present along the alignment. Should the watertable be lowered where ASS are present or during excavation works, ASS may become exposed and oxidation of sulphide minerals could result. This process generates sulphuric acid and increases metal concentrations in solution, which can lead to the degradation of the groundwater. Rainfall runoff could cause acidic water to migrate within the shallow groundwater system and discharge into surface water systems and groundwater receptors.

Impacts to groundwater dependent ecosystems

The potential risk that GDEs may be impacted due to construction activities is low. Local GDEs that may be associated with shallow groundwater flow systems are within elevated parts of the catchment and would continue to be sustained via discharge from springs or seeps following high rainfall events.

The risk of impacts to downstream GDEs in Broughton Creek is low. Groundwater flow volumes in Broughton Creek would remain virtually unchanged and surface water discharged to the creek from sedimentation basins would be treated in accordance with best practice.

3.3.2 Operational potential impacts

On-going impacts may also occur during the long-term operations phase of the project. Road runoff may be impacted by fuels and oils and permanent barriers to groundwater flow may remain following the upgrade.

Interception of groundwater and groundwater drawdown

The capacity of water extraction bores in the vicinity of the deep road cuttings may likely be reduced due to the lowering of the watertable. Similarly farm dams or GDEs recharged by springs which intersect groundwater down hydraulic gradient of the road cuts may also be affected by reduced spring flow due to altered groundwater flow conditions.

The deepest road cutting is up to 27 metres below ground surface through the Toolijooa Ridge cut, bypassing Broughton Village. Preliminary assessments indicate that groundwater would seep into the cutting from the latite and Kiama Sandstone. The predicted drawdown in the vicinity of the Toolijooa Ridge cut is not expected to impact any current users as registered groundwater bores are at a sufficient distance from the cutting so as not to be adversely affected. No GDEs have been identified in the vicinity. Potential future groundwater use in this area has not been identified at this stage.

Other cuts along the alignment are no deeper than 13 metres and may also be subject to groundwater inflows. Inflow to the cuttings may reduce groundwater recharge (as throughflow), lower the local watertable and alter groundwater flow paths. Cuttings in fractured rock may intersect water bearing fractures which are likely to seep.

Groundwater modelling may be required to be undertaken at some locations to quantify the amount of groundwater drawdown during a range of scenarios. The results of the groundwater modelling will be used to develop trigger points within groundwater management plans. The groundwater modelling program, if required would be undertaken in consultation with NOW.

Groundwater quality and recharge

Road runoff can contain pollutants associated with vehicular movement and normal use due to leaks, spills and accidents. The contaminants can include hydrocarbons (petrol, diesel and oils), metals, suspended solids and other compounds. Operational water quality basins and roadside swales are to be established to remove suspended solids to meet surface water quality criteria (refer Section 2.3.2).

Increasing the hard surface road area would increase runoff and decrease groundwater recharge. However recharge decrease would be minor given the small road surface compared to the remainder of the catchment. The risk of impacts to GDEs is slight as flows in Broughton Creek would remain virtually unchanged and surface water discharged to the creek from water quality basins would be treated in accordance with best practice.

3.3.3 Worst case

The worst case scenario adopted for the project assumes that all environmental management measures are ineffective. Groundwater contamination, should it occur, can be difficult, expensive and in some cases impossible to remediate. The severity of contamination would be determined by the type and volume of the pollutant, the nature and scale of the groundwater system, and where in the groundwater system the contamination has occurred. Whilst groundwater in some systems moves quite slowly and over short distances, in some alluvial or fractured rock systems water can travel considerable distances relatively quickly. The severity of the impacts is also dependent on the proximity to active groundwater users including town water supply, stock and domestic bores, and irrigation bores. Environmental impacts may occur in connected GDEs such as wetlands, springs and to surface water systems fed by groundwater base-flow.

Depending on the nature of the interference with a groundwater system, reductions in groundwater levels may be anything from short-term, to long-term or even permanent. Localised impacts from dewatering or additional extraction would generally disappear upon cessation of the activity, and could be mitigated with localised re-injection to ensure continuity of supply. Where an activity significantly alters a groundwater recharge zone or flow-path, or removes whole sections of an aquifer, the resultant impacts are more likely to be permanent.

A key aspect of the DGRs for this project is the provision of appropriate environmental management measures and design standards to minimise the potential risk of groundwater impacts. It is considered highly unlikely that all the management measures nominated for the project would operate ineffectively, and as such there is a very low risk of the worst case impacts occurring.

3.4 Environmental management measures

3.4.1 Construction management measures

Management of groundwater impacts during the construction phase is dependent upon the implementation of various measures which would be included in a CEMP that addresses potential groundwater impacts and details site practices. A separate groundwater management plan would be complied to address groundwater issues during and after construction. Potential impacts to groundwater during construction would be managed by:

- Minimising the depth of excavations in areas of alluvium.
- Limiting the need to dewater during construction.
- Using water treatment devices to treat runoff water quality before it has the opportunity to infiltrate to the water table.

During the construction phase, communications procedures must be in place to educate the project team on groundwater issues. Potential impacts to groundwater would be addressed directly in the groundwater management plan, which would:

- Identify strategies to minimise disturbance and control runoff from construction areas.
- Install bunding around fuel depots and stockpile areas to minimise the risks of contaminants reaching the watertable.
- Detail response plans to address fuel leaks and spills at machinery compounds or during refuelling. It is recommended that a hazardous materials plan (and spill emergency procedure) be implemented as part of the groundwater management plan.
- Detail the establishment of a groundwater monitoring network along the route to adequately characterise groundwater quality and establish background water quality within the alluvial/colluvial aquifers and Shoalhaven Group Sediments, including the Broughton Sandstone and latite... Monitoring wells would also be required adjacent to major cuts to monitor the effect on groundwater levels, where groundwater is encountered. The baseline water quality data would be used for comparison with groundwater quality data collected throughout the construction program.
- Identify strategies to remove or reduce the risks associated with the excavation of ASS or generating acidic groundwater.
- Assess the performance of groundwater mitigation measures.

Road cuttings

Dewatering may be required during the excavation and construction of the Toolijooa Ridge cut and possibly other deep cuts where the watertable is intersected. The dewatering program/s would involve construction of extraction bores, gravity drainage systems and/or pumping. Discharge of the extracted groundwater would depend on the groundwater quality but options include:

- Supplementing farm dams supply (subject to water quality testing and negotiations with farm dam owners)
- Discharge to creeks or temporary storage in water quality basins to reduce turbidity prior to discharge.

Discharge quality would be required to comply with the ANZECC (2000) water quality guidelines. Licensing to extract and discharge may be required through NOW. Dewatering may also be required during the construction of infrastructure such as piles within the floodplain alluvium east of Berry.

Groundwater monitoring

Groundwater monitoring would be required to monitor potential impacts to groundwater quality and levels during and after construction. A detailed sampling, analysis and quality plan outlining the groundwater monitoring programs would be compiled in consultation with the OEH and NOW in accordance with the *Guidelines for the Assessment and Management of Groundwater Contamination* (NSW DEC, 2007). The results of, and any recommendations from the monitoring would be reported to these agencies. The timing of sampling would be more frequent during the construction phase due to the higher risk of contamination to the local aquifers.

The monitoring program would be required to monitor groundwater level fluctuations and groundwater quality parameters within the existing groundwater monitoring network. During the field program the following field parameters and laboratory analyses would be collected from a minimum of four monitoring wells.

- pH, dissolved oxygen, redox, electrical conductivity and temperature (field parameters).
- Total petroleum hydrocarbons/benzene, toluene, ethylbenzene, xylene (TPH/BTEX), PAH, heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn).
- Installation of dataloggers in four key monitoring wells to monitor groundwater levels on a daily schedule.

Groundwater sampling protocols would be defined in the Sampling Analysis and Quality Plan (SAQP) however in summary all monitoring wells would be purged a minimum of three well volumes prior to sampling and metals are to be field filtered. Field meters would be calibrated daily and water samples collected for metals analysis would be field filtered prior to transportation to a NATA accredited laboratory in a chilled cooler.

The ANZECC 2000 Fresh and Marine Water Guidelines are considered the appropriate groundwater investigation levels for the protection of aquatic systems. The 95 per cent level of protection is considered the most appropriate in this sensitive fresh water ecosystem.

Groundwater monitoring should be undertaken and reported on a three monthly basis during construction.

3.4.2 Operational management measures

Following the construction of the project, strategies would be required to address potential on-going impacts to groundwater levels and groundwater quality.

Groundwater is likely to seep into deep road cuts where the watertable is intersected. Seepage from these sections would be directed towards spoon drains that flow by gravity into the road drainage system. At road cuts where large sections of the watertable are intersected a network of vertical drains may be installed into the road cut to allow groundwater to flow to the drainage network relieving hydraulic pressures within the road cut. The slotted connection drains may be lined with geotextile fabric to restrict the migration of fine particles minimising sediment blockages within the drainage system.

Groundwater monitoring

Section 3.4.1 sets out the approach to be taken to groundwater monitoring for the project. During operation groundwater monitoring would be carried out every six months with a review after two years to assess data trends and assess if further monitoring is warranted. The framework for monitoring would be set out in the SAQP. The objectives of the groundwater monitoring program would be established in consultation with NOW and the EPA as appropriate and would likely include an assessment of groundwater level data trends and comparison with rainfall data, and an assessment of water quality trends and exceedences, if any.

4 Flooding

This chapter addresses the DGRs for the assessment of flooding impacts relating to the project. The DGRs and the section in which they are addressed are presented in **Table 1-1**.

4.1 Existing environment

4.1.1 Overview

The project traverses the Broughton Creek floodplain in the north, crosses a number of local ephemeral drainage lines through the hills between Tomlins Road and Tindalls Lane, then crosses the floodplain a second time near the confluence of Bundewallah, Connollys and Broughton Mill Creeks. It passes to the north of Berry before crossing a series of ephemeral creek lines between Berry and Jaspers Brush.

Named creeks and tributaries in the vicinity of the project area are shown on **Figure 1-1** and include (from east to west):

- Broughton Creek.
- Broughton Mill Creek.
- Connollys Creek.
- Bundewallah Creek.
- Town Creek.
- Hitchcocks Lane Creek.

These creeks and tributaries are described in the following sections. There are also 14 minor unnamed waterway crossings that are traversed by the project that have been assessed as part of the project.

4.1.2 Broughton Creek

Broughton Creek and its tributaries drain the hills of the Cambewarra Range that lie north of the township of Berry as well as the broad flat floodplain that lies to the south of Berry. Broughton Creek flows south from Berry for approximately 8km before joining the Shoalhaven River.

The catchment area of Broughton Creek at Coolangatta Road (south of Berry) is approximately 104 square kilometres (SMEC, 2008). Natural forest and cleared pasture are typical of the catchment, with varying levels of development around the townships of Berry, Bundewallah, Foxground, Broughton, Broughton Vale and Broughton Village.

Broughton Creek drains across the northern side of the Shoalhaven floodplain. Agriculture is the major land use, with extensive areas utilised for dairy and cattle grazing. Downstream of the Berry Township, the terrain is flat and swampy. Tidal influence extends about 12 kilometres upstream from the Broughton Creek and Shoalhaven River confluence to the vicinity of the Coolangatta Road Bridge.

The upper reach of Broughton Creek meanders across the northern section of the project in a southerly then westerly direction then south again before flowing south of Berry and into the Shoalhaven River approximately five kilometres west of Shoalhaven Heads.

During larger flood events the banks of the upper Broughton Creek are overtopped with flood waters taking the shorter routes across the floodplains, returning to Broughton Creek some distance downstream.

The existing Princes Highway traverses the upper reach of Broughton Creek near Broughton Village. The project would pass just south of this location.

4.1.3 Berry township

Named creeks traversed by the project in the vicinity of Berry are shown on **Figure 1-1**.

Bundewallah Creek is located to the north of Berry and flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. Broughton Mill Creek flows southwards from the confluence with Bundewallah Creek, under an existing bridge at the Princes Highway, then under a second bridge at the South Coast Railway Line. Downstream and to the east of Berry, Broughton Mill Creek flows into Broughton Creek.

Connollys Creek enters Bundewallah Creek upstream of the confluence with Broughton Mill Creek.

Town Creek (also referred to as Princess Creek) meanders eastwards through the Berry town centre, adjacent to Princess Street, before joining Broughton Mill Creek.

Connollys Creek, Bundewallah Creek, Broughton Mill Creek and Town Creek are the main sources of flooding in Berry. Town Creek in particular presents a flood risk to a significant number of properties within Berry.

According to Cardno (2012) the existing Princes Highway is overtopped at the locations listed in **Table 4-1** during the ARI events indicated. During the 100 year ARI event, the crossings at Broughton Mill Creek, Town Creek and Hitchcocks Lane Creek and Tributary all experience overtopping.

Table 4-1: Existing overtopping of Princes Highway

	ARI event			
Waterway	**2 year**	**5 year**	**20 year**	**100 year**
Broughton Mill Creek	Overtops	Overtops	Overtops	Overtops
Town Creek			Overtops	Overtops
Hitchcocks Lane Creek	Overtops	Overtops	Overtops	Overtops
Hitchcocks Lane Tributary				Overtops

4.1.4 Available data

Previous flood studies

A number of studies have been carried out for the Broughton Creek and wider Shoalhaven River catchments. These studies provide useful background information to understanding the nature of flooding across the study area and include:

- Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012).
- Lower Shoalhaven River Floodplain Management Study & Plan: Climate Change Assessment (WMAwater, 2011).
- Broughton Creek Flood Study (SMEC Australia Pty Ltd, 2008).
- Lower Shoalhaven River Floodplain Risk Management Study and Plan (Webb McKeown & Associates, 2008).
- Lower Shoalhaven River Flood Study (Public Works Department, 1990).

As part of the route selection process for the Gerringong to Bomaderry Princes Highway Upgrade, Maunsell (now AECOM) produced indicative 100 year ARI flood extents as shown in **Figure 4-1** (Maunsell, 2008). The upgrade falls within the indicative 100 year ARI flood extent in a number of places.

Property survey

As part of the Broughton Creek Floodplain Risk Management Study (Cardno, 2012), a floor level survey was conducted in 2010 on properties in Berry that were identified as being affected by the Probable Maximum Flood (PMF). This survey data has been used to assess the potential impacts of the project on properties within Berry.

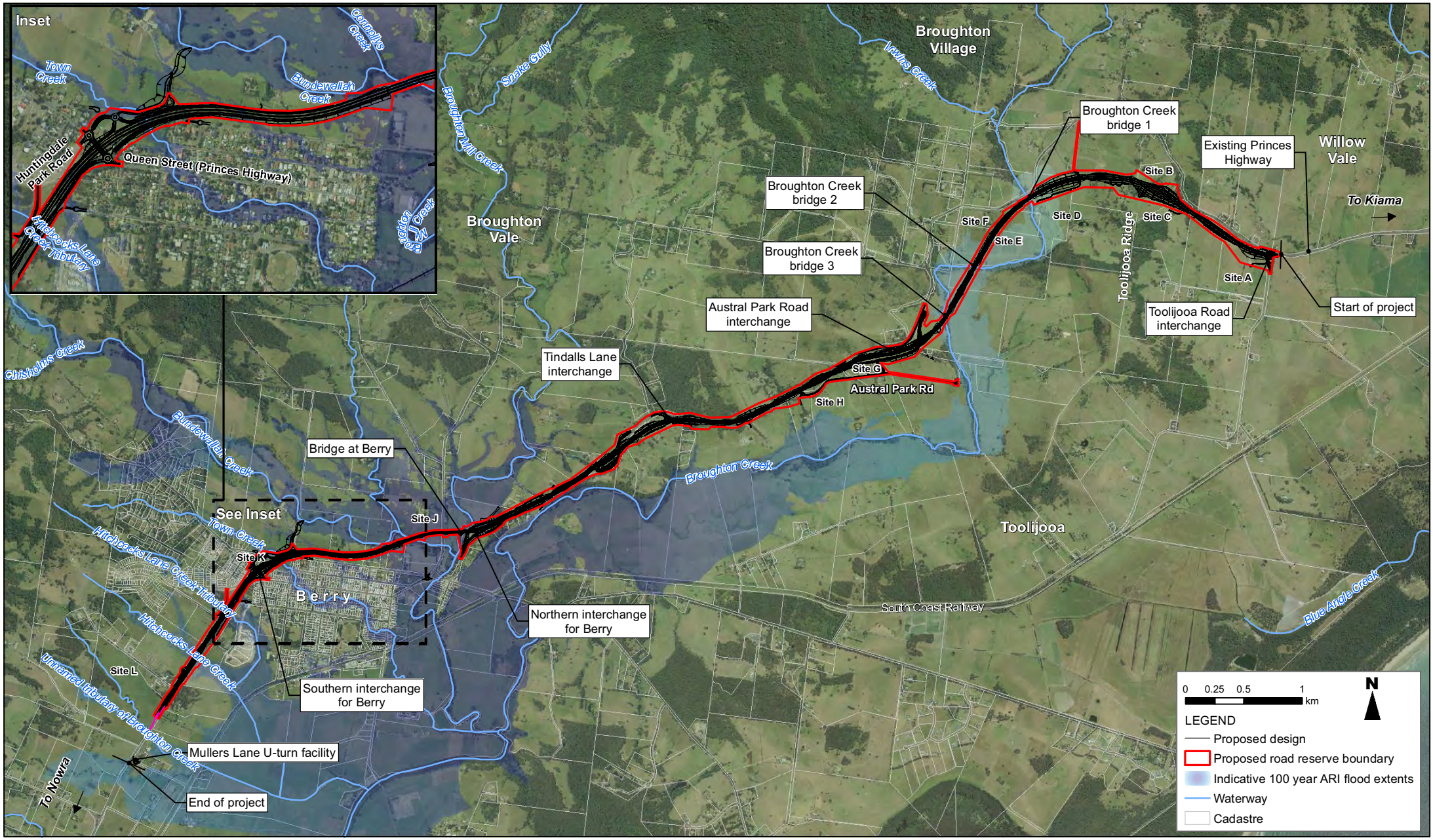

Figure 4-1 Indicative floodplain locations

Source: AECOM (2012), Cardno (2011), LPMA (2011)

4.2 Assessment of potential flooding impacts

4.2.1 Overview

As nominated by the DGRs, consideration has been given to potential flood impacts on upstream and downstream infrastructure and receivers due to the project. Waterways that could potentially be impacted by the project include:

- Broughton Creek (three crossings).
- Connollys Creek / Bundewallah Creek / Broughton Mill Creek (one crossing at Berry).
- Town Creek.
- Hitchcocks Lane Creek.
- Numerous unnamed tributaries to the above creeks.

The location of the highway with respect to the floodplain is an important consideration in the design and construction of the proposed works. Flooding of the highway can restrict access, cause damage and pose a safety risk. Conversely, any works within the floodplain are likely to change existing flood behaviour with the potential for adverse impacts on the surrounding environment. It has therefore been necessary to carry out an assessment of project related flood impacts. This assessment is outlined in the following sections.

4.2.2 Assessment approach

Hydrologic and hydraulic modelling and assessment has been carried out to better understand the flooding characteristics of the creeks and waterways traversed by the project under both existing and proposed conditions. This information has been used to quantify impacts and thus make informed decisions on managing the flood risks to the project and users as well as impacts on the surrounding environment.

The wider area around the alignment (except around the township of Berry) is generally zoned as rural and/or agricultural according to the Shoalhaven City Council and Kiama Municipal Council Local Environmental Plans. There is no indication at this stage that the existing land use patterns would change significantly in future. The flood impact assessment described in this section has therefore been based on the existing catchment characteristics.

Hydrologic and hydraulic modelling

The flood assessment has involved the development of hydrologic and hydraulic modelling approaches to suit the nature and extent of the waterways traversed by the project.

The assessment of the major crossing of the Broughton Mill Creek / Bundewallah Creek / Connollys Creek floodplain immediately north of Berry was carried out using the XP RAFTS and TUFLOW models developed for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012). Other waterway crossings were assessed using the Probabilistic Rational Method (PRM) and a combination of HEC-RAS 1D modelling and culvert hydraulic calculations.

Hydrologic modelling

For Broughton Mill Creek, hydrologic modelling was carried out using the XP RAFTS rainfall runoff routing model to derive inflow hydrographs for the TUFLOW hydraulic model. For this purpose the XP RAFTS model constructed and used in the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012) and the Broughton Creek Flood Study (SMEC, 2008) was adopted. The model was used to derive inflows for the 100 year ARI and PMF events.

Flow results obtained from the XP RAFTS/TUFLOW flood models have been compared against PRM estimates and a summary of 100 year ARI flows is provided in **Table 4-2**. The flow result is reported at a location downstream of the project corridor at the convergence of Broughton Mill, Bundewallah and Connollys Creek. The peak flow from the XP RAFTS/TUFLOW model compares reasonably well, with the PRM flow being 11 per cent higher.

Table 4-2: Comparison of TUFLOW and PRM 100 year ARI flows

Waterway	TUFLOW	PRM
Broughton Mill Creek [1]	947	850 [2]

Notes

1. *Approximately 350m downstream of Berry Bridge .*
2. *For comparative purposes PRM estimate presented here is based on no allowance for climate change and is therefore less than the PRM estimate given in **Table 4-3**.*

For the remaining waterway crossings PRM was used to estimate peak flows. The PRM is based on data from 308 gauged catchments and is applicable to small to medium rural catchments in eastern NSW. The PRM was therefore considered appropriate for application to the present assessment.

In accordance with design criteria established for the project, provisions for potential future climate changes were made by increasing all rainfall intensities by six per cent (DECC, 2007).

For catchments where the PRM was used the PMF flow was approximated by multiplying the 100 year ARI PRM flow by five.

Catchment areas for each proposed watercourse crossing have been defined using 1:25,000 topographic maps and available survey in the vicinity of the highway. The contours used to define these catchment areas were at minimum 10 metre intervals supplemented where available with aerial photogrammetric survey and detailed field survey.

Catchment layouts and identifiers are as shown in **Figure 4-2** and design flow estimates are listed in **Table 4-3**.

Table 4-3: PRM design flow estimates for major transverse drainage infrastructure

Catch ID	Waterway	Design chainage	Catchment area	1 year ARI	5 year ARI	10 year ARI	50 year ARI	100 year ARI
			(ha)	(m^3/s)				
LB	Unnamed Ephemeral	9000	4	0.5	1.3	1.6	2.3	2.7
KA	Unnamed Ephemeral	9840	66	5.8	15	19	28	32
K	Broughton Creek	9950	2781	106	276	358	557	646
LA	Unnamed Ephemeral	10500	6	0.8	2.1	2.2	3.8	4.3
L	Broughton Creek	10700	2869	108	283	366	570	661
M	Broughton Creek	11200	3197	117	306	396	618	715

Catch ID	Waterway	Design chainage	Catchment area	1 year ARI	5 year ARI	10 year ARI	50 year ARI	100 year ARI
			(ha)	(m^3/s)				
N	Unnamed Ephemeral	11900	7	1.0	2.3	2.9	4.2	4.8
O	Unnamed Ephemeral	12150	7	1.0	2.3	2.9	4.2	4.8
P	Unnamed Ephemeral	12310	6	0.8	1.9	2.4	3.5	4.1
Q	Unnamed Ephemeral	12770	106	8.4	21	27	41	48
R	Unnamed Ephemeral	13320	15	1.7	4.2	5.3	7.8	9.0
S	Unnamed Ephemeral	13580	21	2.3	5.6	7.1	11	12
TC	Unnamed Ephemeral	14150	1	0.12	0.29	0.34	0.51	0.6
TA	Unnamed Ephemeral	14420	3	0.5	1.2	1.6	2.3	2.6
TB*	Unnamed Ephemeral	14500	1	0.15	0.36	0.45	0.64	0.73
T	Broughton Mill/ Connollys Creek	16000	4286	146	383	497	775	896**
W	Town Creek	17450	85	7.0	17.8	22.6	34.2	39.5
XA	Duck Pond ephemeral	17950	4.4	0.6	1.6	1.7	2.8	3.2
X	Tributary to Hitchcocks Lane Creek	18100	75	6.5	16.3	20.7	31.2	36.0
Y	Hitchcocks Lane Creek	18550	68	6.0	15.0	1.1	28.7	33.1
Z	Unnamed Ephemeral	19150	4	0.6	1.5	1.8	2.6	3.0

Catchment TB has not been shown on **Figure 4-2 for clarity reasons*

***TUFLOW 100yr ARI flow of 959m^3/s at Broughton Mill Creek has been used in the hydraulic impact analysis.*

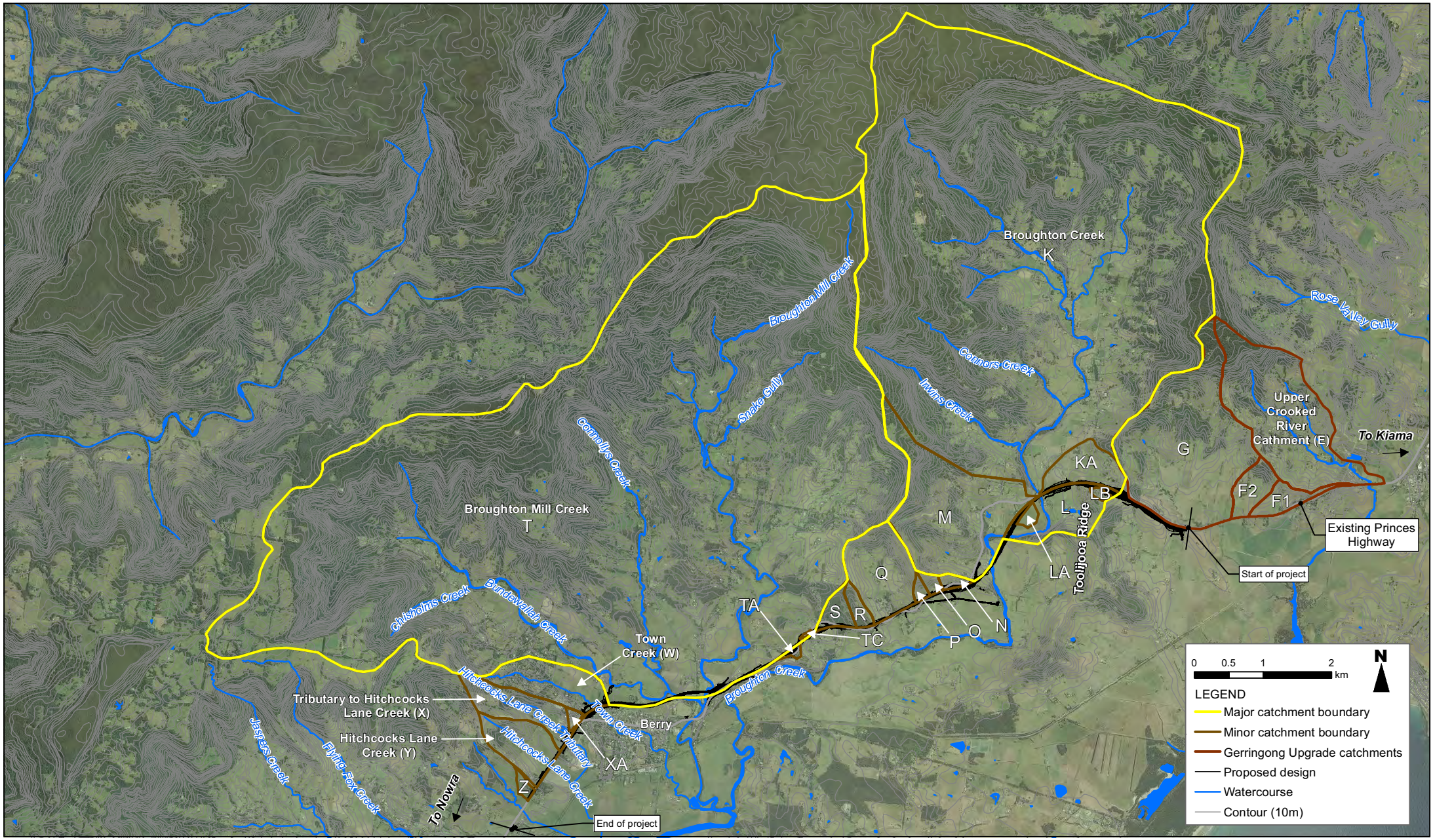

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Figure 4-2 Catchment map

Source: AECOM(2012), LPMA (2011)

Note 1: See Table 4.3 for catchment information
Note 2: Gerringong Upgrade Catchments G,E,F2 and F1 Outside Project Area (shown for information only)
Note 3: Catchment TB has not been shown on the figure for clarity reasons

Hydraulic modelling

Flood levels, depths and velocities were determined from a range of detailed hydraulic analyses.

For the Broughton Mill Creek floodplain in the vicinity of Berry (including Bundewallah Creek, Connollys Creek and Town Creek) the TUFLOW 2D model established for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012) was used as the basis. The Cardno TUFLOW model covers an area of approximately 9 square kilometres covering Berry and its immediate surrounds and is based on a three metres by three metres grid to define the ground topography. The downstream (southern) model limit is approximately 300 metres south of the South Coast railway line.

To assess the impacts of the project on flood behaviour the base model representing existing conditions was modified by adding the road design to the ground definition. For the purposes of concept design, nominal bridge piers were modelled and found to have relatively minor and localised impacts on flood levels and velocities. These impacts would need to be considered in more detail in future investigation or design development stages.

Inflow hydrographs derived from the XP RAFTS hydrologic model were applied to the upstream extents of the TUFLOW model. Rainfall was also applied directly to the 2D grid over the TUFLOW model extent which is consistent with the approach adopted for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012).

The three bridge crossings of Broughton Creek to the north of the project, as well as Hitchcocks Lane Creek and Tributary were modelled using the HEC RAS 1D model. The remaining waterway crossings were modelled using either Bentley Culvert master or HY-8 culvert hydraulic software packages.

4.2.3 Proposed flood and drainage works summary

Culverts

Culverts along the project have been sized to provide 100 year ARI flood immunity to the highway and to minimise flood level impacts upstream or downstream of the crossings.

The proposed transverse drainage infrastructure for major culvert crossings is summarised in **Table 4-4** and the locations are shown in **Figure 4-3a** to **Figure 4-3b**.

Table 4-4: Proposed culvert summary

Crossing name	Design chainage (m)	Design flow (m^3/s)	Type	Size (mm)	Comments
LB	9030	2.7	Pipe	1x1500	Existing culvert drop structure
KA	9840	32	Pipe	4x1800	Goes through northern abutment of Broughton Creek bridge 1
LA	10500	N/A	Box	1x4600x3000	Oversized to provide vehicular access
N	11900	4.8	Pipe	2x1500	Three pipe segments joined by two large drop structures, to provide drainage under main carriageway and secondary roads on each side
O	12150	4.8	Pipe	2x1500	Existing pond at inlet
P	12310	4.1	Pipe	3x1500	Extend existing pipe and install two new pipes
Q	12770	48	Pipe	7x1800	A minimal water level impact is desirable due to upstream property (Existing 3x1500mm RCP)
R	13320	9.0	Pipe	2x1500	
S	13580	12.1	Pipe	2x1500	
TC	14150	0.6	Pipe	1x1500	
TA	14420	2.6	Pipe	1x1500	
TB	14560	0.7	Pipe	1x1500	
XA	17950	3.23	Pipe	1x1500	
X	18100	36.0	Pipe	4x1800	
Y	18550	33.1	Pipe	3x1800	
Z	19150	2.0	Pipe	1x1500	

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Figure 4 - 3a : Location of proposed major culverts

Source: AECOM (2012), LPMA (2011)

Figure 4 - 3b : Location of proposed major culverts

Source: AECOM (2012), LPMA (2011)

Bridges

Three bridge crossings are proposed over Broughton Creek and one bridge over the confluence of Connollys Creek, Bundewallah Creek and Broughton Mill Creek as shown in **Figure 1.1** and in **Table 4-5**. The proposed bridge works have been designed to minimise impacts on the existing flood regime upstream and downstream properties and to provide a suitable level of freeboard to the 100 year ARI flood level.

Table 4-5: Proposed bridge summary

Crossing name	Design Chainage (m)	Design flow (m^3/s)	Indicative Size (m)	Comments
K	9950	646	122m length, 4 spans	Broughton Creek bridge 1
L	10700	661	76m length, 3 spans	Broughton Creek bridge 2
M	11200	715	200m length, 6 spans	Broughton Creek bridge 3
T	16000	896	600m length, 19 spans	Bridge at Berry

At crossing K the project runs just to the south and downstream of the existing Princes Highway. The existing bridge over Broughton Creek would be retained. The proposed new bridge over Broughton Creek at this location (Broughton Creek bridge 1) would consist of four spans with 1.5 metre piers (total bridge span of 122 metres). In order to comply with the vertical alignment road design criteria, the road level at the proposed Broughton Creek bridge 1 has been set significantly higher than 100 year ARI flood levels. The piers would be placed outside the main creek channels.

The second bridge over Broughton Creek (Broughton Creek bridge 2) would be located approximately one kilometre downstream of Broughton Creek bridge 1 (along the main channel centreline). The proposed bridge consists of three spans with 1.5 metre piers (total bridge span 76 metres). The abutments of the bridge would be located to allow for on-grade access tracks to pass underneath on each side of the existing river banks, together with a reasonable allowance for overbank flow under the bridge. The road level at the proposed Broughton Creek bridge 2 has been set to comply with the vertical alignment road design criteria. The piers would be placed outside the main creek channel.

The third bridge over Broughton Creek would be located approximately 600 metres downstream of Broughton Creek bridge 2 (along the main channel centreline). The road level at the proposed Broughton Creek bridge 3 has been set significantly higher than 100 year ARI flood levels in order to comply with vertical alignment road design criteria. The proposed Broughton Creek bridge 3 would consist of six spans with 1.5 metre piers (total bridge span 200 metres). The lowest (underside) edge of the modelled bridge is at the northern abutment.

The bridge at Berry consists of 19 spans with 1.5 metre piers (total bridge span of 600 metres). The lowest (underside) edge of the modelled bridge is at the southern abutment. The road level in the north is set by geometric road design requirements and is considerably higher than the 100 year ARI peak flood level. The road level at the southern end of the bridge is dictated by the 100 year ARI flood level. As a mitigation measure for visual impacts of the bridge, the piers would be spaced to meet aesthetic requirements. This may result in some piers being located within Bundewallah Creek.

Appropriate scour protection would be provided to the bridge abutments and piers where velocities have the potential to cause scour. Further detailed modelling of the bridges would be carried out as part of the detailed design phase of the project.

Diversion of Town Creek

The presence of the proposed alignment around the northern side of Berry presents an opportunity to mitigate the existing flash flooding of Town Creek within Berry. Runoff from the Town Creek catchment (catchment W) north of the highway would be rerouted by a diversion channel passing through culverts under Rawlings Lane into Bundewallah Creek and then into Broughton Creek downstream (see **Figure 2-1** for the diversion channel location).

The diversion channel and culverts under Rawlings Lane would be sized to have adequate capacity to fully convey the 100 year ARI peak flow with appropriate freeboard.

4.2.4 Impacts at Broughton Creek

Flood level impacts along Broughton Creek are summarised in **Table 4-6** and shown in **Figure 4-4, Figure 4-5** and **Figure 4-6**.

Table 4-6: Summary of proposed bridge impacts

Crossing name	Design chainage (m)	Figure reference	Upstream Water Level impact 100 year ARI (m)	Comments
Broughton Creek bridge 1	9950	Figure 4-4	0.4m	Existing Princes Highway flood immunity would be reduced. Flood immune access provided by the project. No other structures affected. Impacts limited to pasture.
Broughton Creek bridge 2	10700	Figure 4-5	0.3m	Impacts are limited to pasture. No structures affected. No change in extent of floodplain due to steep sides of floodplain.
Broughton Creek bridge 3	11200	Figure 4-6	Localised increases due to piers and redistribution of flows. 0.1m	Impacts mitigated by the embankment between bridges 2 and 3 acting to divert flow to Bridge 3

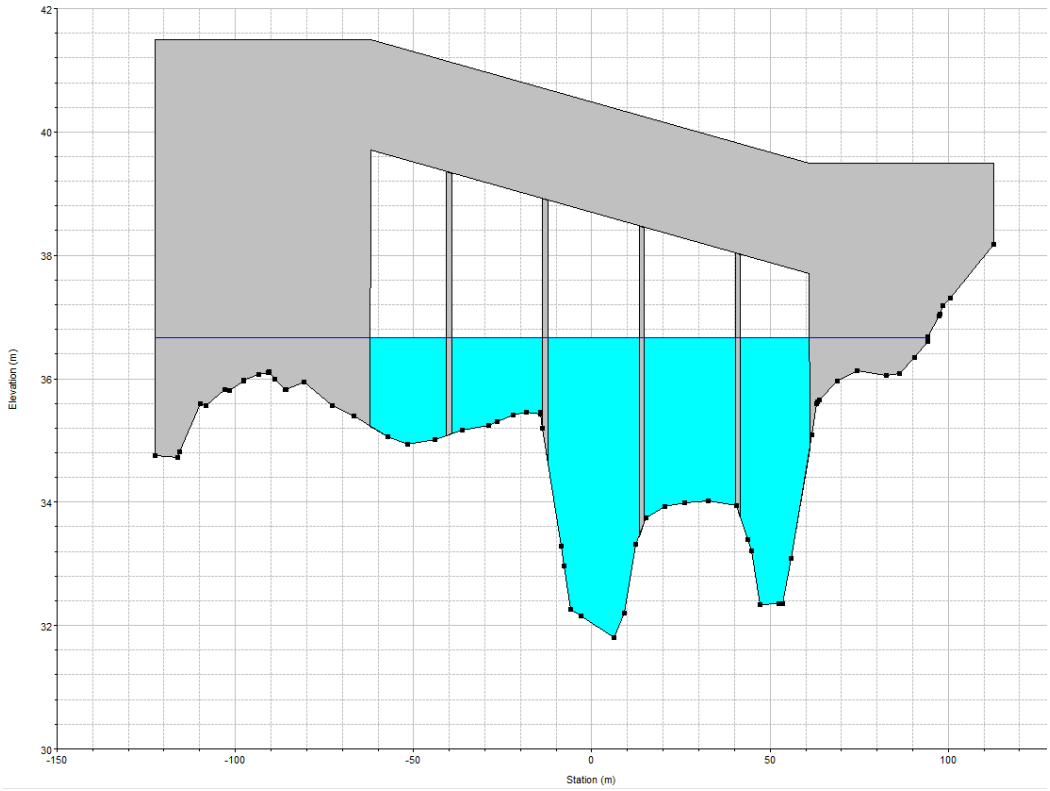

Figure 4-4: 100 year ARI design peak flood level at Broughton Creek bridge 1

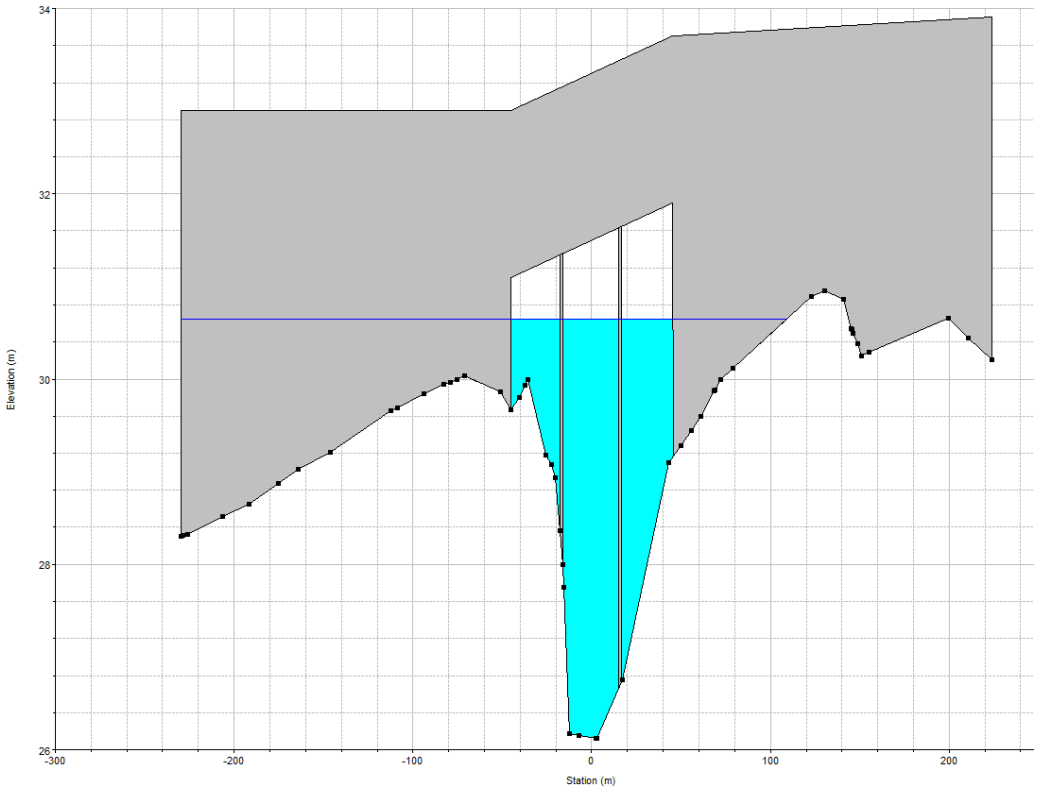

Figure 4-5: 100 year ARI design peak flood level at Broughton Creek bridge 2

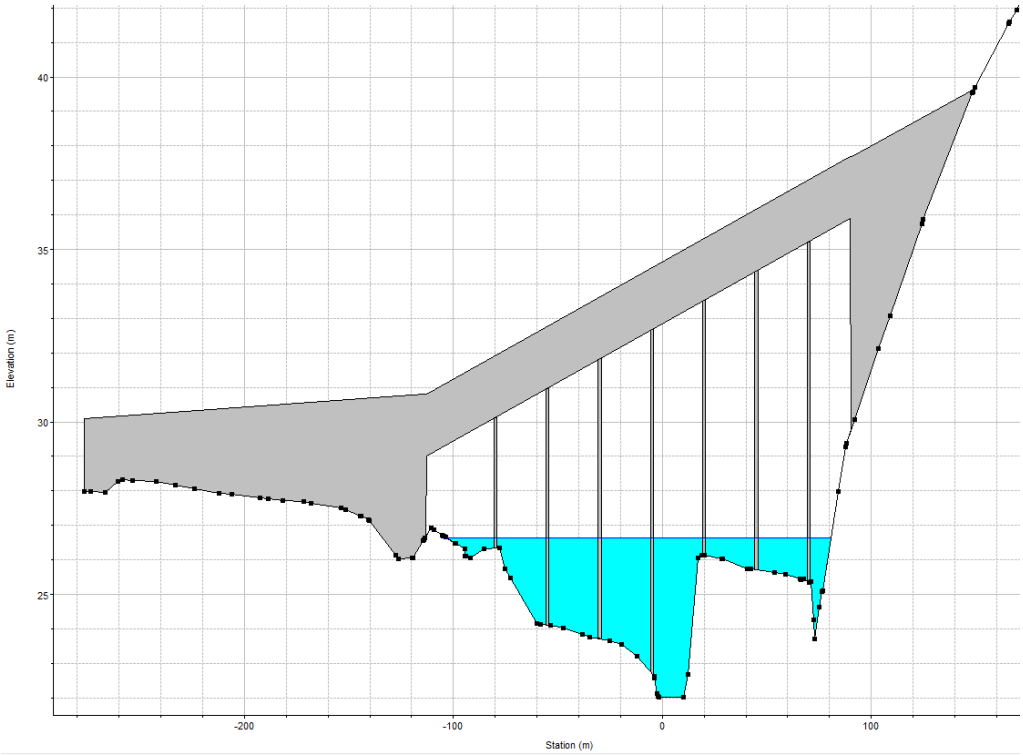

Figure 4-6: 100 year ARI design peak flood level at Broughton Creek bridge 3

Hydraulic modelling indicates that flows would be contained within the Broughton Creek banks for design flood events below the five year ARI. Above the five year ARI flood event, flood waters would overtop the left bank and flow across the floodplain eventually rejoining Broughton Creek further downstream. Under existing conditions the overland flow follows the general flowpaths shown in **Figure 4-7**. The proposed embankment across the floodplain would change the distribution of overland and in channel flows between the three proposed bridges on the upper Broughton Creek.

Between Broughton Creek bridges 2 and 3 the proposed embankment would effectively split this overbank flow into two paths (see **Figure 4-8**) on the eastern and western side of the alignment respectively. This creates three mechanisms by which the proposed works would impact on flood levels.

Firstly, the separated flow caused by the embankment would produce turbulence and energy loss that would increase flood levels upstream. Secondly, the placement of fill within the floodplain would potentially reduce the floodplain's storage capacity. This second mechanism is deemed relatively insignificant due to the large width of the floodplain. The third is that the overland flow distribution across the floodplain would be altered with more flow along the eastern side of the alignment. This could increase flood levels upstream of Broughton Creek bridge 2 and along the eastern side of the embankment between bridges 2 and 3.

The area that could be subjected to water level impacts due to these mechanisms is highlighted in **Figure 4-8**. The impacts are expected to be less than 0.3 metres in a 100 year ARI event and would be limited to agricultural land use areas and would not impact any structures or access. Due to the steep slopes at the edge of the floodplain, the impacts would not result in any significant increase in the 100 year ARI flood extent.

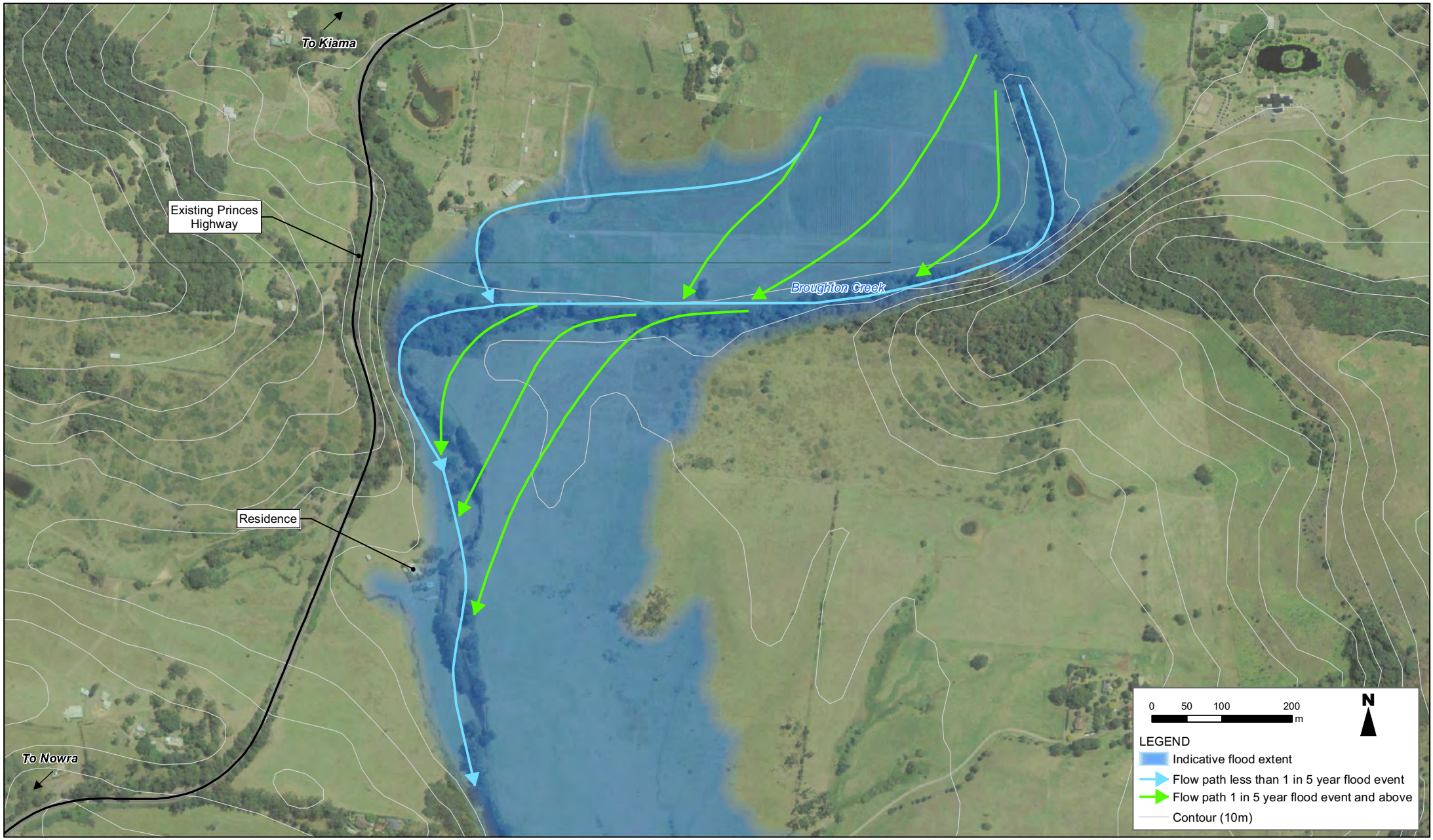

Figure 4-7 Broughton Creek overbank flowpaths

Source: AECOM (2007), LPMA (2011)

Path: P:\60021933_G2B\4_Tech_work_area\4.7_GIS\Maps_20120806_DKennewell\Centred_121030\Fig 4-7_G024_Overland Flow Paths Map1_121030.mxd 30/10/2012

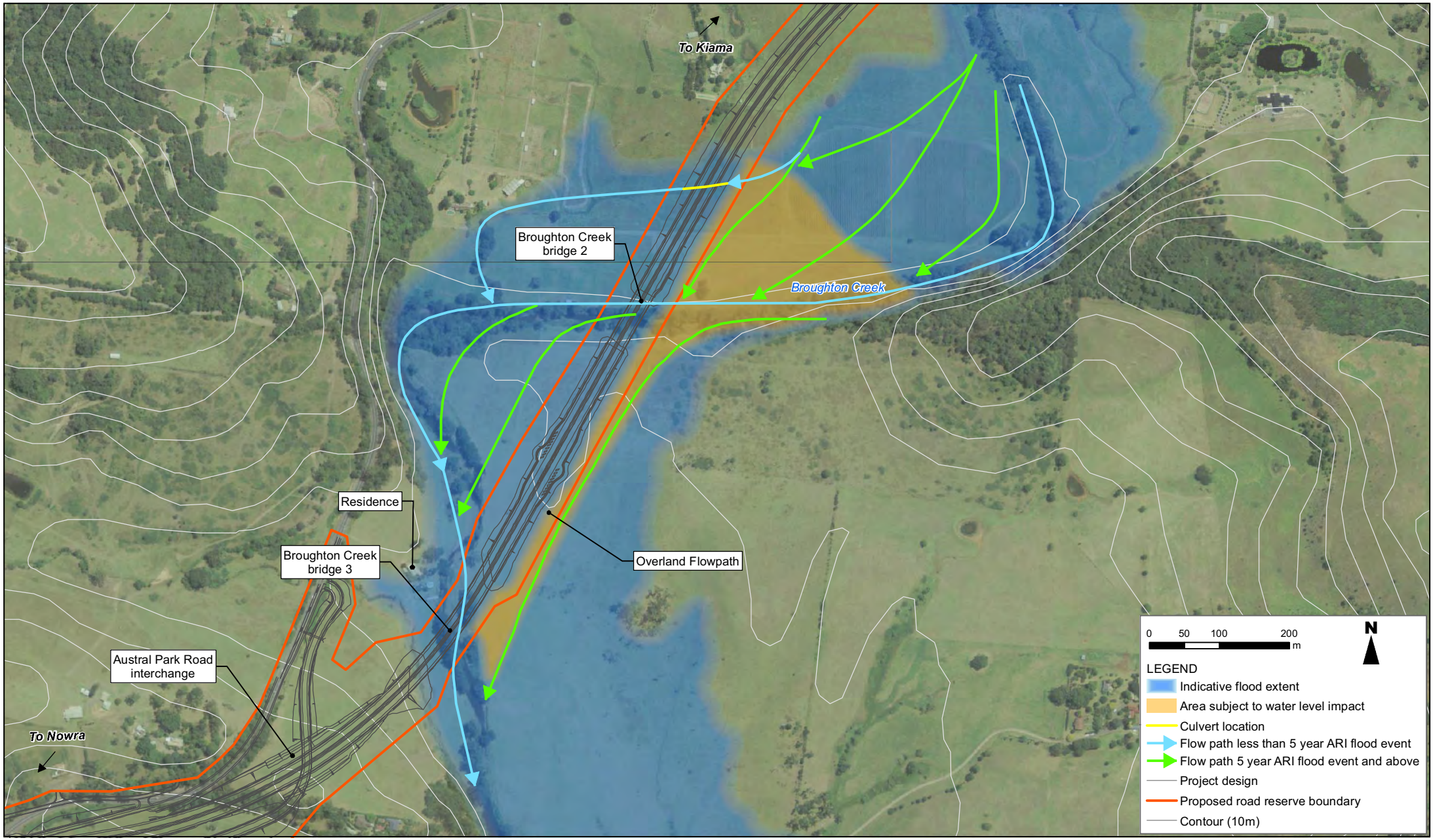

Figure 4-8 Broughton Creek overbank flowpaths

Source: AECOM (2007), LPMA (2011)

On the western side of the embankment upstream of Broughton Creek bridge 3, flood level impacts are expected to be minimal because more flow would be diverted along the eastern side of the embankment. However, the proposed road embankment will change the flow paths across the floodplain on the western side of the embankment and could have localised impacts to properties along Broughton Creek where flows are redistributed.

A small tributary flows across the property just upstream of Broughton Creek bridge 3 and joins Broughton Creek approximately 200 metres downstream of the bridge. The works associated with the proposed interchange with the existing Princes Highway could affect the flow patterns of this tributary and, depending on the redistribution of flows either side of the embankment (between Broughton Creek bridges 2 and 3) this could cause localised flood impacts to the property upstream of bridge 3. The maximum impact immediately upstream of the bridge is estimated up to 0.1 metres but the impact at the residence itself is likely to be less.

The suggested modelling approach during the detailed design phase include 2- dimensional modelling of the floodplain to accurately determine the flow split around the southern abutment of Broughton Creek bridge 2 during major flood events. Depending on the amount of flow that would be conveyed along the embankment, appropriate works for a controlled overland flowpath and scour protection would be designed to minimise erosion and flood impacts.

4.2.5 Impacts at Berry Township

The project traverses the broad floodplain at the confluence of Broughton Mill Creek, Bundewallah Creek and Connollys Creek immediately north of Berry. Existing 100 year ARI flood depths and extent for this area are shown in **Figure 4-9**.

The proposed works will involve the diversion of Town Creek along the north of the proposed highway alignment to discharge into Bundewallah Creek, upstream of Connollys Creek. The proposed works will also involve the construction of highway embankment across part of the floodplain. Flood modelling of the proposed works has been used to identify potential impacts on the surrounding environment, set minimum waterway opening requirements and minimum design levels for the highway and associated infrastructure. Flood depths and extent under proposed conditions for the 100 year ARI event are shown in **Figure 4-10**. Corresponding relative changes in flood levels are shown in **Figure 4-11** and described below.

The flood modelling and assessment has shown that there will be an increase in flood levels upstream (north) of the alignment, due largely to a reduction in waterway area from the highway works encroaching across the floodplain as well as the increased in flows associated with the diversion of Town Creek.

From **Figure 4-11** it is evident that at the southern end of the bridge at Berry, where the abutment extends approximately 200 metres into the existing 100 year ARI flood extent, some localised flood impacts up to 0.3 metres would be expected upstream during the 100 year ARI event. Immediately downstream of the southern abutment, including some areas along North Street, flood levels would be reduced.

Immediately downstream of the proposed there would be an increase in flood levels, due to the concentration of flows through the bridge openings combined with the additional flows from Town Creek.

There would be minimal flood level impacts along the Town Creek diversion route as the channel would be sized to convey the 100 year ARI flow. Box culverts would convey the 100 year ARI flow under Rawlings Lane without overtopping.

An assessment has been made of properties that are potentially affected by the proposed works. Floor level survey information has been used to undertake a review of those properties that may experience adverse flood impacts as a result of the proposed highway upgrade as well as those that will be better off.

Potential increases in flood levels

The flood impact summary in **Table 4-7** includes 11 properties that are potentially affected by changes in flood level as a result of the project. Corresponding flood impact mapping is shown in **Figure 4-11**.

Properties 1, 2 and 3

Properties 1, 2 and 3 are located upstream of the project. Increases in flood levels at these properties are predominantly a function of the reduction in available waterway area across the floodplain. The model results show an increase in 100 year ARI flood level at property 1 of 0.06 metres and 0.08 metres at properties 2 and 3. This would result in a reduction in freeboard at these properties. Properties 1 and 2 would still have in excess of 0.5 metre freeboard. However the freeboard at property 3 would be reduced from 0.18 metres (existing) to 0.11 metres (proposed).

Properties 4 and 5

Properties 4 and 5 are located immediately downstream of the project. The properties are impacted by a combination of the diverted flows from Town Creek together with a greater concentration of flow through the constricted bridge opening. It would therefore be difficult to fully offset the impacts on these properties without removing or reducing the diversion of Town Creek.

No detailed floor level or ground level data are available for property 4. The modelled depth of flooding suggests the property experiences significant inundation around the building. Floor level survey is required to confirm the susceptibility of building floor level to flooding.

Floor level survey for property 5 shows the building is elevated over 3 metres above the 100 year ARI flood level. Consequently, the nominal 0.03 metre increase in flood levels is not significant in the context of the impact.

Properties 6, 7, 8, 9 and 11

Properties 6, 7, 8, 9 and 11 are located further downstream of the proposed road alignment. The nominal impacts at these properties (typically 0.03 metres or less) would be primarily due to the diversion of flows from Town Creek. The increase in flood levels at these properties is considered minor relative to the existing level of above floor inundation. Consequently, no additional local flood mitigation measures are expected to be required. This would however be subject to detailed design development.

Property 10

Property 10, the sports amenities building at the Berry sportsground and the Camp Quality Memorial Park, is located immediately downstream of the southern bridge abutment. Relative flood level impacts based on the current concept design are negligible or minor.

Potential reductions in flood levels

The diversion of Town Creek will provide a significant benefit to properties within Berry that currently experience flooding. The existing portion of Town Creek flowing through the town of Berry (south of the project) would experience a lowering of 100 year ARI flood levels of in excess of one metre as indicated on **Figure 4-12**. The property impacts table in **Appendix A** shows the reduction in flood levels affectation and increases in freeboard at these properties. The tabulated results show over 80 properties will have a measurable reduction in flood level. Of these, there are nine properties that experience above floor inundation in a 100 year ARI event under existing conditions that would become flood free under the post highway scenario (albeit with relatively small freeboard).

It is evident from the above assessment that the proposed diversion of Town Creek flows provides a significant benefit in reducing flooding through Berry. This needs to be considered in the context of evaluating any adverse impacts on properties and developing appropriate mitigation measures.

Changes in flood behaviour for more frequent events

The proposed works will impact flood levels during events more frequent than 100 year ARI through the same mechanisms as described above. Generally, the increases and reductions in flood levels will be of a smaller magnitude during more frequent flood events.

The proposed embankment at the southern end of the bridge at Berry would encroach on the flooded area to a lesser extent during more frequent flood events. This would result in relatively smaller impacts due to constriction of the floodplain and, subsequently, more frequent flood events will have a reduced flood impact relative to the 100 year ARI event.

The diversion of flows from Town Creek to Bundewallah Creek would result in changes to the behaviour of more frequent flood events similar to those described in the 100 year ARI assessment, however the impacts would be of a relatively smaller magnitude as a consequence of the smaller flow rates.

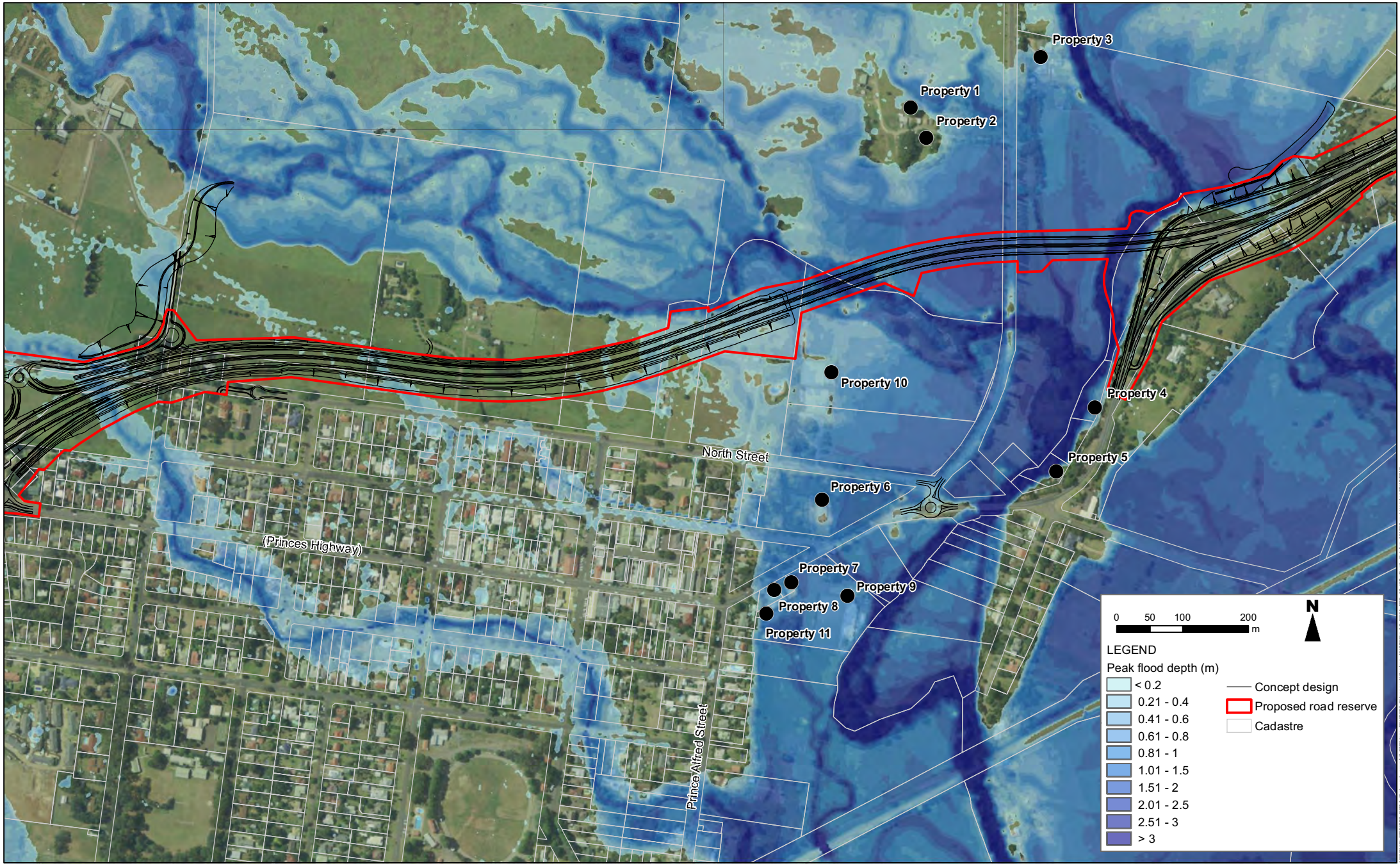

Figure 4-9 Berry Township –100 year ARI peak flood depths – existing conditions

Source: AECOM (2012), Cardno (2011)

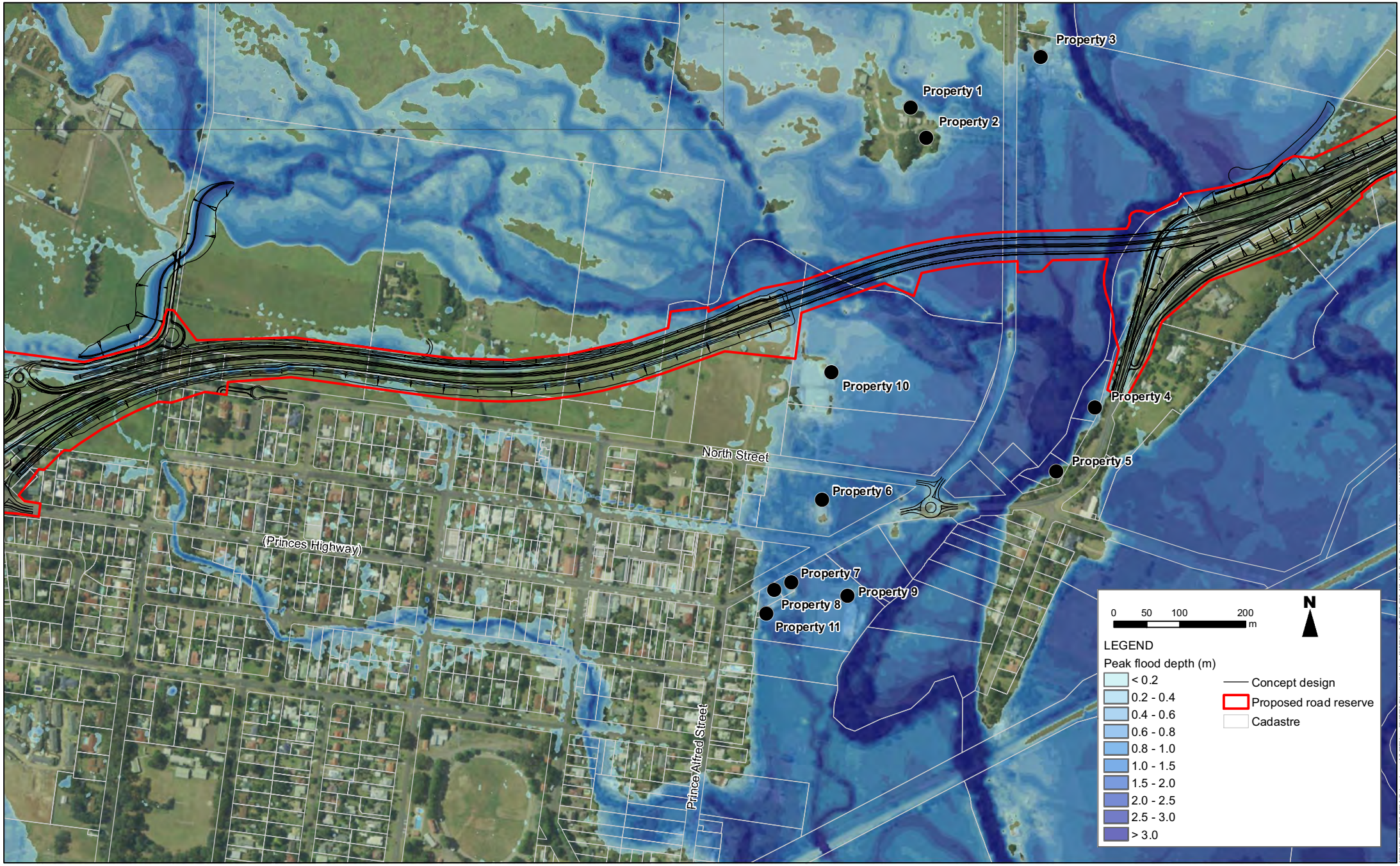

Figure 4-10 Berry Township –100 year ARI peak flood depths – proposed conditions

Source: AECOM (2012), Cardno (2011)

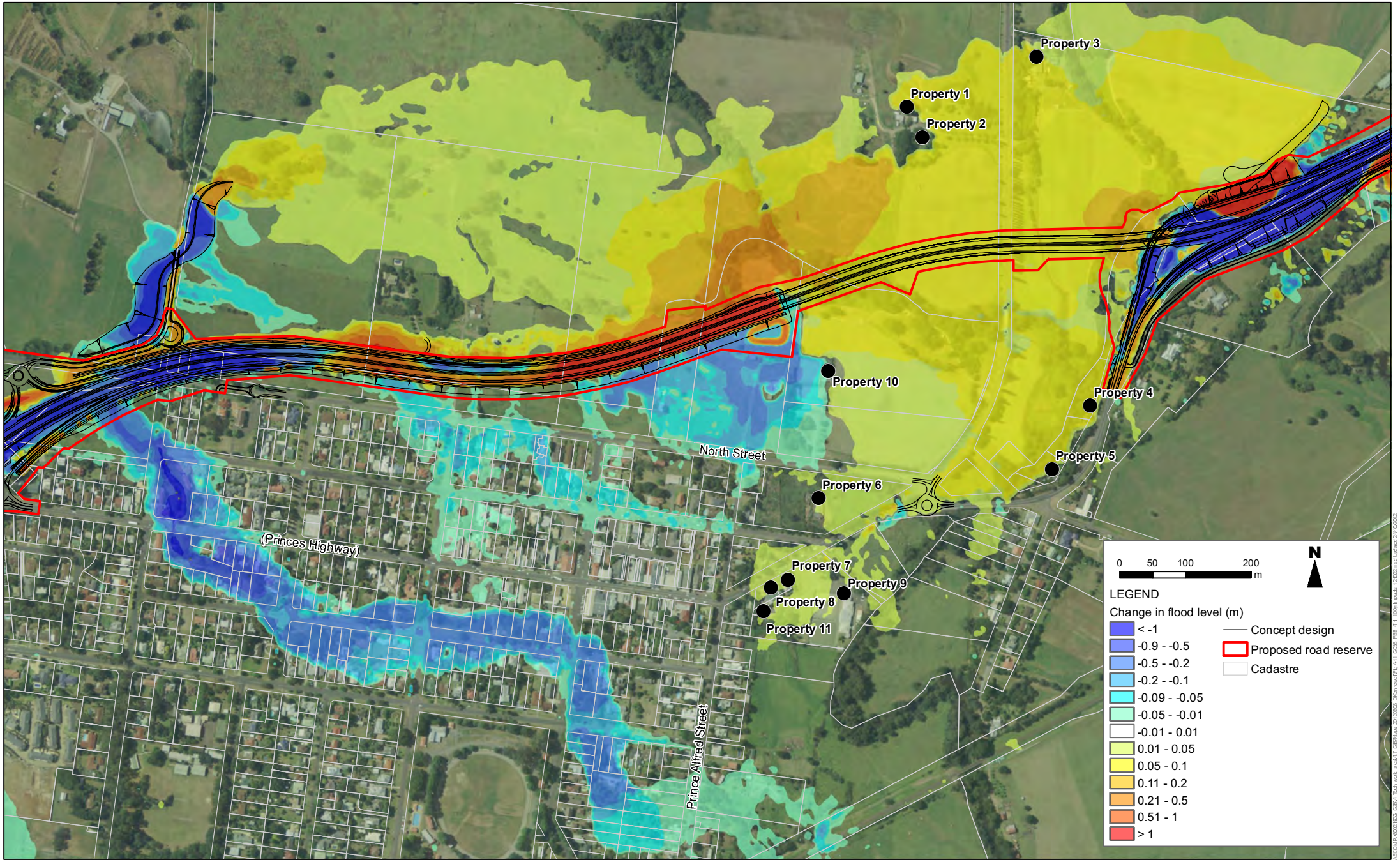

Figure 4-11 Berry Township –100 year ARI change in flood level

Source: AECOM (2012), Cardno (2011)

Notes
- A positive relative impact represents an increase in flood level under proposed conditions relative to existing condtions. A change in flood level of +/- 0.01m is considered to be within the level of accuracy of the model and to have neglible or no impact
- Relative flood level impacts shown along the alignment (within the project corridor) are a function of the direct rainfall on grid hydraulic modelling approach and are a fuction of the relative height between the existing ground and design surface. Impacts indicated in these areas are confined to works within the Proposed Road Corridor.
- The direct rainfall on grid approach can also lead to localised "noise" in flood level results in areas outside the corridor. These isolated pockets of impacts are an artefact of the flood modelling approach rather than a quantifiable impact from the Proposed works.

Table 4-7: Summary of flood levels and relative impacts at property buildings – 100 year ARI event

Property		Survey [Note 1]		Existing Conditions		Concept Design								
						Concept Design 100 yr flood level at property (mAHD)			Change in flood level (m) [Note 4]			Freeboard to floor level (m)		
#	Address	Floor level (mAHD)	Ground level (mAHD)	100 year ARI flood level at property (mAHD)	Free-board to floor level (m) [Note 3]	Concept Design	Arrangement 1	Arrangement 2	Concept Design	Arrangement 1	Arrangement 2	Concept Design	Arrangement 1	Arrangement 2
1	59 Woodhill Mountain Rd	11.15	11.06	10.56	0.59	10.62	10.62	10.62	0.06	0.06	0.06	0.53	0.53	0.53
2	59 Woodhill Mountain Rd	11.29	10.90	10.45	0.84	10.53	10.49	10.48	0.08	0.04	0.03	0.76	0.80	0.81
3	76 Woodhill Mountain Rd	10.69	10.85	10.51	0.18	10.58	10.55	10.54	0.08	0.04	0.03	0.11	0.14	0.15
4	29a Princes Hwy	No data	9.8 [Note 2]	10.12	No data	10.17	10.17	10.16	0.05	0.05	0.03	No data		
5	15 Princes Hwy	13.85	13.56	10.27	3.58	10.30	10.30	10.29	0.03	0.03	0.02	3.55	3.55	3.56
6	152 North St	9.46	8.18	9.09	0.37	9.10	9.11	9.10	0.01	0.02	0.01	0.36	0.35	0.36
7	134 Princes Hwy	7.84	7.02	8.17	-0.33	8.19	8.19	8.18	0.01	0.02	0.01	-0.35	-0.35	-0.34
8	132 Princes Hwy	7.24	7.25	8.18	-0.94	8.20	8.20	8.19	0.01	0.02	0.01	-0.96	-0.96	-0.95
9	140 Princes Hwy (Berry Bowling Club)	7.51	6.55	7.87	-0.36	7.89	7.89	7.89	0.01	0.01	0.02	-0.38	-0.38	-0.38
10	Lot 1 North Street (Camp Quality Park sport amenities)	9.64	9.39	9.83	-0.19	9.82	9.86	9.86	-0.01	0.03	0.03	-0.18	-0.22	-0.22
11	Lot 1 Princes Hwy	7.51	6.92	7.60	-0.09	7.62	7.61	7.61	0.02	0.01	0.01	0.11	0.10	0.10

Notes

1. *Floor and Ground Level survey carried out by Peter Smith & Co for Shoalhaven City Council as part of the Broughton Creek Floodplain Risk Management Study. Except for Properties 1 and 2, which was carried out by RMS.*
2. *No floor level data available for Property 4. Ground levels approximated from flood model DTM.*
3. *A negative freeboard represents the depth of above floor inundation.*
4. *A positive relative impact represents an increase in flood level under proposed conditions relative to existing conditions. A change in flood level of +/-0.01m is considered to be within the level of accuracy of the model and is considered to have negligible or no impact*

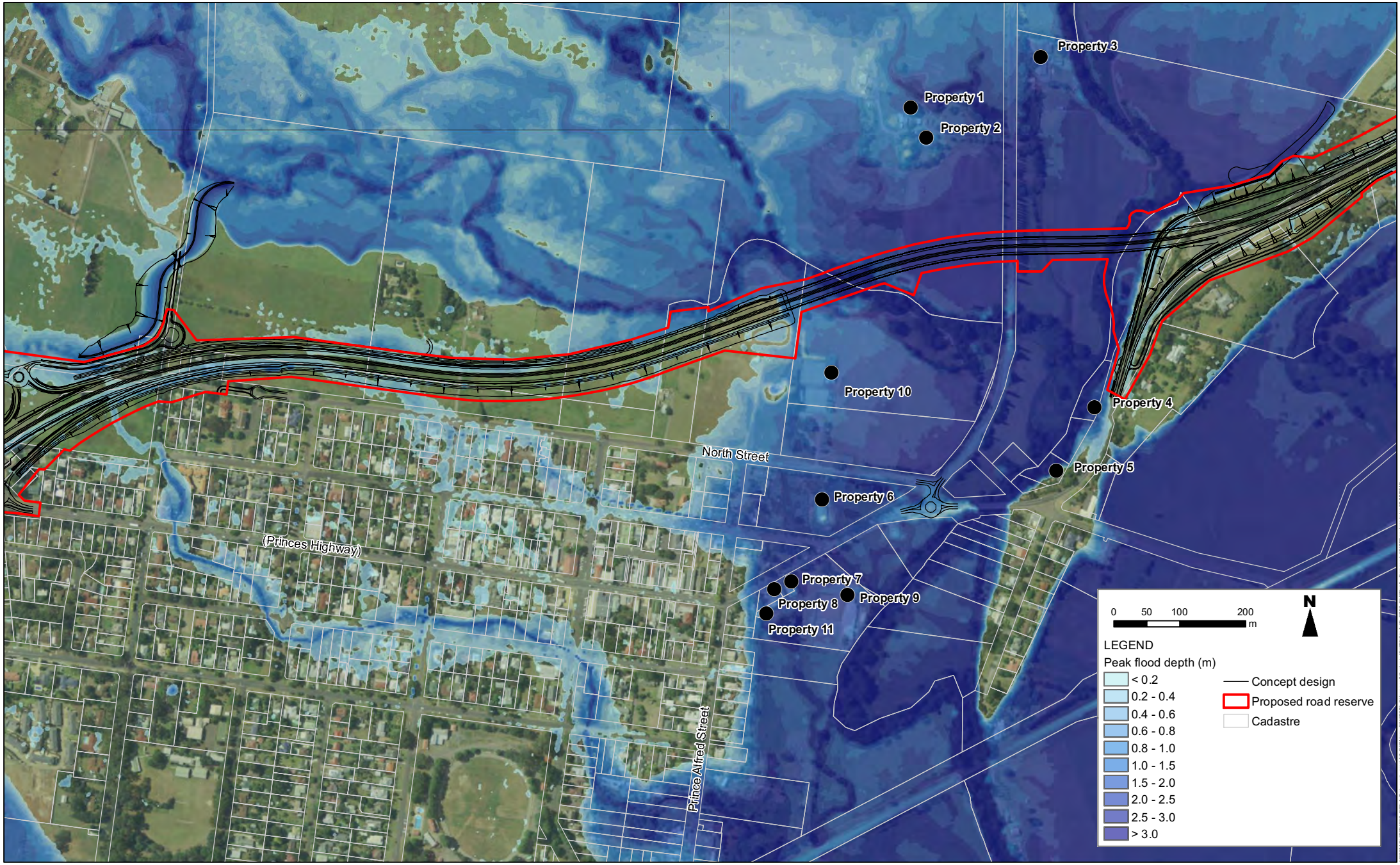

Figure 4-12 Berry Township – PMF peak flood depths – proposed conditions

Source: AECOM (2012), Cardno (2011)

4.2.6 Regional flood impacts during the Probable Maximum Flood

The preceding sections have dealt with local flood impacts around the individual drainage structures. However, flooding on a wider scale has to be considered for emergency planning purposes and impacts on critical infrastructure. The potential flood impacts during the PMF along the proposed route alignment have therefore been investigated. This assessment also serves to identify potential worst case impacts.

The proposed road embankment has the potential to block flood waters. The road could be overtopped by about three metres between Broughton Creek bridges 1 and 2 during the PMF. The raised road embankment could increase flood levels up to two metres above existing levels during the PMF upstream of Broughton Creek bridge 1, and up to two metres at Broughton Creek bridge 2. While there is no critical infrastructure upstream of these bridges, dwellings on private properties could be affected. The project would not adversely affect evacuation routes as the existing highway in this location is already overtopped during a PMF under existing conditions. Flood impacts at Broughton Creek bridge 3 would be mitigated by the large bridge waterway openings and high elevation of the bridge above the floodplain.

The drainage crossings through the middle reaches between the Broughton Creek crossings and Berry convey much smaller flows and impacts in the PMF would be localised and not affect critical infrastructure.

At Berry, the project would be located north of the current highway. This would reduce the flood risk to the main part of the town of Berry as well as some access routes, such as the South Coast Rail Line. There would be an increase in PMF flood level of approximately 0.2 metres at the north of bridge at Berry. Directly north of the western abutment, the flood level would increase approximately 0.6 metres. Downstream of bridge at Berry, the increase would generally be 0.1 - 0.15 metres. The change in flood levels for the PMF event are shown in **Figure 4-13**.

The diversion channel for Town Creek would provide flood relief to much of the Berry township by diverting water upstream of the upgraded alignment toward Bundewallah Creek. Therefore properties within the town of Berry would experience a reduction in flood level of up to 0.9 metres.

Due to the nature of the terrain at Hitchcocks Lane tributary the flood impacts during the PMF would likely be limited to the area between the highway alignment and Huntingdale Park. The proposed road level at this location is approximately three metres above the existing road level and the flood impacts could extend as far as the northern boundary of the property through which the creek runs.

The project would have adverse flood impacts during a PMF. However, it would also reduce the flood risk to the township of Berry and critical infrastructure and evacuation routes should not be affected.

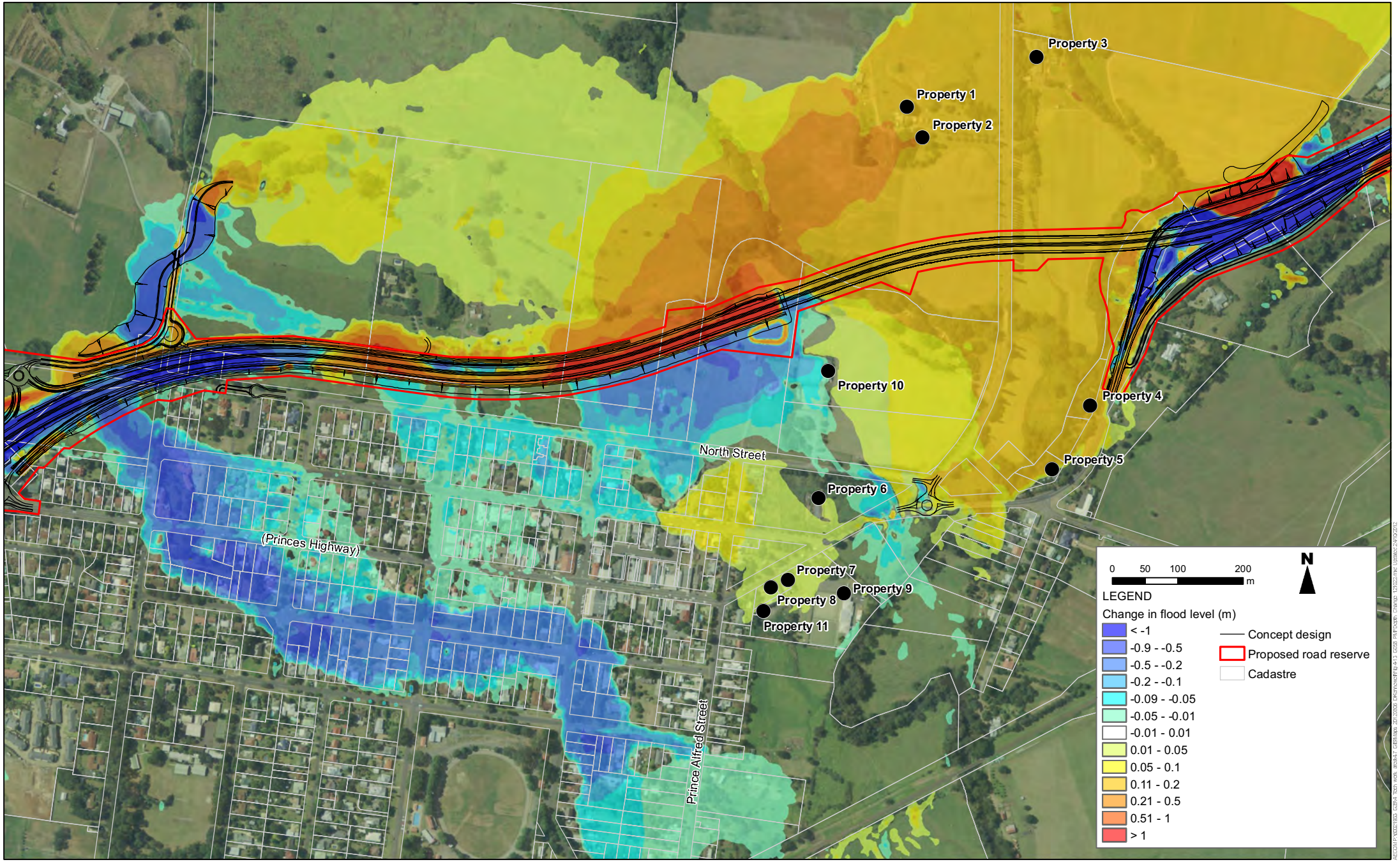

Figure 4-13 Berry Township – PMF change in flood level

Source: AECOM (2012), Cardno (2011)

Notes

- A positive relative impact represents an increase in flood level under proposed conditions relative to existing condtions. A change in flood level of +/- 0.01m is considered to be within the level of accuracy of the model and to have neglible or no impact
- Relative flood level impacts shown along the alignment (within the project corridor) are a function of the direct rainfall on grid hydraulic modelling approach and are a fuction of the relative height between the existing ground and design surface. Impacts indicated in these areas are confined to works within the Proposed Road Corridor.
- The direct rainfall on grid approach can also lead to localised "noise" in flood level results in areas outside the corridor. These isolated pockets of impacts are an artefact of the flood modelling approach rather than a quantifiable impact from the Proposed works.

4.2.7 Site compound and stockpile locations

Site compounds would be used to store plant and equipment and to provide parking and amenities for construction staff. Chemicals and fuels for construction would be stored in appropriately bunded storage areas in the compound site. The compound and stockpile sites would be subject to the site location criteria set out in the Stockpile Site Management Procedures (RTA, 2001).

The exact location of compound and stockpile sites is difficult to determine at this stage of project development and would be subject to change during the detailed design and construction stages. However, potential site compound locations have been identified and are described in **Chapter 4** of the environmental assessment. The site compounds would be located within the project corridor and adjacent lands.

The potential for flood impacts at site compounds and stockpiles would be assessed during the detailed design phase. This assessment would take into consideration factors such as the nature of the sites, the construction sequencing, the duration of operation of these sites and proximity to sensitive waterways.

4.2.8 Stock refuge

The project runs mainly through rural pastures and stock refuges on these rural floodplains are important to protect livestock. Floodwaters can affect livestock in several ways, including injury and drowning or damage to fodder reserves. Stock refuges in the event of flooding on the Broughton Creek floodplain would be maintained by the access road under Broughton Creek bridge 2. This provides a flood evacuation route for stock to walk to higher ground. This outcome could alternatively be achieved by providing mounds of fill within the floodplain, preferably located in fringe areas or at the base of the proposed highway embankment.

4.2.9 Worst case

A key aspect of the DGRs for this project is the provision of appropriate environmental management measures and design standards to minimise the potential risk of flood impacts. For the purposes of determining a worst case scenario in line with the DGRs it has been assumed that all drainage infrastructure (ie culverts, bridges and drains) could experience some form of blockage.

With existing drainage lines blocked, flood waters would follow new overland flowpaths where available, similar to the flood behaviour that might occur during the PMF. Concentrated flows through culverts or bridge openings that are partially blocked could result in increased flow velocities and lead to increased scour and erosion. This could not only affect ecosystems and cause local flood level impacts but could ultimately affect the structural integrity of the road infrastructure.

It is considered highly unlikely that all these measures could fail, and as such there is only a low risk of the worst case impacts occurring.

4.2.10 Climate change potential impacts

Climate change has the potential to alter rainfall and sea level conditions that lead to flooding of the creeks and waterways traversed by the project.

Scientific research into the potential impacts of climate change has been rapidly evolving over recent years. Latest research indicates that climate change is likely to result in more frequent and intense storms, but lower average annual rainfall. This has the potential to increase rainfall intensities for storms leading to increases in the frequency and magnitude of flooding to catchments and waterways in the vicinity of the project.

Research into sea level trends shows that over the period 1870 – 2001 global sea levels rose by 0.2 metres, with the current global rate of increase approximately twice the historical average (DECCW, 2009). Increased sea level rise has the potential to affect Shoalhaven River and Broughton Creek flooding south of Berry. However, the project lies outside the area of Broughton Creek and Shoalhaven River flooding and is therefore not influenced by sea level rise.

The Floodplain Risk Management Guideline Practical Consideration of Climate Change (DECC, 2007) provides estimated changes in rainfall intensities for the 1 in 40 year one day rainfall totals. With regard to the study area the predicted increase in rainfall intensity is plus seven per cent by 2030 and plus five per cent by 2070. On this basis the RMS have established design criteria providing an allowance for six per cent rainfall increase across the overall Gerringong to Bomaderry route alignment (including the project).

While there is general consensus regarding the overall trend of increased rainfall intensities and sea level rise, there is less consensus on the extent of these increases. For this reason the DECC 2007 Guideline recommends assessment of a range of rainfall and sea level scenarios to assess the sensitivity of the catchment to potential increases.

With regard to increase in peak rainfall and storm volume the DECC 2007 guideline recommend consideration of the following:

- Low level rainfall increase 10 per cent
- Medium level rainfall increase 20 per cent
- High level rainfall increase 30 per cent

It should be noted that under the DECC 2007 Guidelines, a high level rainfall increase of 30 per cent is recommended for consideration due to the level of uncertainty in rainfall projections and the implementation of a precautionary approach is recommended. However, on the basis of current research, it is generally acknowledged that a 30 per cent rainfall increase is on the conservative side.

In light of the above, the approach adopted to manage the potential impacts of climate change on flooding has involved:

- Adopting a six per cent increase in design rainfall intensities for design of transverse drainage structures; and
- Undertaking sensitivity analyses for increases in rainfall intensity of 10, 20 and 30 per cent.

Potential increases in rainfall intensities have been assessed as part of the hydrologic and hydraulic modelling of the project. A summary of the implications for 100 year ARI flood levels is provided below.

Potential climate change impacts at the bridge at Berry

Of the total project, the western abutment of the bridge at Berry has the least amount of freeboard provided for in the concept design. As such, flood levels at this location would be most vulnerable to climate change impacts.

Implications for flooding levels due to climate change were assessed for potential increases in rainfall intensity. Variations in rainfall on the local catchment were assessed by factoring the inflows to the TUFLOW model by 10 per cent, 20 per cent and 30 per cent to reflect the respective increases in rainfall intensity. Results of the scenarios assessed are shown in **Table 4-8.**

Table 4-8: Potential impact of climate change on 100 year ARI flood levels at Berry Bridge (metres)

Location	Base case	Increase in rainfall intensity		
	100yr design flood level (mAHD)	10 per cent	20 per cent	30 per cent
Western abutment of the bridge at Berry	11.22	0.05	0.09	0.13

The results show that for a 10 per cent increase in rainfall, the increase in flood level is approximately 0.05 metres. The upper bound of the sensitivity analysis (30 per cent increase in rainfall) would result in an increase in flood level of up to 0.13 metres.

In light of the above, the potential impacts due to climate change at some point in the future are at worst expected to reduce the freeboard which would normally be available. The changes are within the available freeboard provided at this location. On this basis no additional allowance for climate change is considered necessary.

Potential climate change impacts at Broughton Creek

The potential effects of climate change have been investigated at the three proposed bridges over Broughton Creek and the results are listed in **Table 4.9.**

Table 4-9: Potential impact of climate change on 100 year ARI flood levels at Broughton Creek (metres)

Location	Base case	Increase in rainfall intensity		
	100yr design flood level (mAHD)	10 per cent	20 per cent	30 per cent
Broughton Creek bridge 1	36.66	0.13	0.26	0.38
Broughton Creek bridge 2	30.65	0.14	0.28	0.43
Broughton Creek bridge 3	27.65	0.13	0.26	0.38

The results show that for a 10 per cent increase in rainfall, the increase in flood level is approximately 0.1 metres. For the conservative case of a 30 per cent increase in rainfall, the increase in flood level would be approximately 0.4 metres at the three bridges.

In light of the above, the potential impacts due to climate change at some point in the future are at worst expected to reduce the freeboard which would normally be available. The changes are within the available freeboard provided at this location. On this basis no additional allowance for climate change is considered necessary.

4.3 Environmental management measures

4.3.1 Waterway crossings

To minimise the project's potential impact on flooding and to minimise the potential impact of the proposed waterway crossings on the environment, appropriate mitigation measures would be implemented to mitigate flooding. The design of drainage structures would allow for the natural flow of floodwaters and existing overland flow paths to be maintained post-construction where possible.

In order to minimise impacts on flow behaviour culverts would be located and, sized to adequately convey the 100 year ARI runoff event (if on the main alignment) and designed to meet the RMS's design velocity criteria. However, it should be noted that the hydrology and hydraulics of the culverts would be refined during detailed design. Climate change would also be taken into account as discussed in Section 4.3.3.

Bridge configurations would be designed to maintain existing flow patterns as far as possible to minimise increases in flood levels and velocities around the bridge structures. Minimising the clearance footprint for embankments and maintaining clear passage of stream channels, would assist in mitigating the construction impacts on the various creeks within the project area. Piers would be placed outside the main creek channels where possible, and would be designed and orientated to minimise the generation of turbulence and subsequent bed and bank erosion. The intrusion of the bridge abutments into the 100 year ARI flood extent would be limited to minimise flood level impacts.

The need for scour protection at any bridge or culvert crossing would be minimised through appropriate design measures. However, some form of scour protection or energy dissipation would be necessary at those waterway crossings with high velocities to prevent excessive erosion and potential damage to structures. Scour protection measures would be installed along the bed and banks upstream and downstream of these waterway crossings where appropriate and in accordance with relevant design guidelines.

These management measures would be further refined during the detailed design stage.

Broughton Creek

The embankment between Broughton Creek bridge 2 and Broughton Creek bridge 3 may be subject to floodwaters flowing parallel to the alignment and, along the toe of the embankment. Suitable batter treatment needs to be designed to prevent failure of the embankment due to scour.

Further detailed modelling, combined with refinement of the bridge configurations would be carried out as part of the detailed design phase to minimise flood and scour impacts.

Bridge at Berry and Town Creek diversion

As a minimum, all water quality basins located on the floodplain should be constructed at or close to ground level or replaced with swales.

Provision would be made for adequate freeboard in the Town Creek diversion channel to prevent overtopping and scour protection provided where velocities are high.

The assessment outlined in Section 4.3.5 of this report has shown that 11 properties are potentially at risk of adverse flood impacts. This assessment is based on the concept design which is subject to change with any optimisation measures introduced during detailed design. During detailed design potential impacts would be confirmed and necessary mitigation measures developed accordingly. The current recommended mitigation approach for each property, based on the concept design, is outlined below (refer **Figure 4-11** for property locations).

Properties 1, 2 and 3

It is recommended that the implications of these impacts and possible local mitigation measures such as diversion swales, local bunding or flood proofing of buildings be discussed with the property owner.

Alternatively, impacts could be offset by increasing the waterway area across the floodplain. To gain an understanding of the extent of works required to offset impacts two additional design scenarios were run and these are also included in **Table 4-7**. These additional scenarios would involve:

- Arrangement 1 - removing the water quality basins that are located in the floodplain; pulling in the retaining wall at the eastern abutment to maintain the existing flowpath from the billabong at property 3; and creating an opening in the western abutment 30 metres long.
- Arrangement 2 – same as Arrangement 1 with an opening in the western abutment 60 metres long; culverts in the southern abutment and additional retaining wall in the northern abutment as per Arrangement 1. In either case, given the sensitive nature of flooding in this area, all basins on the floodplain should be constructed at or close to ground level and/or replaced with bunded swales.

Properties 4 and 5

Local mitigation works should be discussed and agreed with the owner of property 4 and would include consideration of measures such as diversion swales, local bunding or flood proofing of buildings.

Floor level survey for property 5 shows the building is elevated over three metres above the 100 year ARI flood level. Consequently, the nominal increase in flood levels is not significant in the context of the impacts.

However, appropriate property mitigation measures may be warranted to address the impacts (which are 0.05 metres or less) if these are considered to be unacceptable. Local mitigation works should be discussed with the property owner and would include measures such as diversion swales, local bunding or flood proofing of buildings.

Properties 6, 7, 8, 9 and 11

Properties 6, 7, 8, 9 and 11 are located further downstream of the proposed road alignment. The nominal impacts at these properties would be primarily due to the diversion of flows from Town Creek. The increase in flood levels at these properties is considered minor relative to the existing degree of flood potential or inundation. Consequently, no additional local flood mitigation measures are expected to be required. This would however be subject to detailed design development.

Property 10

Property 10, the sports amenities building for the Berry sportsground and Camp Quality Memorial Park, is located immediately downstream of the southern bridge abutment. Relative flood level impacts based on the current concept design are negligible or minor.

4.3.2 Ancillary facilities

To reduce the risk of flood damage (and potential contamination of waterways) ancillary chemical storage facilities would be located above the 100 year ARI flood level.

Stockpile sites and ancillary construction material facilities would be sited above the 100 year ARI flood level where possible, but may be located above the 20 year ARI flood level. Where storage would be required on the floodplain (for activities such as bridgeworks) appropriate mitigation measures would be implemented, such as bunds around materials and equipment would be designed and scour protection applied to mitigate flood impacts.

In addition, the use of automatic weather stations (AWSs) would be considered to gather accurate and timely weather data and to facilitate weather warnings to construction contractors. AWSs are generally solar powered and record rainfall, wind speed and direction, temperature, relative humidity and dew point. The data is transferred to a remote server every 15 minutes over the 3G/4G telephone network. The data is then made available to RMS and contractors via the internet on an easy to navigate website. Information can also be sent to mobile phones by SMS. The AWSs can alert RMS staff and contactors of selected -predetermined weather conditions, such as when a site has received a certain rainfall amount in a day. This system can be used to mitigate potential adverse impacts of weather events.

4.3.3 Rehabilitation of waterways to pre-construction condition

Best practice management measures would be implemented during construction in accordance with applicable RMS QA specifications, Managing Urban Stormwater- Soils and Construction Volume 1 (Landcom, 2004) and Volume 2D – Main Road Construction (DECCW, 2008).

4.3.4 Climate change management measures

On the basis of the preceding assessment, the recommended measures to manage potential impacts due to climate change would involve:

- The provision of an appropriate freeboard of around 0.5 metres minimum for major bridge waterway crossings on Broughton Creek and Berry.
- The provision of a six per cent allowance for increased rainfall intensities. For minor waterway crossing culverts, additional impacts could feasibly be accommodated (if required) through future local adaptive measures such as culvert amplification and/or lifting the level of the highway.

References

ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. ISBN 0 9578245 2 1. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

ARMCANZ & ANZECC (1995). National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia.

Austroads (2001). Road Runoff and Drainage: Environmental Impacts and Management Options, AP-R180.

Austroads (2003). Guidelines for Treatment of Stormwater Runoff from Road Infrastructure, AP-R232.

Cardno (2012). Broughton Creek Floodplain Risk Management Study and Plan.

Cardno Ecology Lab (2011) Foxground and Berry bypass - Aquatic Ecology and Water Quality Management Assessment. Prepared for: Roads and Traffic Authority NSW

Coffey (2007) Preliminary Acid Sulfate Soil Assessment - Gerringong to Bomaderry Princes Highway Upgrade. Prepared for: Roads and Traffic Authority NSW

Coffey (2010). Geotechnical Interpretive Report or Concept Design - AECOM Preferred Route of the Princes Highway, Gerringong to Bomaderry. Report No GEOTWOLL02580AE-BL., dated May.

DECC (2007) Practical Consideration of Climate Change – Floodplain Risk Management Guideline.

DECCW (2006). NSW Water Quality and River Flow Objectives.

DECCW (2010). NSW Wetlands Policy. Report No DECCW 2010/39. ISBN 978 1 74232 520 0.

DSEWPC (1994). National Water Quality Management Strategy: Water Quality Management – an Outline of the Policies. Department of Sustainability, Environment, Water, Population and Communities.

DLWC (1997). State Groundwater Policy Framework Document.

DLWC (1997a). Burrier / Berry 1:25,000 Acid Sulfate Soil Risk Map (1997) Edition 2, Department of Land and Water Conservation.

DLWC (1997b). Gerroa 1:25,000 Acid Sulfate Soil Risk Map (1997) Edition 2. Department of Land and Water Conservation.

DLWC (1997c). Kiama 1:25,000 Acid Soil Risk Map (Series 9028-S1) Edition 2. Department of Land and Water Conservation.

DLWC (1998). The NSW State Groundwater Quality Protection Policy.

DLWC (2002). NSW Groundwater Dependent Ecosystem Policy, Department of Land and Water Conservation, Sydney.

DNR (2005). Floodplain Development Manual.

The Ecology Lab (2007). Gerringong to Bomaderry Princes Highway Upgrade. Preliminary Aquatic Ecology and Water Quality Assessment. Prepared for Maunsell. The Ecology Lab Pty Ltd, Sydney, NSW.

Engineers Australia (1987), Australian Rainfall and Runoff – A Guide to Flood Estimation.

EPA (1998a). Managing Urban Stormwater: Council Handbook.

EPA (1998b). Managing Urban Stormwater: Source Control.

EPA (1998c). Managing Urban Stormwater: Treatment Techniques.

Fletcher, T., Duncan, H., Poelsma, P. & Lloyd, S. (2004). Stormwater Flow and Quality and the Effectiveness of Non-Proprietary Stormwater Treatment Measures.

Hatton, T. & Evans R. 1998, Dependence of ecosystems on groundwater and its significance to Australia, Land and Water Resources Research and Development Corporation, Canberra.

Healthy Rivers Commission of NSW (2002). Coastal Lakes: Independent Inquiry into Coastal Lakes and Statement of Joint Intent.

Landcom (2004). Managing Urban Stormwater - Soils and Construction, Volume 1; NSW DECCW (2008). Volume 2D - Main Road Construction (NSW DECCW, 2008). The Blue Book.

Maunsell (2007). Preliminary Biological Report - Terrestrial Flora and Fauna. Gerringong to Bomaderry Princes Highway Upgrade. Prepared for: Roads and Traffic Authority NSW.

Maunsell (2008). Preliminary Flooding and Drainage Report. Gerringong to Bomaderry Princes Highway Upgrade. Prepared for: Roads and Traffic Authority NSW.

NPWS (1998). Seven Mile Beach National Park and Comerong Island Reserve. Plan of Management. NSW National Parks & Wildlife Service. Nowra, NSW.

NSW DEC (2007). Guidelines for the Assessment and Management of Groundwater Contamination.

NSW Office of Water – NOW (2011). MP10_0240 – Princes Highway Upgrade – Foxground and Berry Bypass – Director-General Requirements – Kiama and Shoalhaven LGAs, Letter dated 14 April.

NSW Office of Water - NOW (2011a). Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.

NSW Office of Water - NOW (2011b). NSW Policy for Managing Access to Buried Groundwater Sources. Report No NOW 11_133 ISBN 978 1 74263 016 8, dated July.

RTA (n.d.). Guideline for Construction Phase Water Quality Monitoring.

RTA (1997). Water Policy. Roads and Traffic Authority: Sydney.

RTA (1999). Code of Practice for Water Management. Roads and Traffic Authority: Sydney.

RTA (2001). Stockpile Site Management Procedures.

RTA (2003). Road Design Guideline: Section 8 Erosion and Sedimentation.

RTA (2003a). Procedures for Selecting Treatment Strategies to Control Road Runoff. Roads and Traffic Authority: Sydney.

RTA (2005). Guidelines for the Management of Acid Sulfate materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulphidic Black Ooze.

RTA (2006), Environmental Direction No 19, Use of Reclaimed Water

RTA (2006), TIP Sheet T101, Use of Reclaimed Water

RTA (2009). Erosion and Sedimentation Management Procedure. Roads and Traffic Authority: Sydney. October 2009

RTA (2011). Technical Guideline: Environmental Management of Construction Site Dewatering. RTA, April 2011.

SMEC (2008). Broughton Creek Flood Study. SMEC Australia Pty Ltd. Prepared for Shoalhaven City Council.

Webb McKeown & Associates (2008). Lower Shoalhaven River Floodplain Risk Management Plan. Prepared for Shoalhaven City Council.

Zinger, Y., T. D. Fletcher, A. Deletic, G. T. Blecken and M. Viklander (2007). Optimisation of the nitrogen retention capacity of stormwater biofiltration systems. Novatech 2007, 6th International Conference on Sustainable Techniques and Strategies in Urban Water Management, Lyon, France. June 24-28, 2007.

Appendix A

Assessment of creek property flood impacts - Berry

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing (mAHD)	Proposed (mAHD)	(m)	(mAHD)	Existing (m)	Proposed (m)	
110	North Street	15.00	14.97	-0.02	15.65	0.65	0.68	
112	North Street	14.92	14.81	-0.12	15.75	0.83	0.94	
114	North Street	14.89	14.77	-0.12	15.84	0.95	1.07	
118	North Street	14.40	14.30	-0.10	14.51	0.11	0.21	
120	North Street	14.04	13.96	-0.08	14.86	0.82	0.90	
122	North Street	13.90	13.83	-0.08	14.53	0.63	0.70	
124	North Street	13.84	13.80	-0.04	13.98	0.14	0.18	
124	North Street	13.86	13.79	-0.07	14.04	0.18	0.25	
124	North Street	13.86	13.82	-0.04	14.06	0.20	0.24	
126	North Street	13.55	13.49	-0.06	13.85	0.30	0.36	
126	North Street	13.55	13.49	-0.06	13.89	0.34	0.40	
126	North Street	13.19	13.17	-0.02	13.82	0.63	0.65	
126	North Street	13.33	13.30	-0.03	13.83	0.50	0.53	
126	North Street	13.45	13.42	-0.03	13.86	0.41	0.44	
130	North Street	13.08	12.95	-0.13	13.30	0.22	0.35	
130	North Street	12.82	12.69	-0.13	13.36	0.54	0.67	
138	North Street	12.13	12.12	-0.02	12.39	0.26	0.27	

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
0	North Street	12.17	12.17	-0.01	9.64	-2.53	-2.53	
150	North Street	11.99	11.87	-0.11	12.61	0.62	0.74	
2	Prince Alfred Street	8.79	8.75	-0.04	9.12	0.33	0.37	
7	Prince Alfred Street	8.99	8.95	-0.04	9.43	0.44	0.48	
67	Albert Street	11.22	11.17	-0.04	11.90	0.68	0.73	
10	Alexandra Street and Albert Street	11.42	11.35	-0.08	12.15	0.73	0.80	
62	Albert Street	11.85	11.81	-0.04	12.12	0.27	0.31	
0	Alexandra Street	11.98	11.96	-0.02	12.37	0.39	0.41	
65	Albert Street	12.12	12.07	-0.05	12.10	-0.02	0.03	Building no longer flooded
7	Alexandra Street	12.18	12.14	-0.04	12.70	0.52	0.56	
4	Alexandra Street	12.08	12.07	-0.02	12.20	0.12	0.13	
6	Alexandra Street	11.89	11.89	-0.01	12.49	0.60	0.60	
63	Albert Street	12.31	12.26	-0.04	12.51	0.20	0.25	
61	Albert Street	12.43	12.36	-0.07	12.82	0.39	0.46	
59	Albert Street	12.56	12.54	-0.02	13.23	0.67	0.69	
51	Albert Street	14.09	14.07	-0.02	14.49	0.40	0.42	
49	Albert Street	14.29	14.28	-0.01	14.78	0.49	0.50	
44	Albert Street	13.89	13.88	-0.01	14.44	0.55	0.56	
42	Albert Street	14.13	14.08	-0.04	14.53	0.40	0.45	

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
1	Albany Street	14.70	14.68	-0.01	15.87	1.17	1.19	
3	Albany Street	14.62	14.60	-0.02	15.19	0.57	0.59	
3a	Albany Street	14.57	14.56	-0.01	15.11	0.54	0.55	
18	Albert Street	17.98	17.96	-0.02	18.30	0.32	0.34	
4	Albert Street	17.98	17.96	-0.02	18.30	0.32	0.34	
2	Albert Street	18.11	17.73	-0.38	18.96	0.85	1.23	
2	Albert Street	18.10	17.77	-0.33	18.95	0.85	1.18	
2	Albert Street	18.12	17.98	-0.14	19.02	0.90	1.04	
2	Albert Street	18.13	17.96	-0.17	18.98	0.85	1.02	
2	Albert Street	18.02	17.97	-0.05	19.04	1.02	1.07	
2	Albert Street	17.98	17.94	-0.04	18.99	1.01	1.05	
2	Albert Street	17.99	17.67	-0.32	19.04	1.05	1.37	
2	Albert Street	18.01	17.71	-0.30	19.07	1.06	1.36	
3	Albert Street	18.31	18.30	-0.01	19.05	0.74	0.75	
1	Albert Street	18.23	18.21	-0.02	19.06	0.83	0.85	
64	Princess Street	9.82	9.51	-0.31	9.96	0.14	0.45	
66	Princess Street	9.69	9.59	-0.10	10.35	0.66	0.76	
15	Alexandra Street and Princess Street	10.23	10.11	-0.11	10.96	0.73	0.85	
61	Princess Street	10.50	10.24	-0.26	10.82	0.32	0.58	

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
19	Alexandra Street	9.82	9.68	-0.14	10.42	0.60	0.74	
54	Princess Street	9.77	9.69	-0.09	11.78	2.01	2.09	
52	Princess Street	11.03	10.92	-0.11	11.89	0.86	0.97	
50	Princess Street	11.43	11.29	-0.14	12.07	0.64	0.78	
48	Princess Street	11.64	11.41	-0.24	12.04	0.40	0.63	
46	Princess Street	11.70	11.46	-0.24	12.13	0.43	0.67	
44	Princess Street	12.04	11.75	-0.28	12.45	0.41	0.70	
42	Princess Street	12.36	12.05	-0.31	12.26	-0.10	0.21	Building no longer flooded
11	Albany Street	12.48	12.42	-0.07	13.10	0.62	0.68	
13	Albany Street	12.64	12.54	-0.10	13.16	0.52	0.62	
15	Albany Street	12.55	12.52	-0.03	13.40	0.85	0.88	
36	Princess Street	12.96	12.87	-0.09	13.31	0.35	0.44	
34	Princess Street	13.29	13.04	-0.24	14.12	0.83	1.08	
33	Princess Street	13.64	13.62	-0.02	14.27	0.63	0.65	
26	Princess Street	13.65	13.33	-0.32	13.62	-0.03	0.29	Building no longer flooded
31	Princess Street	13.99	13.94	-0.05	14.62	0.63	0.68	
29	Princess Street	14.34	14.31	-0.04	14.59	0.25	0.28	
27	Princess Street	14.76	14.68	-0.08	15.04	0.28	0.36	
37	Edward street and Princess Street	14.88	14.55	-0.34	15.27	0.39	0.72	

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
33	Edward Street	15.53	15.11	-0.42	15.56	0.03	0.45	
19	Princess Street	15.92	15.81	-0.11	16.50	0.58	0.69	
17	Princess Street	16.21	16.21	-0.01	16.48	0.27	0.27	
51a	Victoria Street	13.54	13.33	-0.22	14.41	0.87	1.08	
53	Victoria Street	13.45	13.36	-0.08	14.16	0.71	0.80	
22	Alexandra Street and Victoria Street	9.46	9.11	-0.35	9.55	0.09	0.44	
66	Victoria Street	7.37	7.00	-0.37	7.65	0.28	0.65	
68	Victoria Street	8.70	8.42	-0.27	8.78	0.08	0.36	
87	Victoria Street	9.47	9.31	-0.15	9.57	0.10	0.26	
70	Victoria Street	8.98	8.95	-0.03	9.17	0.19	0.22	
35	Prince Alfred Street	6.97	6.95	-0.02	7.44	0.47	0.49	
43	Prince Alfred Street	6.96	6.94	-0.02	6.79	-0.17	-0.15	
45	Prince Alfred Street	6.96	6.94	-0.02	7.26	0.30	0.32	
80	Queen Street	11.30	11.30	-0.01	12.30	1.00	1.00	
46	Queen Street	15.99	15.76	-0.23	16.58	0.59	0.82	
44	Queen Street	16.44	16.34	-0.10	16.38	-0.06	0.04	Building no longer flooded
42	Queen Street	16.51	16.12	-0.39	16.35	-0.16	0.23	Building no longer flooded
40	Queen Street	16.61	16.16	-0.44	16.76	0.15	0.60	
38	Queen Street	16.62	16.17	-0.46	16.59	-0.03	0.42	Building no longer flooded

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
36	Queen Street	17.44	17.38	-0.06	17.57	0.13	0.19	
24	Queen Street and George Street	17.93	16.89	-1.04	19.02	1.09	2.13	
24	Queen Street and George Street	17.93	17.21	-0.73	19.02	1.09	1.81	
24	Queen Street and George Street	17.96	17.40	-0.55	18.93	0.97	1.53	
24	Queen Street and George Street	17.96	17.42	-0.54	18.95	0.99	1.53	
35	Queen Street	17.82	17.60	-0.22	17.76	-0.06	0.16	Building no longer flooded
35	Queen Street	17.85	17.71	-0.14	17.77	-0.08	0.06	Building no longer flooded
35	Queen Street	17.87	17.64	-0.23	17.75	-0.12	0.11	Building no longer flooded
37	Queen Street	17.52	17.37	-0.14	17.83	0.31	0.46	
37	Queen Street	17.79	17.58	-0.21	18.07	0.28	0.49	
37	Queen Street	17.82	17.59	-0.23	18.10	0.28	0.51	
39	Queen Street	17.55	17.43	-0.12	17.63	0.08	0.20	
41	Queen Street	17.37	17.34	-0.03	17.49	0.12	0.15	
65	Queen Street	13.58	13.57	-0.01	14.39	0.81	0.82	
65	Queen Street	13.75	13.74	-0.01	14.32	0.57	0.58	
65	Queen Street	13.88	13.86	-0.02	14.25	0.37	0.39	
65	Queen Street	13.95	13.93	-0.03	14.29	0.34	0.36	
65	Queen Street	13.95	13.92	-0.03	14.31	0.36	0.39	
65	Queen Street	13.98	13.96	-0.02	14.30	0.32	0.34	

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
69	Queen Street	13.45	13.43	-0.02	13.78	0.33	0.35	
71	Queen Street	13.41	13.40	-0.01	13.89	0.48	0.49	

Notes 1. Flood level has been extracted from flood surface DTM at point location of floor level survey and may therefore be influenced by local features.

A positive relative impact represents an increase in flood level under proposed conditions relative to existing conditions.

2. *A change in flood level of +/-0.01m is considered to be within the level of accuracy of the model and have negligible or no impact.*

3. *A negative freeboard represents the depth of above floor inundation.*

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Volume 2 – Appendix I

Technical paper:
Urban design including landscape character and visual amenity

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Foxground and Berry bypass

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Roads and Maritime Services NSW

Prepared by

AECOM Australia Pty Ltd

Level 21, 420 George Street, Sydney NSW 2000
T +61 2 8934 0000 F +61 2 8934 0001
www.aecom.com
ABN 20 093 846 925

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Foxground and Berry bypass

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Executive summary

The purpose of this report is to:

- Describe the urban design context of the Foxground Berry bypass (the project), identifying key built, natural, landscape and visual features, characteristics and qualities of the route and its setting.
- Describe the project including the proposed urban design and landscape features and aspects.
- Assess the urban and landscape design of the project (including landscape character and visual impacts).
- Address the Director-General's requirements relating to landscape and visual amenity.
- Identify and describe integrated mitigation measures.

While a specific 'Urban Design Framework' does not yet exist for the whole Princes Highway, the design objectives outlined in this report (Section 2.0) are derived from the RMS urban design policies as published in 'Beyond the Pavement: RTA Urban Design Policy, Procedures and Design Principles' (RTA, 2009), 'Bridge Aesthetics: Design Guidelines to Improve the Appearance of Bridges in NSW' (RTA, 2003), and are also consistent with the 'Gerringong to Bomaderry Princes Highway Upgrade Preliminary Urban and Regional Design Strategy' (AECOM, 2007).

Evaluation of the project

The project has been assessed with regard to:

- Urban design objectives and principles.
- Contextual and landscape character analysis.
- Landscape character and visual impact assessment.

The project has been designed to be consistent with the urban design objectives established during the overall route options assessment stage. The scale of the interventions required for the project (in what is generally an undulating pastoral landscape) will result in impacts that will vary in magnitude. Key specific impacts will include:

- Sections of new alignment, including a substantial cut through Toolijooa Ridge.
- A new interchange at the northern end of Berry.
- A significant new bridge over Broughton Mill Creek and Woodhill Mountain Road.
- A bypass around Berry including new alignment and noise attenuation walls, that run in close proximity to the existing North Street.
- A new interchange at the southern end of Berry with a connection into Kangaroo Valley Road.
- New cut and fill embankments along the route.
- The removal of vegetation and cultural landscape patterns that have evolved over a long period of time.

The integrated urban design concept plan included in this report represents the recommended mitigation strategies for minimising these impacts on landscape character and within the visual environment.

Due to the magnitude of the potential impacts on the landscape character of Berry and the close proximity of these impacts to town, an independent targeted urban design study was undertaken with a focus on the Berry bypass. This study involved detailed community consultation to incorporate community inputs into the concept design and potential mitigation measures.

Four landscape character units have been identified and assessed. The landscape character and visual impacts are considered high for two of these units and moderate to high for the remaining two units.

Nine viewpoints have been identified along the route to illustrate potential landscape character and visual impacts. Existing views and artist's impressions illustrating the project are presented for each viewpoint. The artist's impressions incorporate the recommended mitigation strategies derived from the urban design strategy and illustrate the likely outcomes.

The artist's impressions and the urban and landscape design concept plan combine to illustrate the following key urban design initiatives:

- The development of an alignment and road formation for the proposed highway, that has been designed to best fit with the landform and landscape along the route and to minimise the visual and landscape character impacts.
- The widening of the project footprint during the construction phase that will facilitate:
  - The construction of batter slopes ranging from 4:1 to 10:1, assisting with project cut / fill balances and providing more sympathetic landform integration along the corridor.
  - Maintaining the unique cultural landscape character of the region.
- The use of culturally significant tree species for revegetation strategically along the corridor.
- The reestablishment of open pastoral landscape, including pasture grasses, cultural hedge plantings and rural boundary fencing.
- The selective and prudent screening of some of the new infrastructure associated with the upgrade.
- The development of an alignment and design around Berry selected to minimise potential impact on the town's community open space and heritage features.
- The maintenance of internal connections and circulation patterns within the township of Berry.
- The generation of a design along North Street that recognises the potential substantial impact and change to visual connections between the northern edge of Berry and the ridges and escarpment to the north and west.
- The strengthening of the connection between the eastern side of Berry and its western expansion at the new southern interchange.
- The holistic and considered integration of bridge and retaining elements within the urban design framework.

Of key importance to the implementation of the suggested mitigation and management measures would be:

- To engage with the local community to gather feedback as the design develops, foster broader community support and ownership for the design outcome and facilitate integration with existing pedestrian access mobility plans for the township of Berry.
- To facilitate landscape and urban design outcomes that resolve other project opportunities and constraints including:
  - Balancing cut and fills.
  - Utilising RMS owned land along the corridor to facilitate increasing the short term footprint of the project to reduce the long term footprint and therefore maintenance requirements (primarily through the return to pasture land).

1

Introduction

1 Introduction

1.1 The project

The Roads and Maritime Services (RMS) is proposing to upgrade the Princes Highway between Toolijooa Road and Schofields Lane with a bypass to Foxground and the town of Berry. The project is part of the RMS's program to upgrade the Princes Highway between Gerringong and Bomaderry, providing increased road safety and traffic efficiency in the South Coast region.

The horizontal and vertical alignments of the existing largely two-lane highway between Toolijooa Road and Schofields Lane require upgrading to meet current design safety and traffic efficiency requirements. The highway has limited overtaking opportunities, many junctions with rural roads and private, uncontrolled accesses. The existing road also passes directly through the township of Berry (along Queen Street), having a detrimental effect on the safety and amenity of the street.

The preferred route option best meets the objectives applied across the program of projects for the Princes Highway upgrade between Toolijooa Road and Mullers Lane. The route performs well across a combination of the technical inputs gathered through investigations carried out to date (including a review of studies from previous investigations into the project), community feedback and the findings of the value management process.

Other projects included in the ultimate program of works to upgrade the Princes Highway between Gerringong and Bomaderry include:

- The Gerringong upgrade (GU).
- The Berry to Bomaderry upgrade (BBU).

The GU is currently within the detailed design phase. The BBU will be assessed in a future report.

1.1.1 The study area

The study area extends from Toolijooa Road in the north (the southern extent of the proposed GU), to Mullers Lane in the south. Mullers Lane is located just south of Berry township, refer to **Figure 1.1.** The study area varies in width from about one to three kilometres and is strongly influenced by the underlying natural landform and the past and present cultural settlement and pastoral practices. The northern and western sections of the study area are bordered by the southern end of the Illawarra escarpment, Curry's mountain and the Cambewarra range. The eastern and southern sections are bordered by Broughton Creek, Toolijooa Ridge and the South Coast railway line.

From north-east to south-west the study area includes Toolijooa Ridge and Broughton Village where it crosses the Broughton Creek floodplain. At Broughton, the terrain climbs and follows an undulating low ridge line towards the south-west before gently descending down into the township of Berry.

West of Berry the terrain starts to rise into the foothills of the Cambewarra Range while to the south and east, the broad floodplain of the lower Broughton Creek meanders toward the Shoalhaven river landscape.

The undulating landscape, pastureland and rural settlement patterns are defining features within the study area. The broader context is dominated by the almost constantly visible backdrop of the ridges and escarpment of the Cambewarra Range. The rural landscape includes a mix of past agricultural and pastoral activities that have been occurring since the first half of the nineteenth century combined with smaller scale rural allotments with varied practices.

The largest agricultural influence is dairy farming. This has defined the general pattern of vegetation clearance, rural boundaries (by linear cultural plantings) and the distribution of rural houses and farm buildings along the route.

Within the pastoral landscape, topography and drainage patterns provide the major source of variation. The character of the rural backdrop is markedly different between the undulating higher elevations associated with the forested foothills of the Cambewarra Range and the openness of the Broughton Creek floodplain. There is a constant interplay between areas of roadside vegetation and undulating open pastoral landscape that provides for a mix of intimate landscape experiences and broad vistas. North west of the confluence of Broughton and Broughton Mill creeks is the township of Berry. The older section of Berry is set out in a traditional grid pattern and is strongly contained by the South Coast railway line to the south and east and flood prone land to the north. For a detailed description of Berry refer to **Section 5.4.2.**

The rural backdrop is slowly changing due to the partial decline of the dairy industry. This has created a more complex landscape pattern with a wider variety of agricultural activities resulting in increased areas under cultivation.

For further description of the study area refer to **Section 5.0.**

1.1.2 Design constraints

Significant constraints which influence the location and design of the project include:

- The existing highway corridor.
- Extensive areas of slope steeper than 30 per cent.
- The existing sub-standard road geometry.
- Floodplains and soft soil conditions.
- Numerous creek crossings.
- Existing land uses and settlement patterns.
- The Berry township.
- The location of the eastern gas pipeline.
- Indigenous and non-indigenous cultural heritage locations within the study area.
- The residences and communities within and adjacent to the study area.

Figure 1.1 - The overall Princes Highway upgrade between Gerringong and Bomaderry

1.1.3 Major design elements

The project is about 11.6 kilometres in length. **Figure 1.1** highlights the project in the context of the three highway upgrade sections between Gerringong and Bomaderry. **Figure 1.2** illustrates the proposed route and the key elements of the project as they relate to the urban and landscape design. The project is part of the overall Princes Highway upgrade, the over arching objectives of which are to improve road safety and reduce travel times. A detailed description of the project elements is outlined in **Section 3.2**.

1.2 Study methodology

Early planning is the key to achieving an integrated urban design strategy for major infrastructure projects. The project would ultimately become part of the fabric of the community and landscape into which it is integrated. The establishment of a collaborative multidisciplinary design team prior to route selection has ensured consistent, high level awareness of the landscape and urban design objectives. This enables an integrated 'whole of corridor' outcome within the context of the entire Princes Highway.

Development of the urban design concept plan has been a process of informing and being informed by each of the design team disciplines to ensure a holistic integrated solution.

In this report the following studies are documented as part of the design process:

- Urban and landscape design objectives and principles in **Section 2.0** were developed for the strategic concept design (alignment) of the whole of the Princes Highway upgrade between Gerringong and Bomaderry. These objectives and principles were then used to develop and assess the project.
- A contextual analysis of the Princes Highway was documented to assist in understanding the environment around the project. This analysis was undertaken through field surveys and desktop studies to determine character units, identify key local and regional characteristics and qualities; and identify site opportunities and constraints.
- A landscape character assessment and visual analysis was undertaken in accordance with the 'Environmental Impact Assessment Guidance Note: Guidelines for Landscape Character and Visual Impact Assessment: EIA-N04' (RTA, 2009b) to identify key viewpoints and to review the character of the study area. The visual analysis was used to identify potential impacts of the proposed engineering concept design and to make recommendations for impact treatment and mitigation measures.

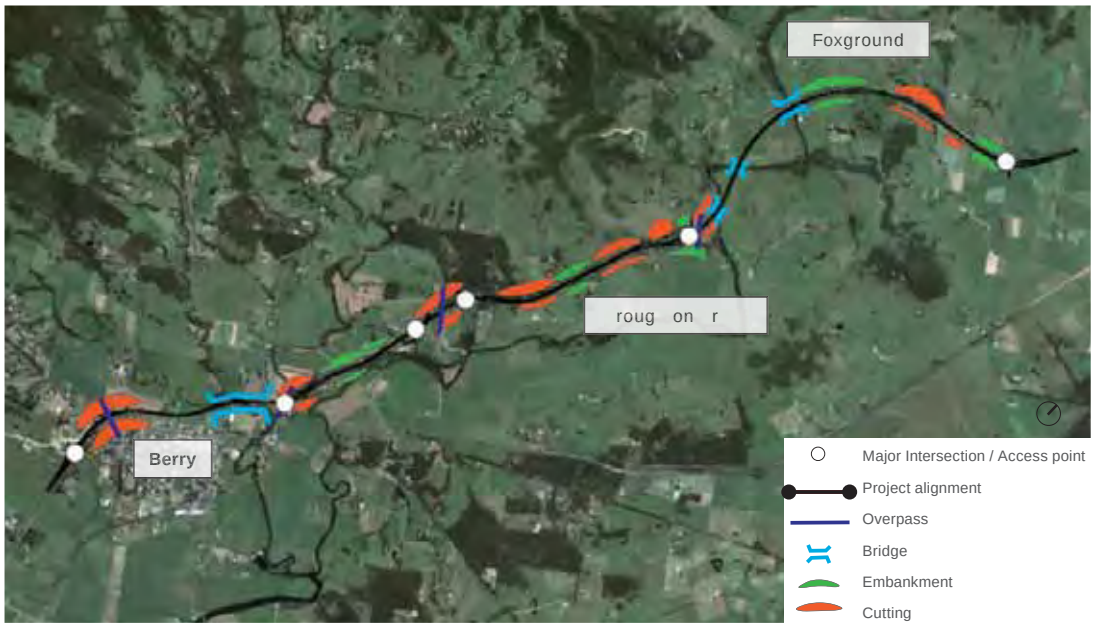

Figure 1.2 The project and the key elements associated with the project

In order to realise the full potential of the integrated approach used to develop the concept design and leave a positive legacy within the landscape and community, collaboration between design disciplines will continue through the detailed design phase of the project to ensure that the 'whole of corridor' landscape and urban design objectives are met.

This report uses both desktop and field studies to define the contextual landscape, physical characteristics and visual analysis of the project area. Information was gathered from the site by undertaking field surveys (in public areas such as, along local roads, within Berry township and along the existing Princes Highway corridor) to assess likely view points and impacts of the project.

1.2.1 Concept design development approach and process

Consistent with the overall philosophy and goals for urban design, as described within 'Beyond the Pavement: RTA Urban Design Policy, Procedures and Design Principles' (RTA, 2009), the urban and landscape design team have been continually engaged throughout the concept design phase of the project.

Maintenance of the integrity of the urban design objectives has been met through a range of initiatives including:

- Participation in value management and value engineering workshops.
- The preparation of visualisations and diagrams to measure the potential impacts of the proposed design options.
- Collaboration with the environmental, geotechnical and earthworks; and road and drainage design disciplines to maximise opportunities for integrated concept design solutions.
- Urban design studies of Berry that illustrate the broader contextual impacts of the bypass and what opportunities and constraints these present.

Adjustments to the alignment were developed through consultation with residents in a community review group and an independent urban design review was undertaken by CM+ to assess the design of the Berry bypass section of the project. The agreed outcomes of the adjusted alignment have been included in this report. The artist's impressions prepared by CM+ are included in **Section 6.8.11** through **Section 6.8.14**, and **Appendix A.**

1.2.2 Landscape character units

The project was broken down into a series of landscape character units that were used as the basis for the strategy and assessment of the urban and landscape design.

The landscape character units are defined and discussed in **Section 5.5**.

1.2.3 Options identification and testing

A number of options were identified and tested during design refinement. These options were worked through in a collaborative process to provide a balanced multi-criteria analysis of all of the opportunities and constraints. The key areas of focus were:

- The Toolijooa Ridge cutting and transition onto the Broughton Creek floodplain.
- The Austral Park Road interchange and connection with the existing highway.
- The Berry east interchange and bridge at Berry alignment and arrangement.
- The North Street corridor and Town Creek alignment.
- The Kangaroo Valley Road interchange.

1.3 Director General's requirements

The Director-General's requirements (DGRs) relating to landscape and visual amenity for the project, and where they are addressed, are listed in **Table 1. 1.**

1.4 Structure of this report

The structure of the report is as follows:

- **Section 1.0 -** Introduction.
- **Section 2.0 -** Urban design objectives and principles.
- **Section 3.0** - Concept design description.
- **Section 4.0 -** Urban and landscape design strategy.
- **Section 5.0 -** Contextual and landscape character analysis.
- **Section 6.0 -** Landscape character and visual impact assessment (describing the likely visual impacts of the project through a review of key viewpoints towards and along the route).
- **Section 7.0 -** Mitigation and management measures (integrated design and management measures and reference design parameters for key project elements).
- **Appendix A -** This includes the Berry Bypass Urban Design Report prepared by CM+ documenting the outcomes of the community engagement process.

Table 1.1 - Director-General's requirements related to landscape and visual amenity

Director General's requirements	Where addressed
Landscape and visual amenity - including but not limited to:	
• Assessment of visual significance of the area, including the escarpment and ridges and the township of Berry, and impact of the proposed alignment.	• **Section 5.0** and **Section 6.7**
• Design of the project (including noise barriers, retaining walls and landscaping) consistent with the existing (and desired) character of affected localities, including consideration of RMS' 'Noise Wall Design Guideline: Design Guidelines To Improve The Appearance of Noise Walls in NSW' (RMS, 2006). The assessment should also consider highway/street lighting and the potential lightspill impacts on nearby residents.	• **Section 3.0**, **Section 4.0**, **Section 5.0** and **Section 7.0**

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2

Urban design objectives and principles

2 Urban design objectives and principles

2.1 Purpose of project urban design objectives and principles

While a specific 'Urban Design Framework' does not yet exist for the whole Princes Highway, the design objectives outlined in this report (**Section 2.0**) are derived from the RMS's policies regarding urban design as published in 'Beyond the Pavement: RTA Urban Design Policy, Procedures and Design Principles' (RTA, 2009). This is explained in further detail in **Section 2.2** and **Section 4.0** - Urban and landscape design strategy.

The purpose of defining the project's urban design objectives and principles

Design objectives and principles provide a framework to ensure the project's design integrates harmoniously within the context of the natural and cultural landscape. Their intent is to guide the design process while allowing flexibility to refine the fine detail of the design to achieve a best-for-project outcome. The objectives and principles encourage integration with other road infrastructure upgrades within the region (including the North Kiama bypass, upgrade of the Princes Highway between Oak Flats and Dunmore, and the Sea Cliff bridge) which provide successful precedents for culturally relevant urban design.

The objectives and principles, along with the visual assessment and landscape character assessment (refer to **Sections 4.0** and **5.0**) are used as a basis for the interrogation of the preferred route and concept design for the project throughout this report. They will also continue to be used as a benchmark for future stages of the project design development.

2.2 Objectives and principles of the project

The objectives that form the urban and regional design framework for the project are supported by specific design principles which guide their achievement. These include:

Objective One: Provide a flowing highway alignment that is responsive and integrated with the natural landscape

- The route selection should respond to the grain of the landscape, including following the edges of valleys and hills and avoid, where possible the disruption of stands of vegetation, both natural and cultural.
- Integrate cut and fill embankments with surrounding terrain by grading out and varying slopes.
- Consider independently graded carriageways.
- Preserve existing cultural patterns within the landscape.
- Avoid where possible impact to significant local features through which the project passes.
- Vary the gradient of earthworks to provide visual interest and reflect the characteristics of the surrounding landform and landscape.
- Grade out cuttings and embankments, where possible to best fit the characteristics of the local landform, returning the land to its former use or replacing vegetation lost to the project.

Objective Two: Protect the natural systems and ecology of the corridor

- Avoid, where possible areas of natural vegetation, particularly those containing threatened species and communities.
- Minimise disruption to natural drainage patterns both through route selection and road design.
- Minimise the number of creek crossings.
- Use medians and road verges to maximise habitat value and maintain pollination paths and wildlife movement patterns.
- Integrate the landscape qualities and characteristics of the project landscape with the locality through which it passes.
- Integrate water quality basins within the landscape form and character.

Objective Three: Protect and enhance the heritage and cultural values of the corridor

- Avoid, where possible areas of identified historic and Aboriginal heritage and cultural value.
- Acknowledge and respond to the heritage and cultural values of the rural landscape.
- Acknowledge and respond to Aboriginal values placed on the broader landscape.
- Reduce the visual and noise impacts of the project.
- Consider the important value of productive landscapes.

Objective Four: Respect the communities and towns along the highway

- Minimise the project impacts to local township residents.
- Provide safe and efficient access to towns.
- Divert the highway around the town of Berry to improve the amenity of its centre in particular, Queen Street.
- Minimise, where possible the visibility of the highway from the edges of Berry, particularly those views along its north - south streets.
- Provide safe and efficient access from the highway into Berry, maintaining visual connections that encourage road users to visit the town.
- Minimise the disruption and loss of amenity to rural residents within the study area.

Objective Five: Provide a safe, enjoyable and interesting highway with strong visual connections to the Pacific Ocean, immediate hinterland, and mountains to the west

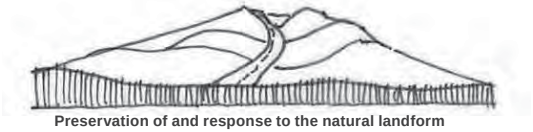
- Acknowledge the role of this section of the Princes Highway as an important part of a longer scenic drive along the New South Wales South Coast.
- Maximise the opportunities for high quality and varied views of the coast, the rural landscape and adjacent mountain ranges.
- Provide visual connections (way finding and directional signage) marking access to the towns/communities along the route.
- Use landscape treatments to soften the appearance of the road for its users without compromising opportunities for key views.
- Consider the heritage aspects of the route to enable road users, where practicable to experience them.

Objective Six: Develop a simple and unified palette of elements and details that are easily maintained

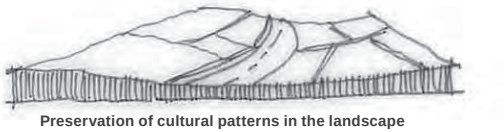
- Develop a consistent approach to the design of bridges along the project. Urban design principles to be consistent with those outlined in 'Bridge Aesthetics: Design Guidelines To Improve The Appearance of Bridges in NSW' (RTA, 2003).
- Develop a consistent approach to the design of noise walls along the project. Apply urban design principles consistent with those outlined in RMS' 'Noise Wall Design Guideline: Design Guidelines To Improve the Appearance of Noise Walls in NSW' (RTA, 2006).
- Develop an integrated strategy for the avoidance, minimisation and improved appearance of shotcrete as outlined in 'Shotcrete Design Guidelines: Design Guidelines to Avoid, Minimise and Improve the Appearance of Shotcrete' (RTA, 2005).
- Develop a consistent approach to the design of soft landscaping along the route. Planting design principles to be consistent with those outlined in 'Landscape Guideline: Landscape Design and Maintenance Guidelines to Improve the Quality, Safety and Cost Effectiveness of Road Corridor Planting and Seeding' (RTA, 2008).

The unifying philosophy behind these objectives (and associated design principles) is the goal to develop a project that not only meets functional and engineering criteria, but one that respects the environment in which it is located. The urban and regional design framework is intended to be a fundamental component of all stages of highway planning and design.

Conceptually, these principles are illustrated in **Figure 2.1.**



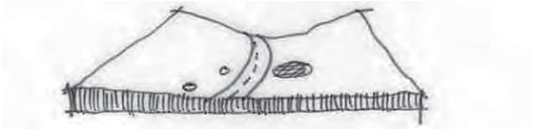
Preservation of and response to the natural landform



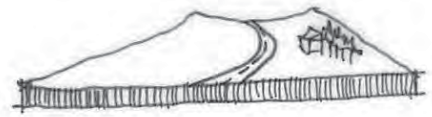
Preservation of cultural patterns in the landscape

Avoidance of wetlands, unique habitats and remnant plant communities

Respect for rivers, streams and natural drainage ways



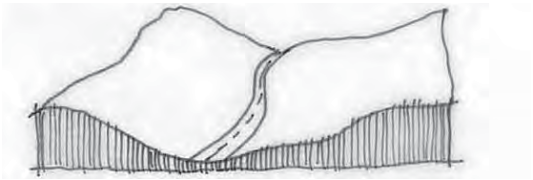
Preservation of historical archaeological sites



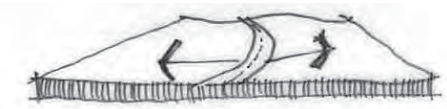
Preservation of historical cultural landscapes

Preservation of context of communities

Consideration of adjacent land uses and access to and from highway



Highway location to engage with terrain



Recognition of special view sheds and scenic character

Figure 2.1 Design principles

3

Concept design description

3 Concept design description

3.1 The concept plan

The project concept design is illustrated and described in **Figure 3.1**. The urban design and landscape concept plans supported with sections, typical treatment illustrations and enlargement plans are illustrated in **Figure 3.2** through to **Figure 3.27.**

3.2 The design elements

RMS propose to upgrade 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project comprises the following key features:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 167 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 76 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.
- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.
- Eight underpasses including roads, drainage structures and fauna underpasses:
  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Tindalls Lane, Gembrook Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two cul-de-sacs on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent ancillary facility site for general road maintenance.

The project and the key features of the project are shown **Figure 3.1**

- Construction activities as part of the project would include the following:
  - Site preparation and establishment works.
  - Temporary construction facilities, including construction compounds, stockpile sites, creek crossings, sediment control basins and haulage roads.
  - Temporary works, including relocation/protection of services, tie-ins, traffic facilities and side tracks.
  - Earthworks and bridge construction.
  - Pavement construction.
  - Drainage construction.
  - Street furniture installation.
  - Site restoration.

3.3 Application of the urban and landscape design principles

The concept design utilises existing landscape elements to integrate a design response which is sensitive to its landscape context. The key design elements that relate to the overall strategy are:

- Widening the project footprint during construction to flatten batters, reestablish pasture grasses and ultimately minimise the footprint impact. This will also allow for better ultimate landform and land use integration.
- Reducing the size and scale of structural elements within the landscape.
- Minimising the impacts on the township of Berry and reinforcing the opportunities that the bypass presents.
- Reinforcing the cultural landscape by planting trees perpendicular to the carriageway at the interface of creeks, fence lines and existing vegetation lines.
- Extending the pastoral landscape to the edges of the carriageway.
- Responding to the open nature of the broader landscape setting.
- Integrating the design to minimise impacts to the existing landscape character.

3.4 Urban design and landscape concept plan

The urban design and landscape concept plans are illustrated in **Figure 3.2** through to **Figure 3.27**. The concept design responds to the Urban and Landscape Design Strategy (**Section 4.0**), which was informed by the visual assessment and contextual analysis as documented in **Sections 4.0** and **5.0**.

The visual assessment and contextual analysis identify impacts associated with the project and the Urban and Landscape Design Strategy proposes treatments and mitigation measures that have been integrated into the concept design to minimise its impacts.

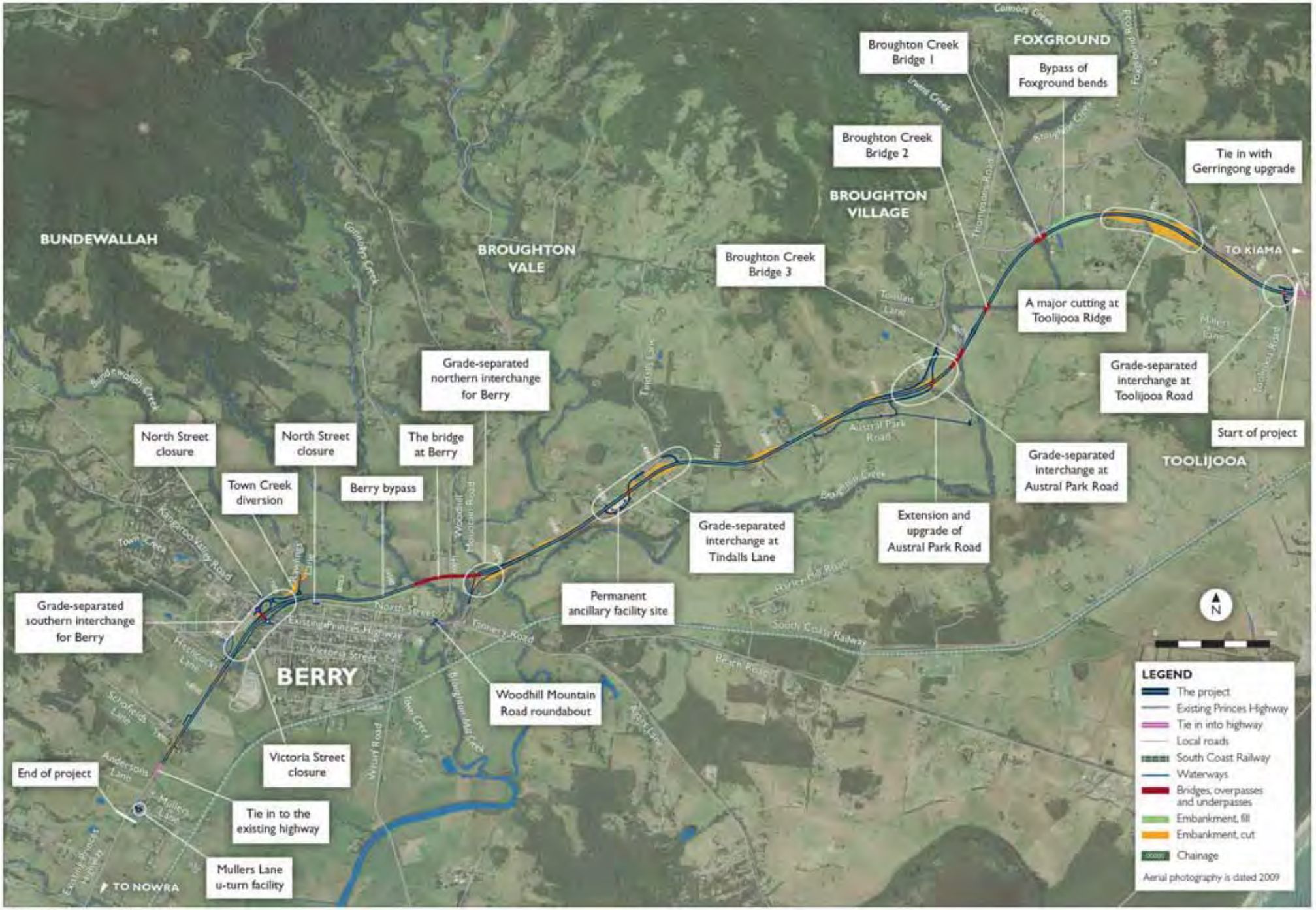


Figure 3.1 The project engineering concept drawing

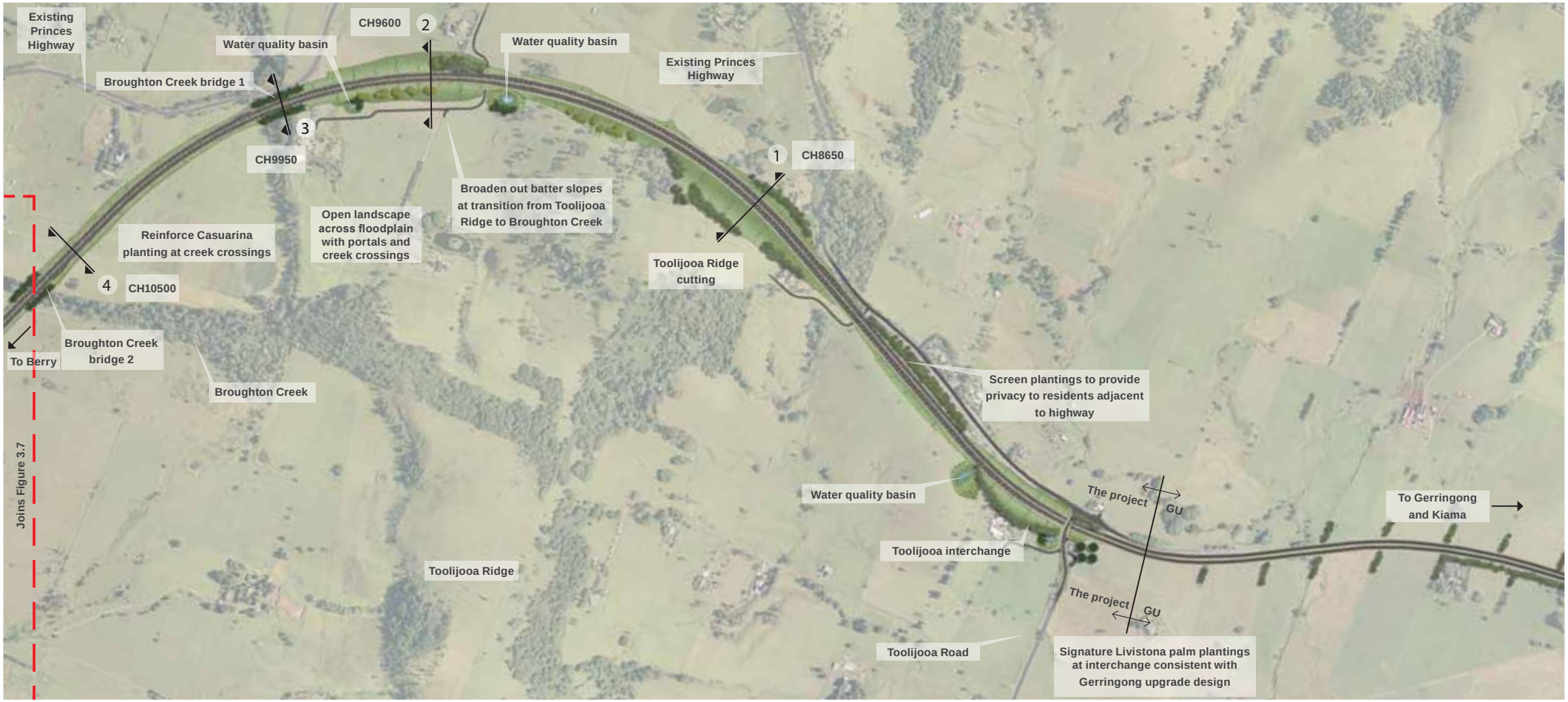


Figure 3.2 Concept for northern section of the project including Toolijooa and Broughton Creek

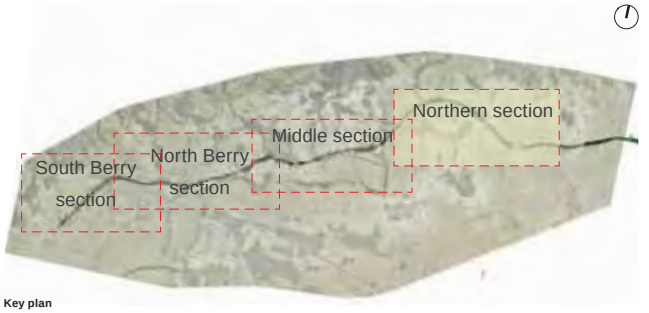
Legend

- Existing Princes Highway
- Proposed road alignment
- Pasture reestablishment to edge on embankments
- Livistonia palm tree (feature)
- Isolated tree plantings Eucalyptus and or Fig Trees
- Eucalyptus trees in forest style planting
- Riparian / Casuarina tree planting
- Water quality basin
- Noise attenuation barrier (indicative extent only)

- 1 Section number 1 at CH 8650
- 2 Section number 2 at CH 9600
- 3 Section number 3 at CH 9950
- 4 Section number 4 at CH 10500

0 100 200 300 400 500 600

1:8000 metres



Key plan

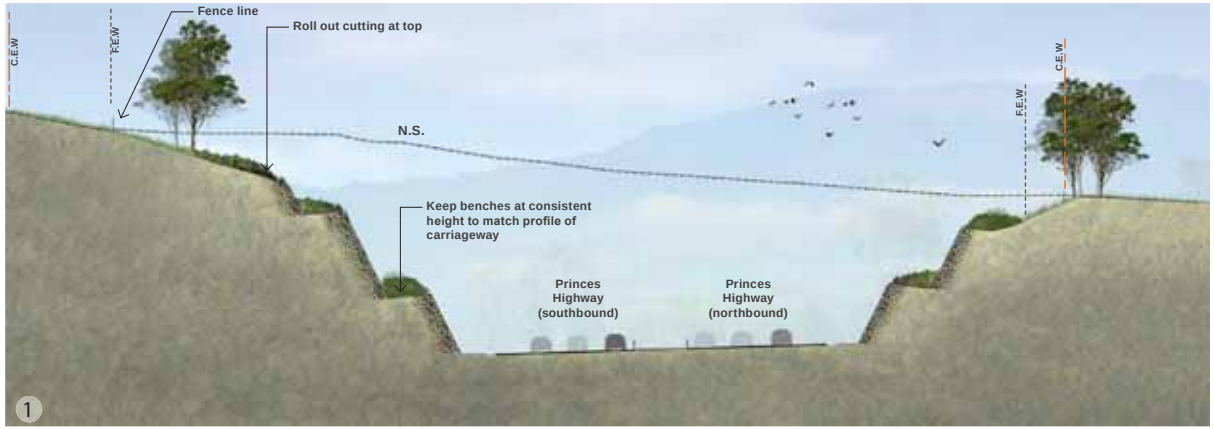


Figure 3.3 Elevation / section 1 - Toolijooa - chainage 8650

Legend:
N.S. Natural surface
C.E.W Construction extent of works
F.E.W Final extent of works

0 4 8 12 16 20 24 metres

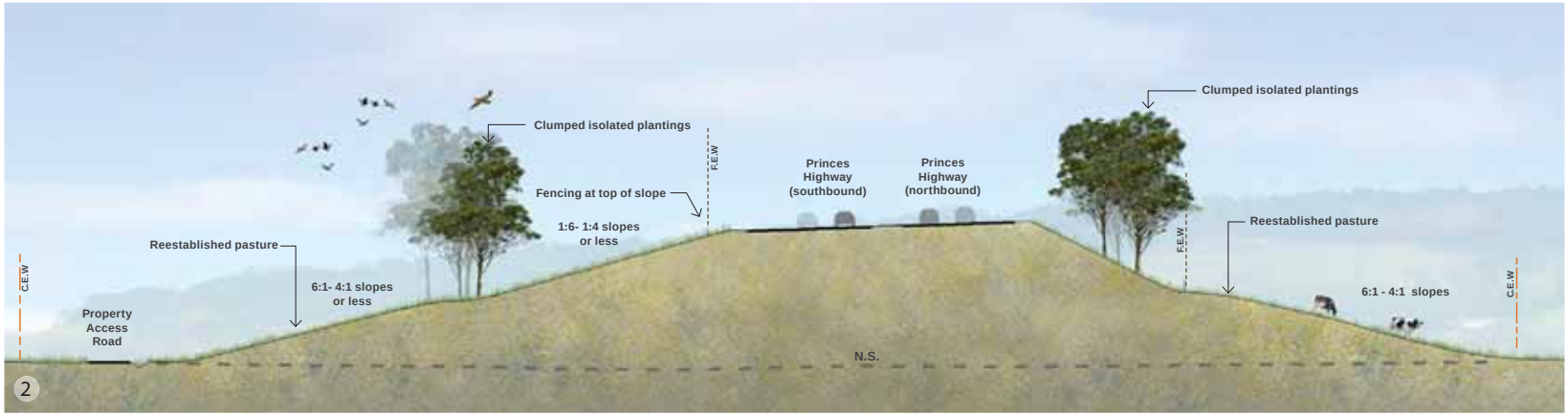


Figure 3.4 Elevation / section 2 -Broughton Creek - chainage 9600

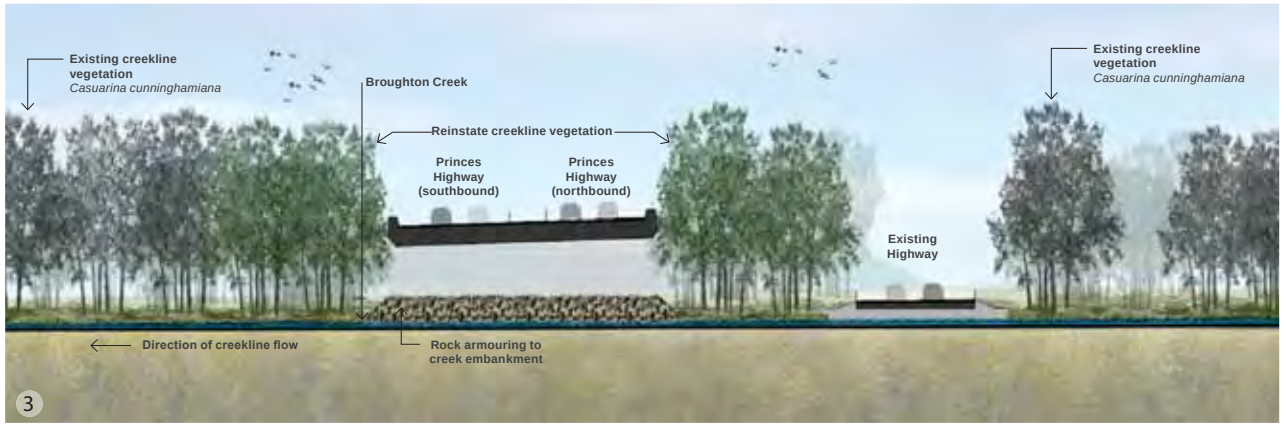


Figure 3.5 Elevation / section 3 - Broughton Creek - chainage 9950

Figure 3.6 Elevation / section 4 -Broughton Creek - chainage 10500

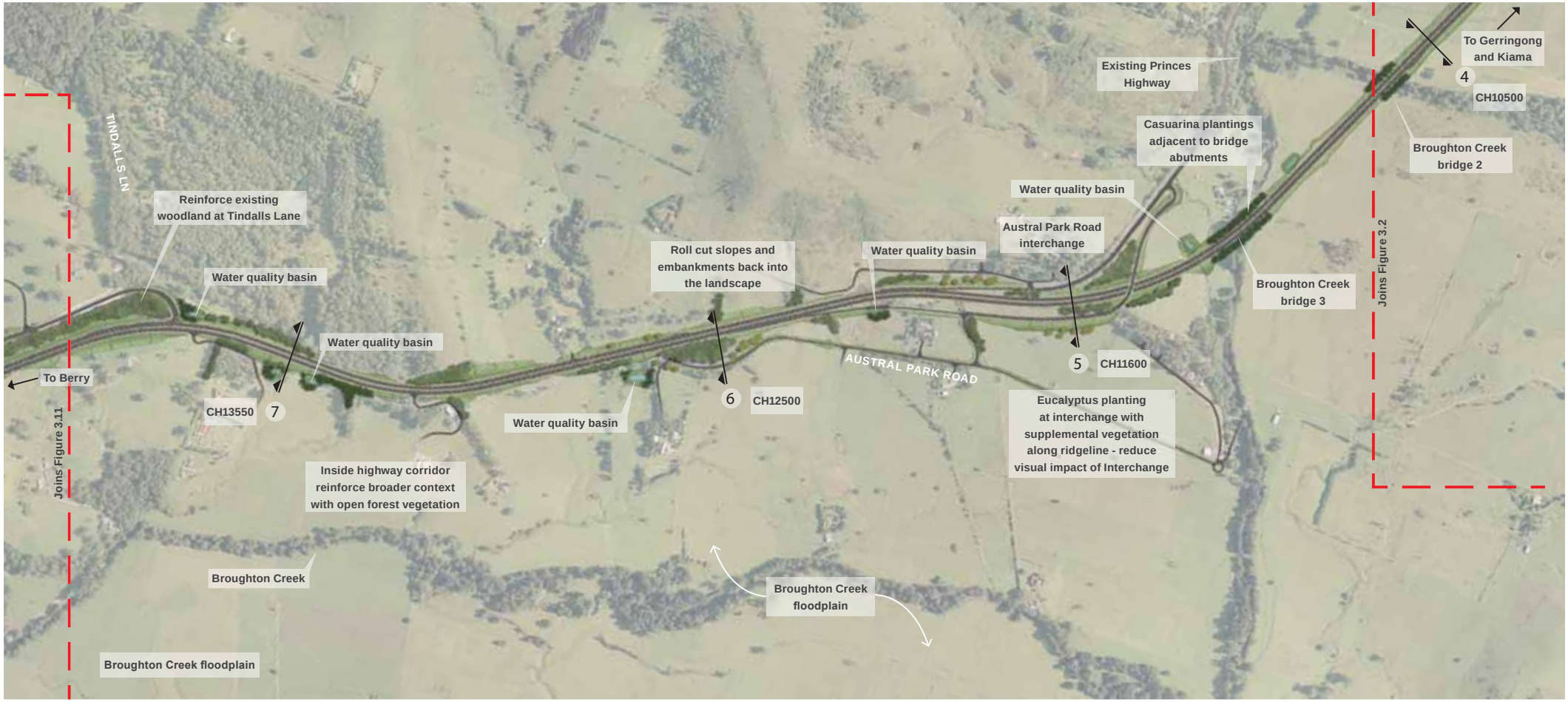


Figure 3.7 Concept for middle section of the project including Broughton Creek and North Berry

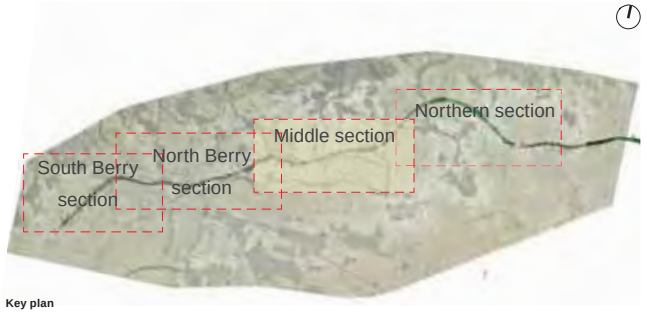
Legend

- Existing Princes Highway
- Proposed road alignment
- Pasture reestablishment to edge on embankments
- Livistonia palm tree (feature)
- Isolated tree plantings Eucalyptus and or Fig Trees
- Eucalyptus trees in forest style planting
- Riparian / Casuarina tree planting
- Water quality basin
- Noise attenuation barrier (indicative extent only)

- 5 Section number 5 at CH 11600
- 6 Section number 6 at CH 12500
- 7 Section number 7 at CH 13550

0 100 200 300 400 500 600

1:8000 metres



Key plan

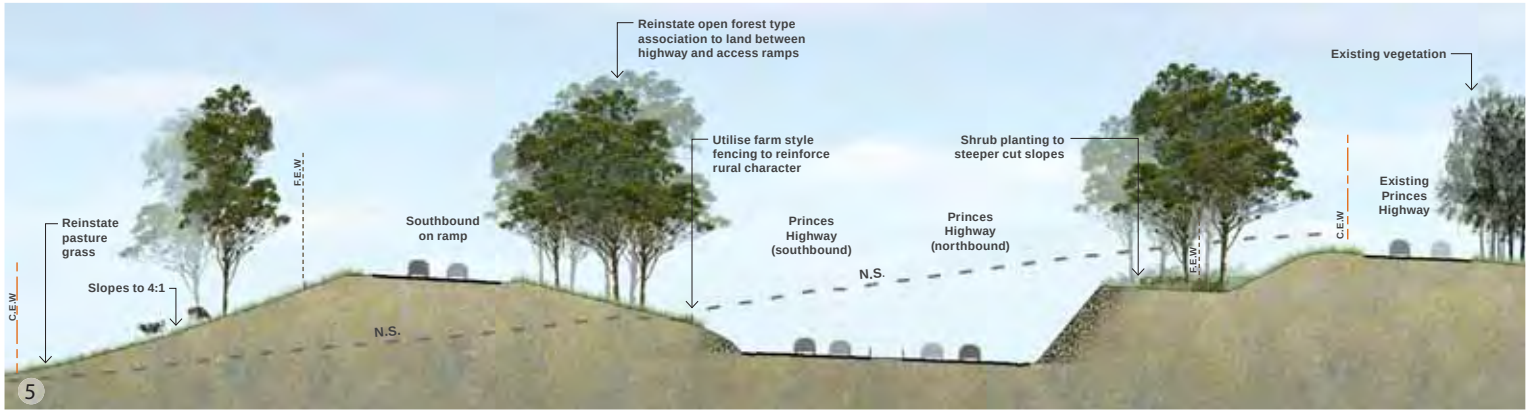


Figure 3.8 Elevation / Section 5 - North Berry - Chainage 11600

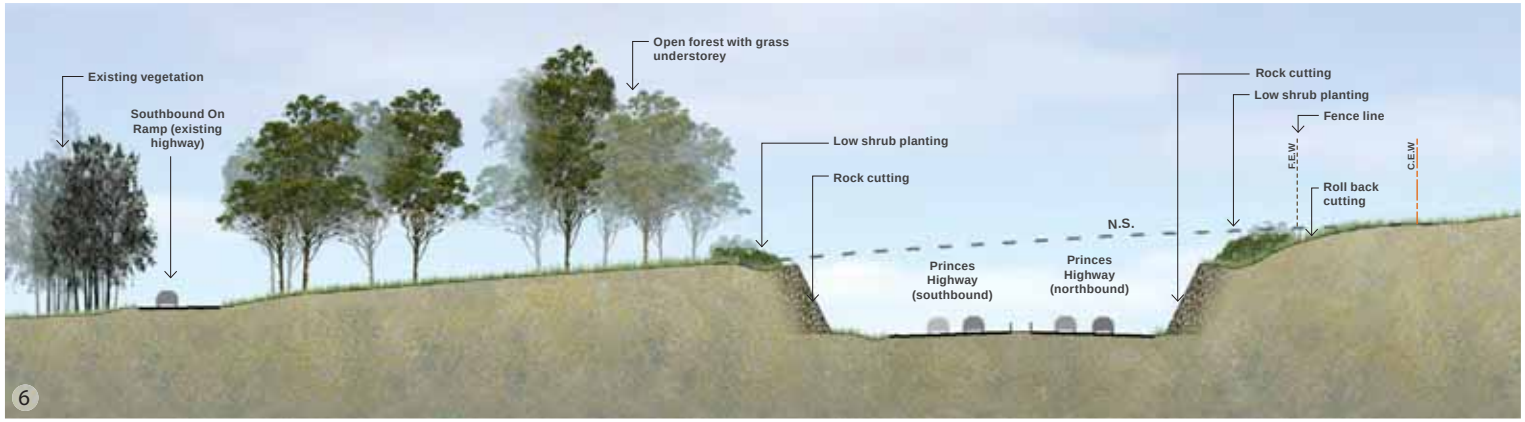


Figure 3.9 Elevation / Section 6 - Broughton Creek - Chainage 12500

Figure 3.10 Elevation / Section 7 - North Berry - chainage 13550

Legend:
N.S. Natural surface
C.E.W Construction extent of works
F.E.W Final extent of works

0 4 8 12 16 20 24 metres

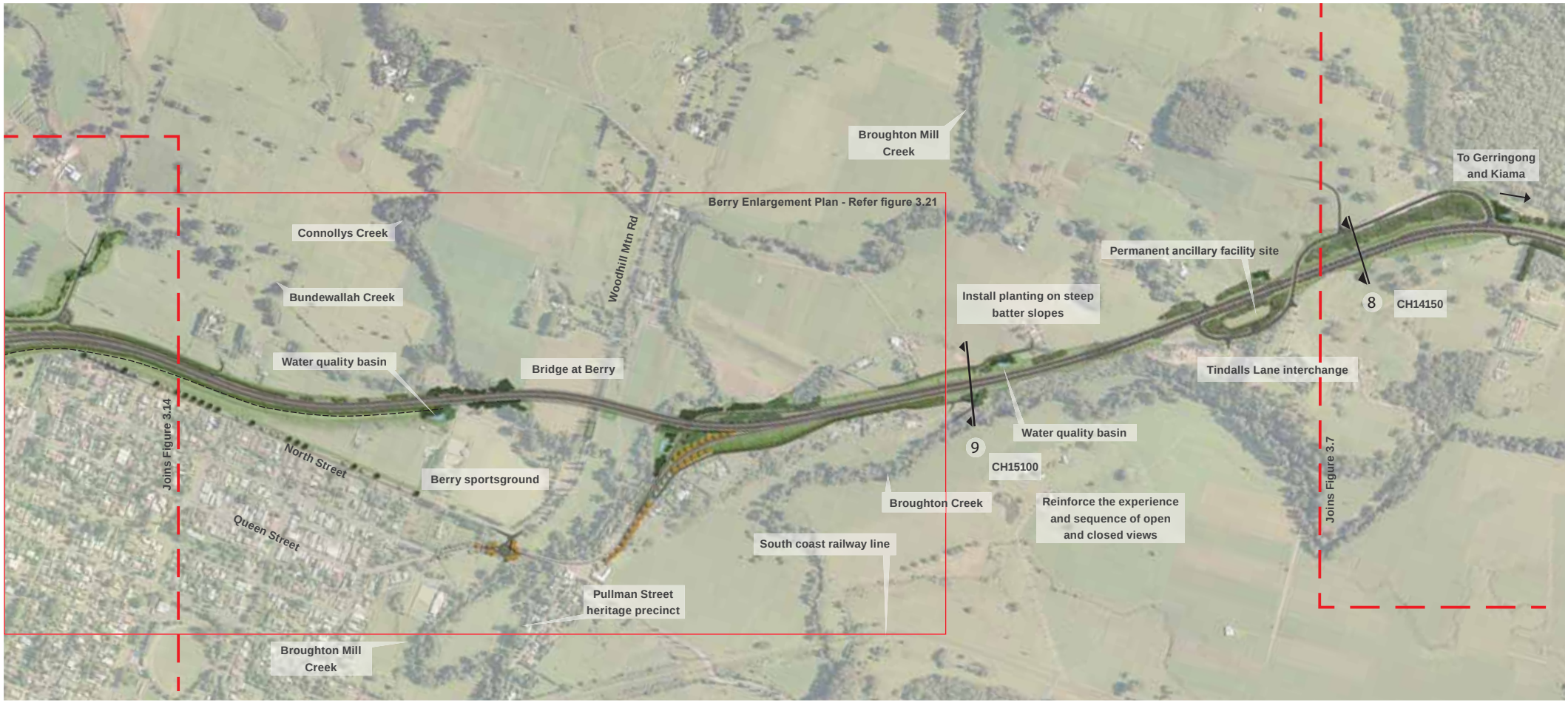


Figure 3.11 Concept for southern section of the project including North Berry and Berry

Legend

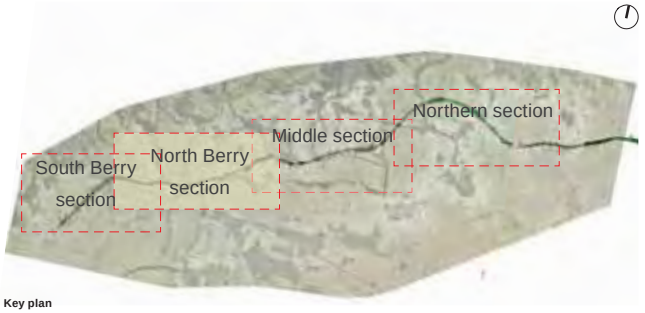
- Existing Princes Highway
- Proposed road alignment
- Pasture reestablishment to edge on embankments
- Livistonia palm tree (feature)
- Isolated tree plantings Eucalyptus and or Fig Trees
- Eucalyptus trees in forest style planting
- Riparian / Casuarina tree planting
- Water quality basin
- Noise attenuation barrier (indicative extent only)

8 Section number 8 at CH 14000

9 Section number 9 at CH 15100

0 100 200 300 400 500 600

1:8000 metres



Key plan

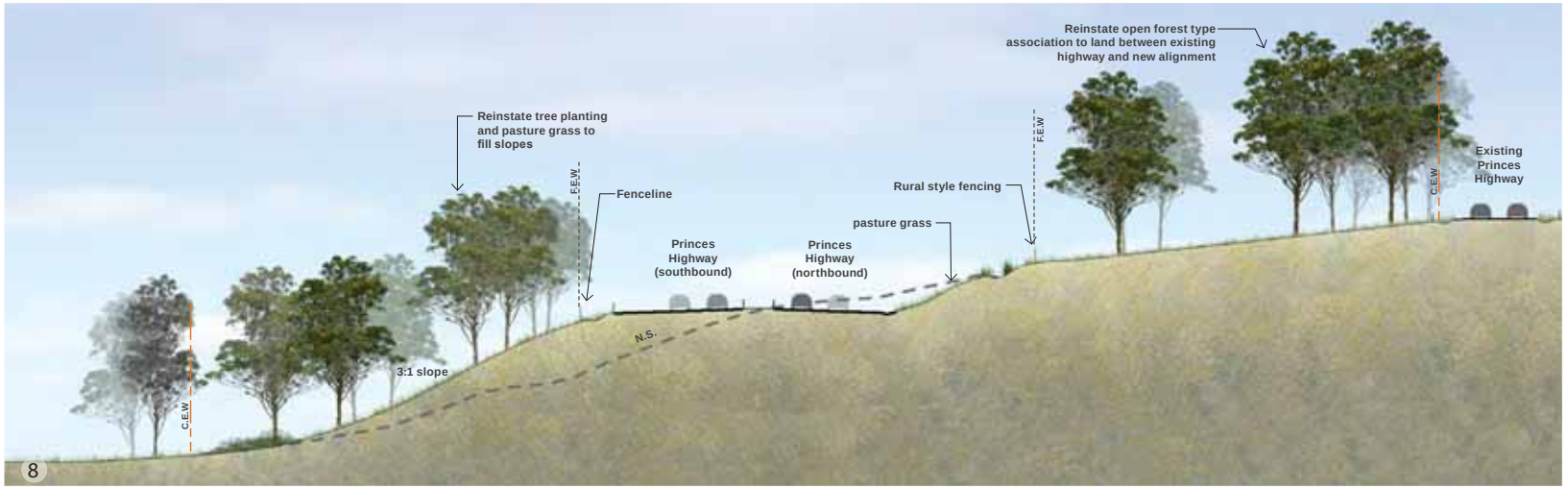


Figure 3.12 Elevation / section 8 - North Berry - chainage 14150

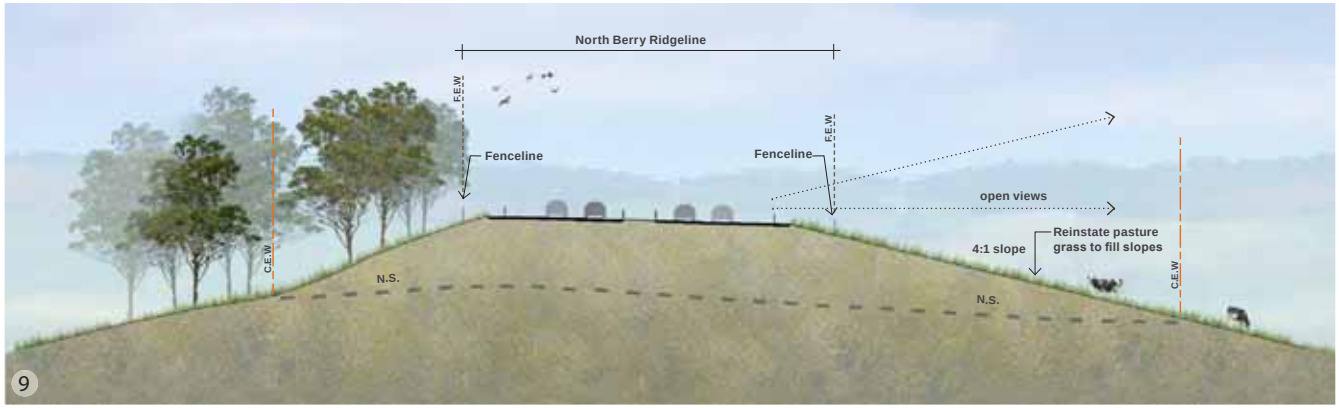


Figure 3.13 Elevation / section 9 -North Berry - chainage 15100

Legend:
N.S. Natural surface
C.E.W Construction extent of works
F.E.W Final extent of works

0 4 8 12 16 20 24 metres

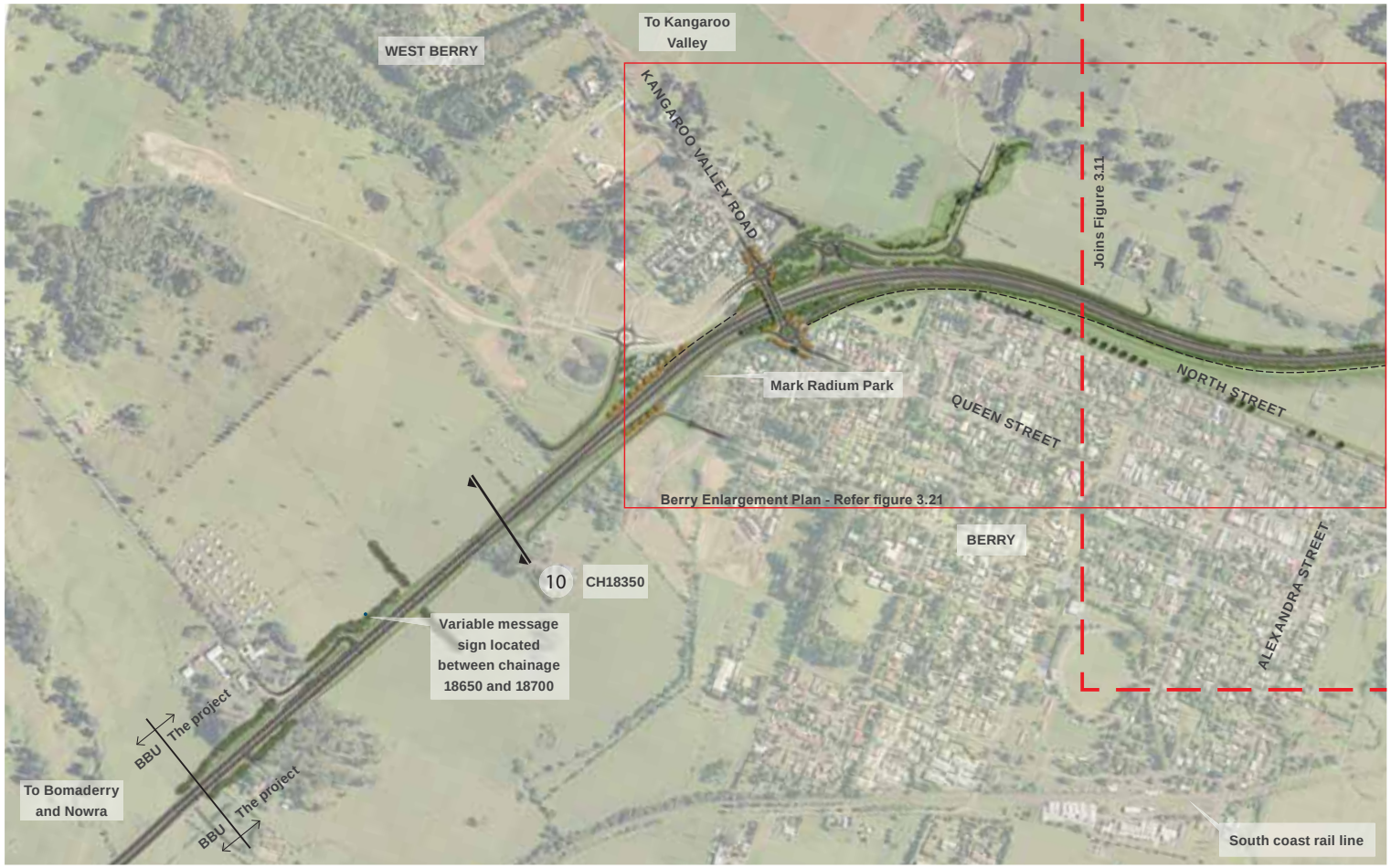


Figure 3.14 Concept for south Berry section of the project including North Berry and Berry

Typical treatment - Fills

The proposed fill treatment (refer **Figure 3.16** and **3.17**) will:

- Maintain consistency with the existing landscape character and patterns.
- Engage road users with the landscape.
- Reduce road width corridor by returning land to its former use.
- Integrate the ultimate road corridor by utilsing larger construction footprint during construction and construct broader flatter batters. Reestablish the adjacent pasture and return to prior use as much as practicable. This would ultimately minimise the apparent road corridor width.
- Reduce total area of maintenance.
- Balance project cut and fills.
- Reduce the perceived carriageway width.

Typical treatment - Cuts

The cut batters would be designed to ensure:

- Shotcrete is not required for stabilisation.
- A sufficient depth of soil is maintained in order to support vegetation.
- Ease of maintenance.

Where unstable rock exists consider:

- Slopes of 3:1 or flatter that can potentially be returned to existing use and/or better integrated within the surrounding landscape character (refer **Figures 3.18** and **3.20**).

Where stable rock exists consider:

- Close to vertical cuttings (refer **Figure 3.19**).
- Leaving room (a minimum of two metres) at the base of the cutting for vegetation (refer **Figure 3.19**).
- Where cuttings are made to include the ultimate widening of the corridor to six lanes the opportunity arises to include additional vegetation at the base of the cutting up until the widening occurs.

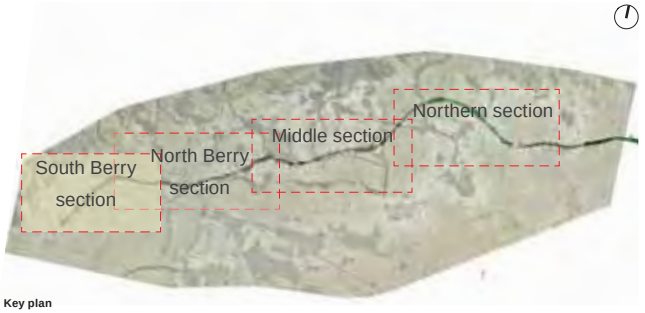
Legend

- Existing Princes Highway
- Proposed road alignment
- Pasture reestablishment to edge on embankments
- Livistonia palm tree (feature)
- Isolated tree plantings Eucalyptus and or Fig Trees
- Eucalyptus trees in forest style planting
- Riparian / Casuarina tree planting
- Water quality basin
- Noise attenuation barrier (indicative extent only)

10 Section number 10 at CH 18100

0 100 200 300 400 500 600

1:8000 metres



Key plan

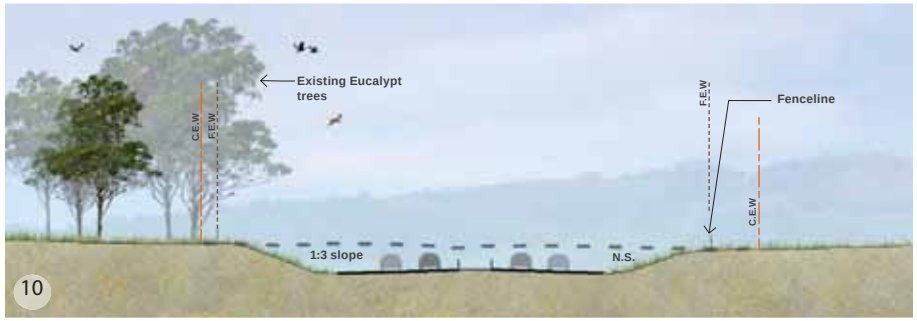


Figure 3.14 Elevation / section 10 - Berry - chainage 18350

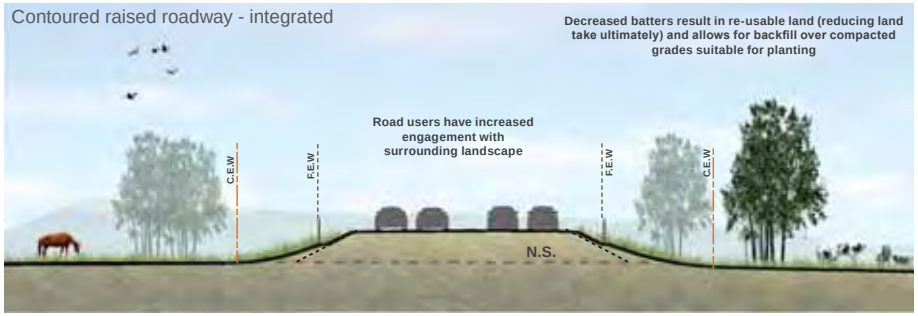


Figure 3.16 Section - Typical corridor approach (fills)

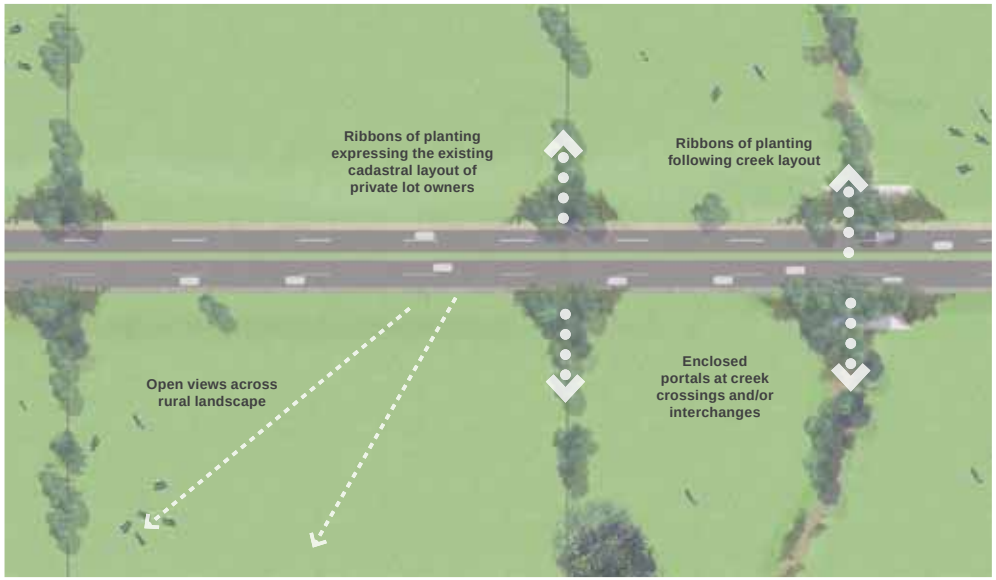


Figure 3.17 Typical corridor approach (fills)

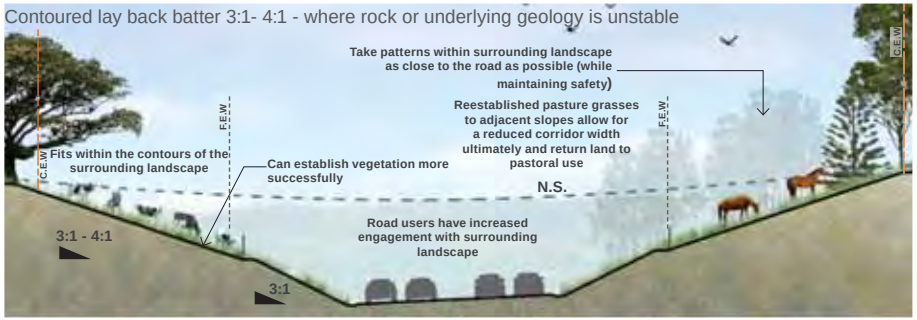


Figure 3.18 Section - Typical corridor approach (cuts)

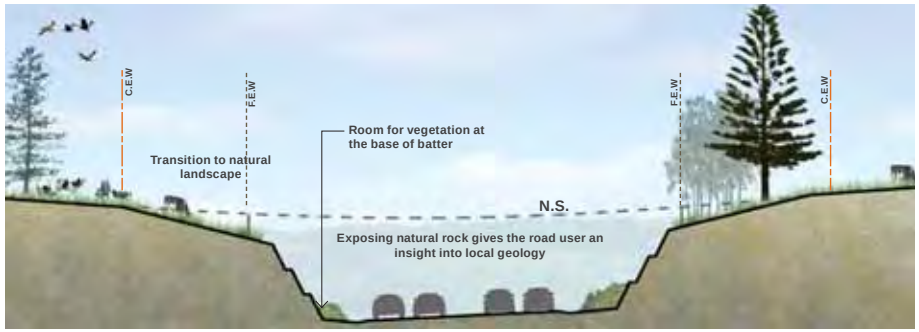


Figure 3.19 Section - rock cut batter 2:1-1:1 - in suitable rock formation

Legend:
N.S. Natural surface
C.E.W Construction extent of works
F.E.W Final extent of works

0 4 8 12 16 20 24 metres

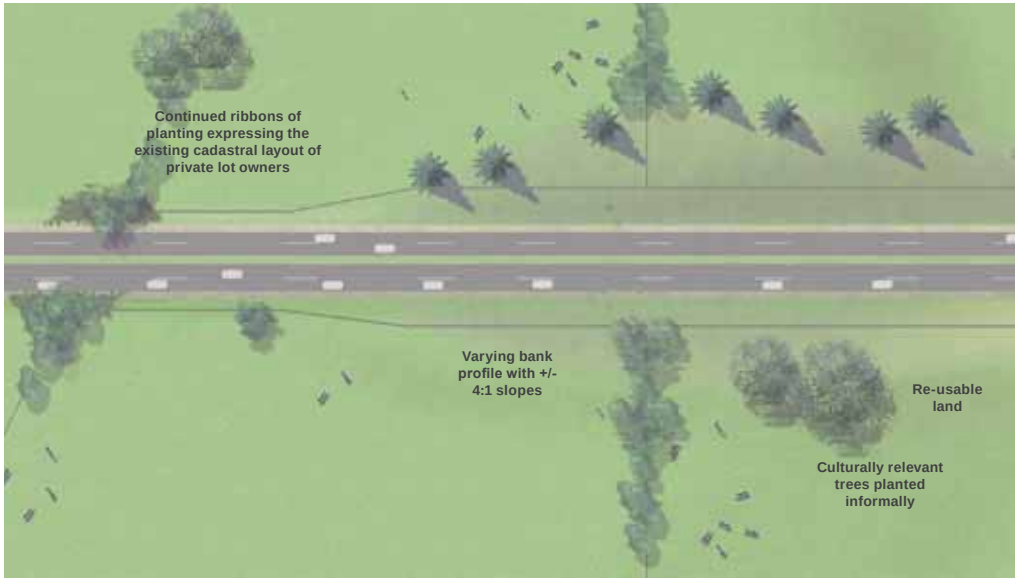
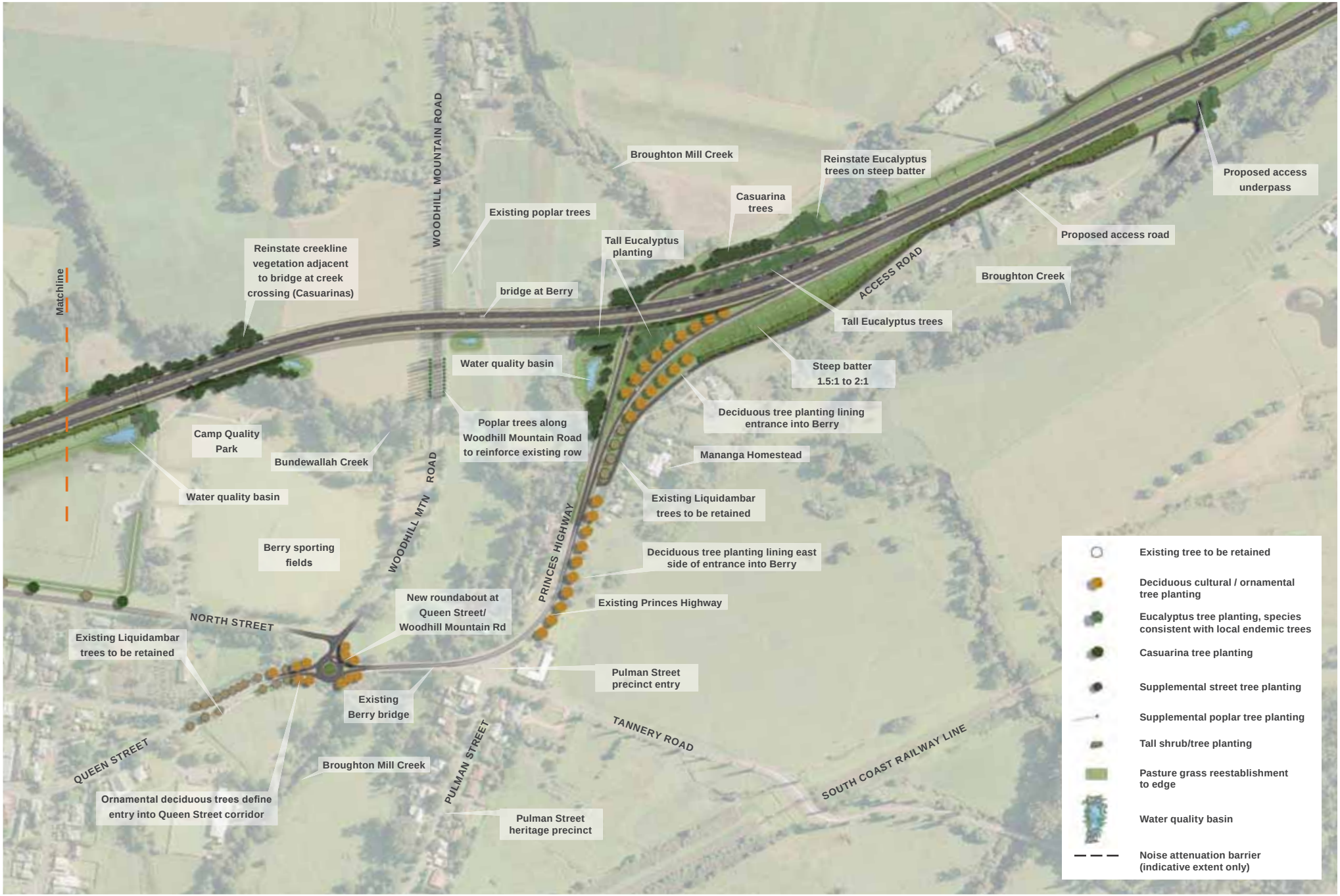


Figure 3.20 Typical corridor approach (cuts)

Figure 3.21 Concept enlargement plan - Berry township


WOODHILL MOUNTAIN ROAD
Broughton Mill Creek
Reinstate Eucalyptus trees on steep batter
Proposed access underpass
Existing poplar trees
Casuarina trees
Tall Eucalyptus planting
Proposed access road
Reinstate creekline vegetation adjacent to bridge at creek crossing (Casuarinas)
Matchline
bridge at Berry
ACCESS ROAD
Broughton Creek
Tall Eucalyptus trees
Water quality basin
Steep batter 1.5:1 to 2:1
Deciduous tree planting lining entrance into Berry
Poplar trees along Woodhill Mountain Road to reinforce existing row
Camp Quality Park
Bundewallah Creek
WOODHILL MTN ROAD
Mananga Homestead
Water quality basin
Existing Liquidambar trees to be retained
PRINCES HIGHWAY
Berry sporting fields
Deciduous tree planting lining east side of entrance into Berry
New roundabout at Queen Street/ Woodhill Mountain Rd
Existing Princes Highway
NORTH STREET
Existing Liquidambar trees to be retained
Pulman Street precinct entry
Existing Berry bridge
TANNERY ROAD
QUEEN STREET
PULMAN STREET
Broughton Mill Creek
SOUTH COAST RAILWAY LINE
Ornamental deciduous trees define entry into Queen Street corridor
Pulman Street heritage precinct
Existing tree to be retained
Deciduous cultural / ornamental tree planting
Eucalyptus tree planting, species consistent with local endemic trees
Casuarina tree planting
Supplemental street tree planting
Supplemental poplar tree planting
Tall shrub/tree planting
Pasture grass reestablishment to edge
Water quality basin
Noise attenuation barrier (indicative extent only)
1:4,000
metres
0 20 40 80 120 160 200 240

4

Urban and landscape design strategy

4 Urban and landscape design strategy

4.1 Urban and landscape design process

Urban and landscape design objectives/issues and the goal of reducing visual impacts have been integral to the design process at all stages of the project to date and the development of the concept design has been continually assessed against these urban design objectives. A 'Gerringong to Bomaderry Princes Highway Upgrade Preliminary Urban and Regional Design Strategy' was prepared by AECOM in November 2007 prior to the identification of route options. This report informed the development of route options and the preferred option selection process.

This assessment was refined based on the:

- Urban design objectives and principles for the project study area as described in **Section 2.0.**
- Contextual analysis (based on landscape character units) of the project study area as described in **Section 5.0**.
- Landscape character and visual impact assessment and suggested mitigation measures (based on landscape character units and view shed analysis) of the project study area as described in **Section 6.0.**

4.2 Urban and landscape design assessment

The table shown in the following pages provide an assessment of the proposed concept design route against the urban design objectives and principles, and the design responses to that ongoing assessment.

Table 4.1 - Design assessment

Objective one **Provide a flowing highway alignment that is responsive and integrated with the landscape**		
	Design principles	**Design responses**
1)	Respond to the grain of the landscape, including following the edge of valleys and hills and avoiding disruption of stands of vegetation, both natural and cultural planting.	The project comprises an upgrade, including widening, of the existing highway alignment and new alignment in the vicinity of Toolijooa Ridge and the Broughton Creek floodplain. Some remnant stands of vegetation would be disturbed as part of the project. The creek crossings would impact on the mature stands of River She Oaks *(Casuarina cunninghamiana)* that line the banks. The surrounding landscape has developed around the existing road for more than 80 years therefore the project would impact adjacent stands of cultural vegetation that have evolved over time. The vertical alignment has been designed to improve grades and improve road safety. The landscape topography includes many areas where slopes are greater than 20 per cent and in some locations greater than 30 per cent. This presents a number of challenges to fitting a road with design speeds of 110 kilometres per hour (posted 100 kilometres per hour). Nevertheless, the road generally responds to the natural grain of the landscape by following the existing contours and utilising the existing road alignment where possible. Essential areas where topography is integrated with the road design include: • The interchanges at Austral Park Road and Tindalls Lane where utilising spurs result in road cuttings allowing for bridge overpasses. • Following the narrow ridgeline down into Berry.
2)	Integrate cut and fill embankments with surrounding terrain by grading out and varying slopes.	Cut and fill embankments would integrate with the adjacent landscape and be assessed at a detail level based on detailed geotechnical survey, slope, aspect and existing adjacent landscape character. Where significant embankments would be required, slopes would be decreased to improve visual and landscape character integration. Excess spoil would be used to soften batter slopes from 2:1 to 4:1 or less where the width of the corridor allows. The ultimate objective is that these flatter batter slopes would be restored to productive pastoral landscape consistent with the existing landscape character.
3)	Consider independently graded carriageways.	Independent grading of carriageways has been reviewed and the benefits to be gained are negligible. Generally, the nature of the landform through which the project passes does not require the consideration of independently graded carriageways.
4)	Preserve cultural patterns in the landscape.	The project alignment would minimise the long term impacts on productive land through appropriate earthworks and revegetation to essentially preserve the existing cultural patterns. This would be achieved by reinforcing the patterns of the broader landscape context. The use of cultural and local endemic species would be used to complement and reinforce existing landscape character.
5)	Avoid as much as possible impact to significant features of the areas through which the alignment passes.	The impact on significant landscape and landform features would be minimised as far as practicable without compromising road safety. The project would impact existing properties along the route (how they presently function and operate). The steep gradients and slopes in the vicinity of Toolijooa Ridge would necessitate the construction of a substantial cutting. The bridge to the north of Berry, while being a significant intervention, has been located to avoid severing the town's sporting facilities from the town centre. Along the North Street corridor, the strong visual and physical connection between the rural landscape (the foreground pastoral landscape and the background ridges and escarpments) and the townscape would be impacted. The project also aims to maximise the connectivity of west Berry to Queen Street along Kangaroo Valley Road with a 21 metre wide bridge over the proposed highway that would include space for a 3 metre wide shared path.
6)	Vary the gradient of the earthworks to provide visual interest and reflect the characteristics of the surrounding landform and landscape.	Earthworks would be integrated by incorporating where possible the opportunities and constraints identified by the geotechnical investigations. A number of embankment strategies have been developed including: • The increase in usability of pasture land adjacent to the road and integration of the highway with the surrounding landscape. • Reducing the visual impact of cuttings and embankments by introducing planting to the base and top of new batters where practicable. • Where corridor width permits and excess spoil is being generated, embankment widths would be increased to tie back into the existing landform.
7)	Grade out cuttings and embankments, wherever practicable, to best fit the characteristics of the local landform, returning the land to either its former use or replacing vegetation lost to the highway upgrade.	Cuttings and embankments would be graded to integrate with the local landform, land coverage and land use. Areas of vegetation lost would be reinstated, where possible. It is expected that there would be a large surplus of material resulting from the cutting at Toolijooa Ridge. To minimise this surplus it is proposed that some of that material be utilised to significantly soften the large (up to sixteen metres) 2:1 embankment to the west of Toolijooa Ridge. This land could then be reinstated to rural pasture blending in with the existing landscape more sympathetically. This would have no detrimental impact on the existing drainage patterns.

Objective two Protect the natural systems and ecology of the corridor		
	Design principles	**Design responses**
1)	Avoid areas of natural vegetation, particularly those containing threatened species and communities.	Much of the landscape surrounding the project has been cleared for agricultural purposes. Some of the remaining vegetation within the current road reserve would be impacted during construction. Impact to threatened species and communities would be minimised and any natural vegetation removed would be replaced and rehabilitated where possible. The most significant impact to existing vegetation would be at the creek crossing points and in the vicinity of Austral Park Road.
2)	Minimise disruption to natural drainage patterns both through route selection and road design.	Existing drainage systems would be retained and improved where appropriate. Upgraded and new crossings of Broughton Creek, Bundewallah Creek, and Broughton Mill Creek would be designed to minimise potential impacts on the existing drainage patterns. It is proposed that Town Creek would be diverted into Bundewallah Creek allowing for the bypass alignment to be lowered in the vicinity of North Street.
3)	Minimise the number of crossings of Broughton Creek and other creeks in the study area.	There are a total of five creek crossings within the study area. These include three crossings of Broughton Creek, one crossing of Broughton Mill Creek, and one crossing of Bundewallah Creek. All of these crossings are unavoidable as much of the proposed corridor runs through floodplain and natural drainage corridors. Broughton Creek meanders back and forth across the upper catchment resulting in the requirement for three crossing points.
4)	Use medians and road verges to maximise habitat value and maintain pollination paths and wildlife movement patterns where feasible.	The proposed planting areas include the embankments associated with new interchanges, and new embankments along the project and ribbon planting along property boundaries and waterways. The first crossing of Broughton Creek is a potential fauna movement corridor. Reinforcement of planting at this location would be considered in the detailed design phase of the project. Planting would also be carried out at the base of new cuttings where possible. Median widths are not sufficient to support planting of any major significance or scale. To reduce ongoing maintenance and occupational health and safety issues the median would be concrete pavement.
5)	Integrate the landscape qualities and characteristics of the highway corridor with the landscape form and character.	The project would pass through four landscape character unit types. These differ in topography, vegetation type, land use, land form and overall landscape character. The highway corridor would reflect and respond to the differences in these landscape units and their associated patterns. The four landscape units are: • Toolijooa Ridge. • Broughton Creek. • North Berry. • Berry.
6)	Integrate water quality basins with the landscape form and character.	Water quality basins would be integrated into the landscape to best represent how water bodies appear within the natural landscape. Design may consist of organic shapes, a low profile form by reducing steep batters, placing naturalistic objects in and around the basins and planting throughout the basins with native grass and ephemeral plant species. The detailed design would develop a mix of swale and basins for the treatment of runoff from the carriageway.

Objective three Protect and enhance the heritage and cultural values of the corridor		
	Design principles	**Design responses**
1)	Avoid items of identified European and Aboriginal heritage and cultural value.	Consultation in regard to Aboriginal heritage is ongoing. The cutting at Toolijooa Ridge has the potential to impact on both Aboriginal and European cultural and heritage items. Another area of European heritage where there are potential impacts from the project is at the intersection of Pullman Street and Queen Street at the entrance into Berry. These impacts have largely been avoided during the route selection process and any remnant impacts associated with the introduction of a roundabout at Tannery Road would be minor.
2)	Acknowledge and respond to the heritage and cultural values of the rural landscape.	Important values and connections to the cultural landscape would be maintained by using a range of strategies including: • Ribbon planting to emphasise property boundaries and waterways. • Reestablishment of pasture grasses. • Use of culturally relevant trees. • Reinstatement of rural fencing.
3)	Acknowledge and respond to indigenous value placed on the broader landscape.	The design would consider the recommendations of the heritage consultant and the outcomes of ongoing consultation with the Aboriginal community.
4)	Reduce the visual and noise impact of the highway through the design of the project.	Visual and noise impact to local residents may be significant for: • Isolated residences along the corridor. • The residents of Berry, particularly in the vicinity of the North Street corridor, the west end of Berry (between Queen Street and North Street) and Huntingdale Park Estate to the west of the proposed bypass of Berry. The alignment adjacent to the most populated section of Berry would be elevated for some of its length, up to two metres above existing grades at the western abutment of the bridge at Berry before a transition into cut underneath Kangaroo Valley Road. Detailed community engagement has been undertaken throughout the concept design. Feedback from a series of community working groups, focused on the development of the urban design treament along the North Street corridor has informed the design of the project and its interaction with its surroundings in this area. The inclusion of earth embankments and different noise wall treatments to minimise the visual impacts of the infrastructure in this area and maximise the use of the open space between North Street and the project have been carried through into the concept design (refer Appendix A).
5)	Consider the important value of the productive landscapes.	As the project involves both a widening of the existing alignment and bypasses of Foxground and Berry, it would impact on areas that are presently utilised as productive landscapes. New works would be integrated with the surrounding landscape to maximise the productive use of land (eg. by merging landscaping to the road edge and reducing batter slopes to gradients that would allow for grazing).

Objective four Respect the communities and towns along the highway		
	Design principles	**Design responses**
1)	Minimise the impact of the project on the amenity of residents of Berry.	The impact of the project to the township of Berry would be significant in its magnitude of change. Importantly, the project provides numerous opportunities for the town that could help to counteract identified constraints and / or adverse impacts. The amenity within Queen Street would be greatly enhanced by the removal of through traffic and heavy vehicles in particular. The proposed highway and bridge over Broughton Mill Creek and Woodhill Mountain Road, while large, would generally be obscured by the existing vegetation. The impacts have been greatly reduced through consultation with the community and multiple refinements of the design to reduce the height and scale of the proposed structure. As the project sweeps closer to town at the western end of the North Street corridor, there would be impacts on the existing amenity for residents and some form of noise attenuation would be required. The impact to amenity on the North Street corridor would be minimised by providing a legible circulation system, mounding, and suitable cultural and indigenous planting that would provide a refined pastoral landscape consistent in character with Berry. The longer term connectivity of the older established part of Berry and the newer growing western part of Berry (along Kangaroo Valley Road) has been considered, with the proposed provision of two shared paths over the Kangaroo Valley over bridge, to ensure that existing and future development is well integrated and suitable for pedestrians and cyclists. Residents living in Huntingdale Park Estate would be impacted with the north bound off ramp running immediately in front of Huntingdale Park Road before connecting into Kangaroo Valley Road.
2)	Provide effective and efficient access to Berry.	Connectivity between the project and Berry would be provided at the northern and western ends of town, which have been located and designed to ensure that the internal road structure and hierarchy of the township remains unaltered.
3)	Design new town access points as an important and integral part of the town, ensuring a clear and consistent way finding.	The new town access points would include landscaping and planting that is consistent with the existing landscape character of Berry. At the Berry east interchange, an appropriate relocation of the Alexander David Berry memorial would be considered. The City of Shoalhaven also utilises entry signage that would be considered for relocation. User views from the new access to the north of Berry (travelling southbound) would be restricted by embankments and bridge abutments. The Berry west interchange access to the town would be located in flatter terrain and the view of the township would be more evident than from the northern entrance. A self explanatory landscape environment would allow road users to transition from the highway into town in a legible and safe way. Generous landscape gestures and pedestrian and cycle integration would be integrated into this transitional landscape and road environment.
4)	Minimise the disruption and loss of amenity to rural communities in the study area.	There would be a range of loss of amenity to rural communities and residents depending on their proximity to the project. Access points would be provided at Austral Park Road and Tindalls Lane. The revegetation strategy would provide a balance of visual screening and reinforcement of the existing landscape character to minimise any loss of amenity.

Objective five Provide a safe, enjoyable and interesting highway with strong visual connections to the Pacific Ocean, immediate hinterland and mountains to the west		
	Design principles	**Design responses**
1)	Acknowledge the role of this section of Princes Highway as an important part of a longer scenic drive along the New South Wales South Coast.	The project has a visual connection to the ocean, township, rural land and forested escarpment. The visual experience shifts in this section from the dramatic coastal engagement seen further north, to the rural and rolling pastoral landscape. The urban design strategy takes advantage of this by maximising broader views, integrating the project with the existing landscape and using planting and design techniques for infrastructure that are culturally and visually relevant within the landscape context.
2)	Maximise opportunities for high quality and varied views of the coast, the rural landscape and adjacent mountain ranges.	The project would increase the opportunities for experiencing the coast, rural landscape and adjacent mountain ranges by opening up views across the rural landscape towards the Broughton Creek and Broughton Mill Creek catchments, the Toolijooa Ridge landscape, the coast (travelling north bound through Toolijooa Ridge) and the forested escarpment of the Cambewarra range. There would be a dramatic transition travelling southbound through the Toolijooa cutting and into the Broughton Creek landscape. Views to the ridges and escarpment specifically at the west end of North Street in Berry, would be impacted.
3)	Provide visual connections and easy, well marked access to the towns along the route.	The project locates the new southbound entrance (at the Northern Interchange) approximately 650 metres north of the existing entrance into the town. Visually the connection is difficult as the access (southbound off ramp) is in a cut on the ridge. The access would take users into the heritage precinct of Berry and to the main commercial centre along Queen Street. The second south bound exit would be at Kangaroo Valley Road and would have a stronger visual connections to the town with views from the bridge at Berry. Travelling northbound, an easy visual connection would be made with the township as the built form areas would be evident on both the eastern and western sides of the highway. The topography in this vicinity is generally flat to gently undulating.
4)	Use landscape treatments to soften the appearance of the road for the road user without compromising opportunities for key views.	The landscape is both a balance of the subtle detail of the foreground rolling open pasture, isolated trees, small forested clumps and tree lined creeks, contrasted against the dramatic escarpment beyond. The landscape treatment would endeavour to reinforce the existing landscape character and allow for the continuing engagement with it. Where possible the landform associated with the road corridor would be blended into the existing landscape. This would be further embellished with planting that is characteristic in form and species of the broader landscape. Around Berry the landscape treatments would embellish the existing landscape qualities and character to assist in integrating the proposed bridge at Berry, and earth mounds, low planting and noise attenuation walls along North Street into the landscape. The important cross connection between the established Berry (Queen Street) and West Berry (Kangaroo Valley Road) would include landscape treatments to reinforce connection and circulation. This would consider the connection at a pedestrian scale ensuring connectivity across the proposed highway.

Objective five Provide a safe, enjoyable and interesting highway with strong visual connections to the Pacific Ocean, immediate hinterland and mountains to the west		
	Design principles	**Design responses**
5)	Consider the heritage of the highway in the project so that where practicable road users may experience it.	Much of the heritage along the project may be experienced by the road user through the broader visual engagement with the landscape. The northern entrance into Berry takes the road user through the heritage precinct consistent with the existing town circulation.

Objective six Develop a simple and unified palette of elements and details that are easily maintained		
	Design principles	**Design responses**
1)	Develop a consistent approach to the design of bridges along the project. Urban design principles to be consistent with those outlined in the 'Bridge Aesthetics: Design Guidelines to Improve the Appearance of Bridges in NSW' (RTA, 2003).	There would be eight bridges associated with the project: • A bridge over the highway at the Toolijooa Road interchange. • Three bridges over Broughton Creek. • A bridge over the highway at the Austral Park Road interchange. • A bridge over the highway at Tindalls Lane interchange. • A large bridge north of Berry over Broughton Creek and Woodhill Mountain Road. • A bridge over the highway at Kangaroo Valley Road. The above would consist of a design family of bridges with their various contextual requirements influencing their individual specific elements. This approach is consistent with the 'Bridge Aesthetics: Design Guidelines to Improve the Appearance of Bridges in NSW' (RTA, 2003). The key driving objectives for the bridges are to make them as simple and elegant as possible to complement their landscape settings. The bridge at Berry would be located in close proximity to the main Berry sports grounds and the existing Camp Quality Park. The alignment and form of the bridge has undergone significant community consultation and design refinement to improve its form and reduce the height and scale of the structure. Careful consideration would be required through detailed design development with regard to the treatment of the bridge elements, particularly the soffits, headstocks, columns and abutments. The Kangaroo Valley Road bridge would serve as the key connection between the eastern side of Berry and the growing western side of Berry. The design of this bridge and adjacent connections onto the highway needs to consider pedestrians and cyclists and the connection into the landscape character of the town. Strategies around planting, lighting and bridge parapet detailing all require an integrated design approach to provide a legible and appropriate design outcome. Minimum design reference requirements would be provided (refer to **Section 7.0**) to ensure commitment to a quality design outcome for: • The overpass at Toolijooa Road. • The three Broughton Creek bridges. • The over bridges at Austral Park Road and Tindalls Lane. • The bridge at Berry. • The Kangaroo Valley Road interchange.

Objective six Develop a simple and unified palette of elements and details that are easily maintained		
	Design principles	**Design responses**
2)	Develop a consistent approach to the design of noise walls along the project. Urban design principles to be consistent with those outlined in the 'Noise Wall Design Guidelines: Design Guidelines to Improve the Appearance of Noise Walls in NSW' (RMS 2006).	Earth mounds, planting, and noise attenuation walls would be integrated as required particularly along the interface of the project with the township of Berry and in the vicinity of Huntingdale Park Road. Planting would be included to screen these elements where appropriate. This would be further addressed in the detailed design stage. A set of detailed design objectives is outlined in **Section 7.0**.
3)	Develop an integrated strategy for the avoidance, minimisation and improved appearance of shotcrete as outlined in the 'Shotcrete Design Guidelines: Design Guidelines to Avoid, Minimise and Improve the Appearance of Shotcrete' (RTA 2005).	A detailed geotechnical investigation would be undertaken during detailed design to investigate the need for shotcrete and minimise its use where possible.
4)	Develop a consistent approach to the design of soft landscape along the project. Planting design principles to be consistent with those outlined in the 'Landscape Guideline: Landscape Design and Maintenance Guidelines to Improve the Quality, Safety and Cost Effectiveness of Road Corridor Planting and Seeding' (RTA, 2008).	The project would include soft landscaping at the new interchanges, along embankments and at property boundaries and creek crossings, as well as along the project alignment where appropriate. The project would not pass through any large stands of existing vegetation, as the majority of the landscape consists of pasture lands with isolated clumps of either remnant or historic cultural planting. The soft landscaping approach would draw from this existing landscape character blending the new infrastructure with that character. A significant part of the soft landscape will be the reestablishment of pasture grasses disturbed during the construction of the project.

5

Contextual and landscape character analysis

5 Contextual and landscape character analysis

5.1 Regional context

The Princes Highway is the main north-south corridor between Sydney (the Illawarra and the South Coast of NSW) through to Victoria. It is a critical link for both passenger and freight transport and is a major route for tourism with significant peaks in holiday periods.

5.2 Local context

The project is located west of Gerringong, between the intersection of the Princes Highway and Toolijooa Road, and the intersection of the Princes Highway and Mullers Lane, south of Berry. The project traverses Toolijooa Ridge, Foxground bypass, crosses Broughton Creek in three locations and bypasses the town of Berry. The project lies partly within the Kiama local government area (LGA) and partly within the Shoalhaven LGA.

The surrounding landscape is strongly influenced both culturally and physically by the dairy industry. This activity has defined the general pattern of vegetation clearance, defined rural boundaries with linear cultural planting and influenced the distribution of rural houses and farm buildings.

The existing highway closely follows the interface between Broughton Creek floodplain and the foothills of the escarpment to the north and west. The landscape includes a number of minor ridge lines that radiate down into the floodplain. This association results in a number of sudden changes in grade from generally flat into slopes equal or greater than 25 per cent. This is reflected in the undulating alignment of the existing highway.

The backdrop is generally a pastoral and agricultural landscape on the flat and gently undulating slopes, punctuated by rows of cultural planting along field boundaries and isolated specimens or clumps of cultural planting. North and west of Broughton Creek and Foxground the terrain becomes steeper with pasture land and open forested slopes becoming more heavily forested.

5.3 Cultural landscape context

Within the study area the combination of the natural and cultural landscape forms a uniquely rich, engaging and tangibly enjoyable experience. This harmonious and attractive character is strongly identified with by local residents and more widely recognised as a key regional asset. The naturally occurring interaction between ocean, beaches and rocky headlands, narrow coastal floodplains, rolling hills and ridges and escarpments has greatly influenced the settlement patterns and land use types. The qualities of this interaction between the natural and cultural landscape are a defining feature for those who live and work within the study area and its broader surrounds. The valleys are verdant green and generally open, the ridges and escarpment enclose the landscape and reinforce its intimate and engaging properties while the trees are generally large and grand in stature. The cultural plantings and farming practices have developed in what appears as a harmonious and balanced way. The existing highway is very much part of this cultural landscape following each of the twists, bends and undulations. The highway also serves as direct access for many residents and has developed and influenced much of the local landscape response.

The significance of this natural and cultural landscape has been widely acknowledged and recorded. Navin Officer Heritage Consultants Pty Ltd (NOHC) prepared the *Foxground and Berry bypass – Princes Highway Upgrade, Cultural Heritage Assessment (Non-Aboriginal) Report (NOHC 2011)* which describes in detail the recorded cultural landscape framework. This report defines the broader region, including the project study area, as the Southern Illawarra Coastal Plain and Hinterland Cultural Landscape (SICPHCL). The recording of the landscape values associated with the SICPHCL are listed in **Table 5.1.** Consistent with all of these recordings is the recognition that the region retains a unique, aesthetically balanced and fundamentally nineteenth century pastoral structure.

For the road users there are many experiences and interpretations, the highway reveals a complex and harmonious landscape to its users. The coast and fertile coastal plains are often present in distant views across the rural landscape. There is a sense of prosperity due to the many well-established, stately trees (both indigenous and exotic) planted in both random and more formal arrangements. These create the 'portal' experience of travelling from open landscape with broad views to enclosed tunnel where canopies almost enclose the road corridor, before opening up again. Views also encapsulate the tree covered ridges and escarpments and meandering creeks and rivers that flow into the fertile coastal plains, lakes and wetlands. Creek lines are engaged frequently as the highway closely follows the varying topography.

The study area sits within the coastal hinterland west of Gerringong and Toolijooa Ridge and the floodplain and adjacent slopes of the Broughton and Broughton Mill Creeks. The topography varies from flat to undulating, graduating through to the relatively steep slopes around Toolijooa Ridge and a second ridge north of Berry. Immediately adjacent to the project are strong cultural patterns in the landscape associated with its ownership and agricultural and pastoral land uses.

The assessment of the landscape context is explored by its component parts of topography (slope), water courses, vegetation cover and land use. A visibility analysis has also been undertaken to assess the level of visibility of the project elements.

Table 5.1 - Cultural landscape framework

Southern Illawarra Coastal Plain and Hinterland Cultural Landscape*		
Cultural landscape framework identification	Recording background	Extents
Berry Bolong - Pastoral Landscape*	Defined by the 'Shoalhaven City Council heritage study' (Freeman, P. et al, 1998).	Extends south from the Southern Illawarra Range and includes the landscape between Mt Pleasant to the east, Browns Mountain to the west and Greenwall Point and the Shoalhaven River to the south. Refer **Figure 5.1**
Berry District Landscape Conservation Area*	Defined by the National Trust of NSW.	Refer **Figure 5.1** and **Figure 5.6**
Berry Township Urban Conservation Area (BTUCA)*	Defined by the Shoalhaven City Council heritage study. Listed on the National Trust register in 2011	Refer **Figure 5.1** and **Figure 5.6**

*** Refer to NOHC (2011) Foxground and Berry Bypass – Princes Highway Upgrade Cultural Heritage Assessment (Non Aboriginal) Report for detailed description of the Cultural Landscape Framework Identifications**

Figure 5.1 Cultural landscape conservation areas image provided courtesy of NOHC Pty Ltd (2011)

Legend

- **Visual boundary of the BTUCA***
- **Buffer Zone of the BTUCA**
- **Sub-division Boundary of the BTUCA**
- **Boundary of the Berry Bolong Pastoral Landscape**

* Defines the boundary of the Berry District Landscape Conservation Area

5.3.1 Topography (slope analysis)

There are four main geographic features that have an influence on the landscape character and visual qualities of the study area:

- The first is the Toolijooa Ridge which runs in a north south direction and separates the immediate coastal plain from the upper catchment of Broughton Creek.
- The second and most dominant features are the ridgelines and escarpment of the Cambewarra Range that forms the upper catchment for Broughton, Broughton Mill and Bundewallah Creeks. These ridgelines dominate views to the north, northwest and west within the study area.
- The third, Broughton Creek meanders across the study area from the escarpment in the west, to the Shoalhaven River catchment to the south east of Berry.
- Berry town is situated on the fourth geographic feature, an area of generally flat land, contained to the east and south by the South Coast railway line and pastoral flood prone land to the north. To the west of Berry is a ridge line that follows a valley up the escarpment. The future growth of Berry is almost exclusively to the west along the Kangaroo Valley Road corridor.

Figure 5.2 illustrates the relationship between the project route (in red) and the surrounding topography.

5.3.2 Land use

The main human influence on the landscape within the study area has been the agricultural practices that have occurred since European settlement. During early settlement of the Shoalhaven area, agricultural estates were established on land grants and much of the study area was progressively cleared for agricultural purposes. The predominant form of agriculture since the second half of the nineteenth century has been the dairy industry, resulting in a characteristic landscape of cleared rolling pasture with prominent cultural planting marking farmhouse locations, access roads and property boundaries. Corridors of native vegetation are often retained along drainage lines within the pastureland, while isolated native trees, particularly larger specimens of fig, remnant gum trees and cabbage tree palms, also occur.

Historically, the scale and character of settlement patterns were dependent on the distribution of small dairy farms. The town of Berry developed in response to the growing dairy industry. The settlement pattern today generally conforms to this historical pattern. **Figure 5.3** illustrates the relationship between the project route (in red) and its adjacent land uses.

5.3.3 Vegetation cover

Over time, much of the adjacent land surrounding the project has been cleared for agricultural and pastoral use, resulting in vast areas of grazing land. Extensive areas of native vegetation still remain, generally on the higher ridge lines and steeper slopes and escarpments which are unsuitable for grazing and along the existing drainage lines. Stands of cultural planting define property and fence lines and are particularly prominent as they flow downhill into the valley floors. There are isolated specimens of large gum trees in a number of open paddocks. At Tindalls Lane there is a larger remnant stand of eucalypt forest. When viewed in plan, the vegetation distribution seems sparse, however when viewed from ground level, its scale and size results in an alignment that appears well treed. **Figure 5.4** illustrates the relationship between the project route (in red) and the surrounding vegetation cover.

5.3.4 Water courses

There are four main water courses within the study area. Broughton Creek to the east of Berry and Broughton Mill Creek, Bundewallah Creek and Connollys Creek to the north and west of Berry.

These creeklines are generally well vegetated, dominated by large mature *Casuarina cunninghamiana* (River She Oak). **Figure 5.5** illustrates the relationship between the project route (in red) and the drainage lines/associated tributaries.

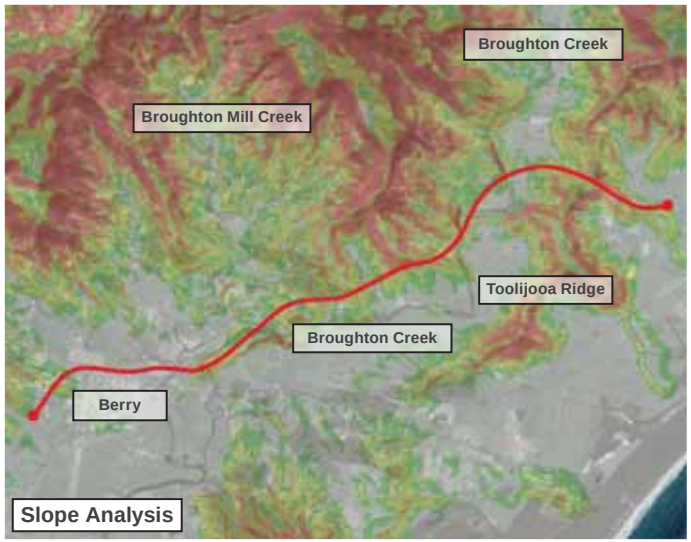


Figure 5.2 - Topography (slope analysis)

The slope analysis clearly illustrates the location of the project in relation to the surrounding topography, including the Upper Broughton Creek catchment between Toolijooa Ridge and the Cambewarra Range (ridges and escarpment). Minor ridge lines are also clearly evident fanning out into the Broughton Creek floodplain. The steep slope of Toolijooa Ridge is clearly evident.

Legend
< 5%
5% - 10%
10% - 20%
20% - 30%
+30%

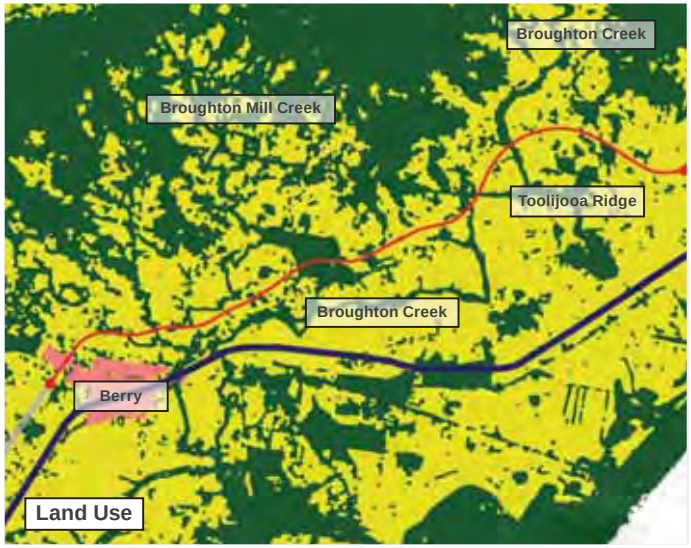


Figure 5.3 - Land use analysis

The land use diagram illustrates the project route traversing mostly farming / agricultural land. Vegetation is distributed chiefly along the drainage corridors or in isolated small clumps.

Legend
Residential/ urban*
Farm / Agricultural
Vegetation
Rail Corridor

* Not including scattered / isolated rural residences

Figure 5.4 - Vegetation cover

Adjacent to the project route vegetation cover is limited and planting consists of a mixture of cultural planting that identifies boundaries and fence lines with remnant River She Oaks defining the main drainage corridors. There are isolated clumps of large Eucalyptus trees on the undulating slopes of the escarpment. To the west and north the forested hills are clearly evident. There are larger stands of vegetation in the vicinity of Tindalls Lane adjacent to the existing highway.

Legend
Vegetation

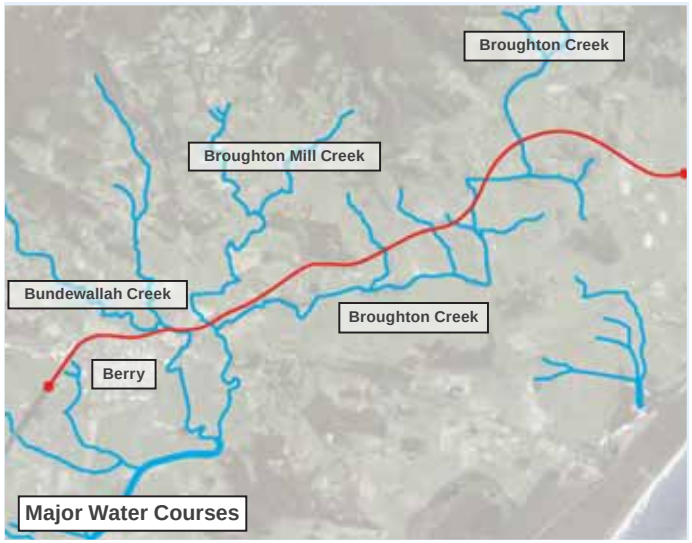


Figure 5.5 -Major water courses

Consistent with the slope analysis, the key drainages are clearly evident moving in a north to south/south-west direction and interacting with the highway in a number of locations.

Legend
Water course

5.4 Built form context

The built form and landscape elements together define the local character of the region. The towns that have developed in support of the farming and dairy industries (and later tourism) have evolved in harmony with the surrounding landscape.

5.4.1 The Princes Highway

The existing Princes Highway is a significant element in the context of the study area. From Toolijooa Road the highway traverses open landscape and scattered rural residential properties before it enters the urban area of Berry.

5.4.2 Berry township

Berry is located at the southern end of the study area and with its rich heritage it is a very popular stopover point and destination for tourists and travellers.

The town (originally called Broughton Creek) developed as an extension to the rural activities that were occurring in the area. The original township of Berry consists of a number of attractive buildings and quaint shop fronts reflecting the wealth of the surrounding agricultural landscape. More recent development is ongoing to the south and west of the town. Presently the town can be considered as having three component parts, these being:

- Original Berry or the Pullman Street Heritage Precinct.
- Established Berry.
- West Berry, where the majority of future expansion and growth will occur along Kangaroo Valley Road.

Figure 5.7 and 5.8 illustrates these three areas.

Original Berry is a small area occupying a narrow piece of flood free land just upstream of the confluence of Broughton and Broughton Mill creeks.

The street grid that comprises established Berry represents early development patterns with the growth area (west Berry) along Kangaroo Valley consisting of a less rigid development pattern.

The existing Princes Highway runs along established Berry's main street (Queen Street) with the resulting traffic generally creating a negative influence on the amenity of the town centre. Queen Street does however remain the focus of activity in the town both for locals and visitors, with the historic character of the built form largely maintained and a range of boutique stores and stores more typical of a country town occurring.

Berry is a key component of the broader cultural landscape that has been widely recognised and recorded (refer **Table 5.1)**. 'Foxground and Berry Bypass - Princes Highway Upgrade: Cultural Heritage Assessment (Non-Aboriginal) Report' (NOHC, 2011) describes in detail the important cultural landscape items within the BTUCA.

The BTUCA identifies a number of key elements that have strong influence on the landscape and visual character of the region including:

- The rural context of the town.
- The street tree and garden/ park plantings within the town.
- The strong containment of the town's urban footprint and the abrupt boundaries with the adjacent rural landscape.
- The views to the escarpment and rural landscape.
- The views into the town from the surrounding countryside.

The BTUCA outlines three zones:

- A visual boundary that is consistent with the regional boundary of the Berry Bolong District Landscape Conservation Area illustrated in **Figure 5.1.**
- A subdivision boundary defining the 19th century town grid illustrated in **Figure 5.6.**
- A buffer zone which aims to protect the adjacent rural setting of the town's grid **Figure 5.6.**

In general, Berry's character is one of an intimate historic rural town. This strong and well established identity suggests that a bypass of the town should enhance its visitor and resident experience by eliminating through traffic and heavy vehicles from the town centre.

The northern section of Berry is defined by North Street which forms a clear delineation of the northern edge of town, with adjacent rural landscape to the north and sporting grounds to the east. This land is flood prone and has limited the expansion of the town. The North Street corridor is well used by locals connecting the sporting grounds with the town and providing uninterrupted views across the rural landscape to the escarpment beyond.

The South Coast railway line defines the southern edge of Berry with the track line and station forming prominent features. Views south consist of generally flat and flood prone pastureland.

To the north and west the forested ridgelines and escarpment have a prominent visual presence from many locations within the town. They provide a strong connection with the surrounding natural environment influencing the character of the town (particularly that of Queen Street). Views towards the flatter pastureland to the east and south east are generally less prominent from within town, being most evident from the southern and eastern fringes of the town.

5.4.3 Berry township - constraints and potentials

A review of the proposed Berry bypass alignment was undertaken in order to understand the constraints and potentials.

The following bypass constraints have been identified.

- Maintaining escarpment views to the north and west of the town.
- Maintaining east west connection between the established town of Berry and the West Berry area.
- Maintaining farm viability to the north of Berry.
- Noise attenuation requirements being visually dominant.
- Extensive areas of flood prone land, existing drainage patterns and high water table.
- Requirements for bypass user safety (engineering geometry standards) and 1: 100 year flood immunity.
- North Street streetscape integrity.
- Berry township urban integrity and legibility.
- Berry sportsground integration.

These constraints are illustrated in **Figure 5.7**.

The following bypass opportunities have been identified.

- Reducing impact on escarpment views.
- Maximising the east west connection within Berry.
- Minimising impacts on a viable farming property to the north of Berry.
- Minimising the visual prominence of the bypass and noise attenuation measures.
- Minimising the road corridor impacts on creek lines and flood prone land.
- Enhancing the new Berry arrival and departure interchange locations.
- Reinforcing the connectivity of recreational green space.
- Reinforcing the township street grid and North Street integrity.
- Improve the Town Creek flooding during storm events and reduce the frequency of nuisance flooding.

These opportunities are illustrated in **Figure 5.8.**

Figure 5.6 -Berry township buffer zone and sub-division boundary image provided courtesy of NOHC (2011)

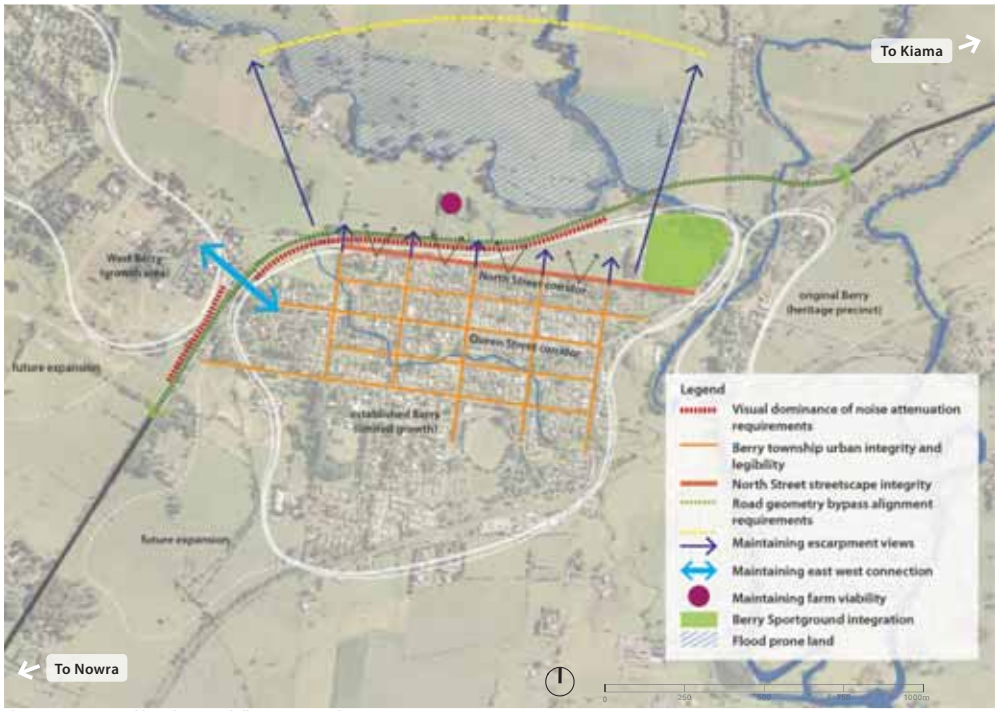


Figure 5.7 -Berry township and proposed alignment constraints

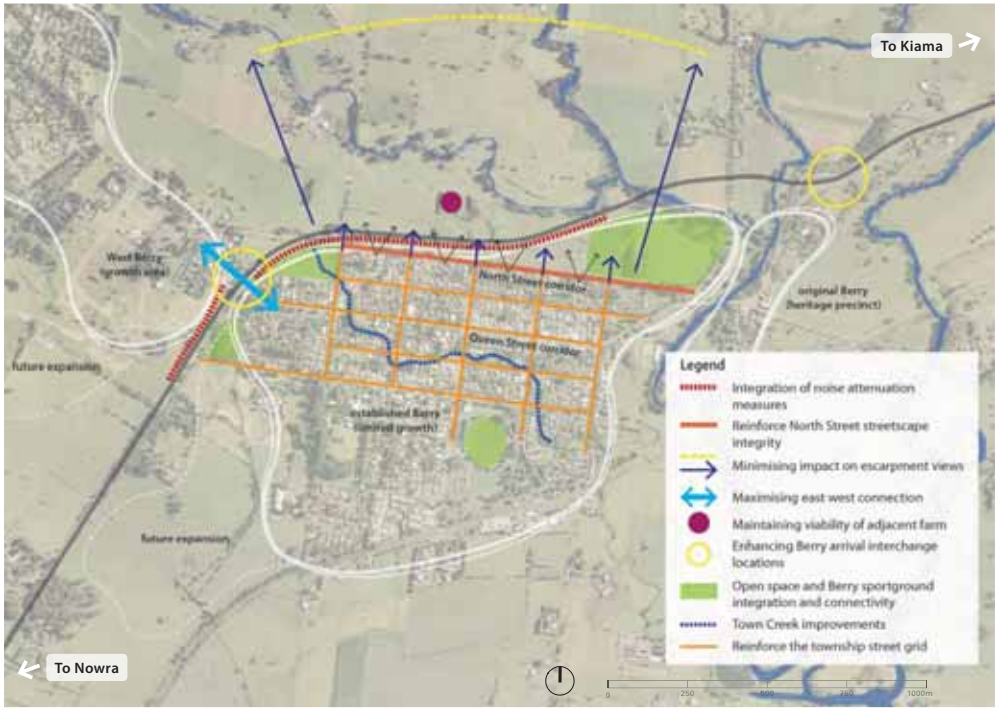


Figure 5.8 -Berry township and proposed alignment opportunities

5.5 Landscape character units

To assist with the assessment process landscape character and visual impact assessment, four landscape character units have been identified within the project study area. These are described below and illustrated in **Figure 5.9** and **5.10.**

1. **Toolijooa Ridge -** At the northern end of the project the prominent Toolijooa Ridge extends south from Currys Mountain. Its landscape consists of a mix of agricultural land and larger tracts of remnant vegetation including some Ecologically Endangered Communities (EECs).
2. **Broughton Creek -** Forms the valley between the western side of Toolijooa Ridge and the east facing lower slopes of the Cambewarra Range. Its landscape is characterised by a harmonious balance of small rural residencies, isolated clumps of native vegetation and cultivated landscapes set within broad open pastoral fields. The main areas of remnant vegetation are located adjacent to Broughton Creek, as illustrated in **Figure 5.11**. The creek banks are populated with mature stately River She Oaks *(Casuarina cunninghamiana)*. Small rural dams also punctuate the landscape and the patterns of land ownership, reinforced by fence lines, access drives and other cultural planting provides an organised element within the landscape. The meandering drainage lines and verdant backdrop combine to provide the experience of a harmonious, nurturing and intimate landscape.
3. **North Berry -** Undulating hills and a ridge line separate the Broughton Creek and Broughton Mill Creek drainages. This landscape is a mosaic of rolling pasture, remnant trees and isolated pockets of forest. The existing trees are large in stature and the terrain changes quickly in terms of steepness of slope and varying aspect. Travelling through this landscape highway users are exposed to a constant interplay between open or sparsely treed paddocks and densely forested stands. There are glimpses across the landscape to both the east and west as the highway encounters the ridge line. As the highway travels south into Berry views become more restricted.
4. **Berry -** The town developed to support rural activities that were occurring within the area. The established section of town occupies the flatter area west of Broughton Creek. Its overall growth has been constricted to the north and south by the limits of flood immunity and to the south east by the railway line which forms a physical barrier. East of this is the much smaller historic heritage precinct or original Berry. To maintain the town's growth, development is occurring on the higher ground along Kangaroo Valley Road to the north west. A detailed description of the town's character is provided within **Section 5.4.2.** A bypass of the main street of Berry was first proposed in 1968 and despite the reduced amenity caused by the current highway alignment the town has thrived. Berry's character is one of a richly diverse rural town. Three clearly identifiable sub-units relating to the project exist within Berry, illustrated in **Figure 5.10,** including:

- **Bridge at Berry -** a proposed bridge over Broughton Mill Creek, Woodhill Mountain Road and Bundewallah Creek (approximately 600 metres in length and up to 20 metres in height).
- **North Street Corridor -** defines the northern extent of the town. The bypass would be sited approximately 90 metres from the eastern end of North Street, approaching to 40 metres, before crossing North Street at its western end.
- **Kangaroo Valley Road interchange -** including a 55 metres long road bridge with associated access ramps into Berry and Huntingdale Estate.

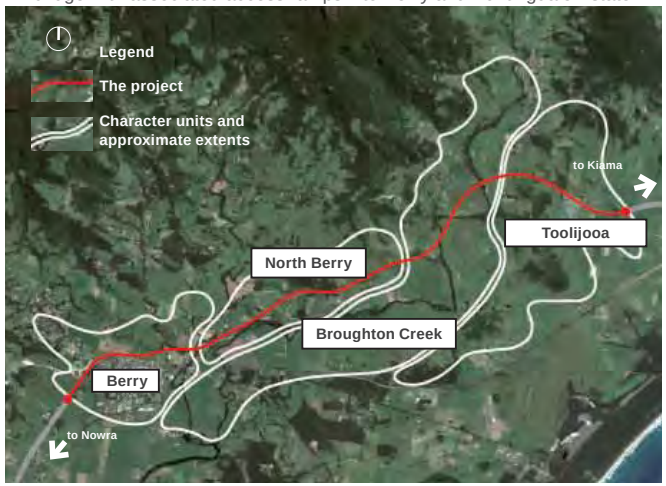


Figure 5.9 - Landscape character units within the Berry Bypass study area

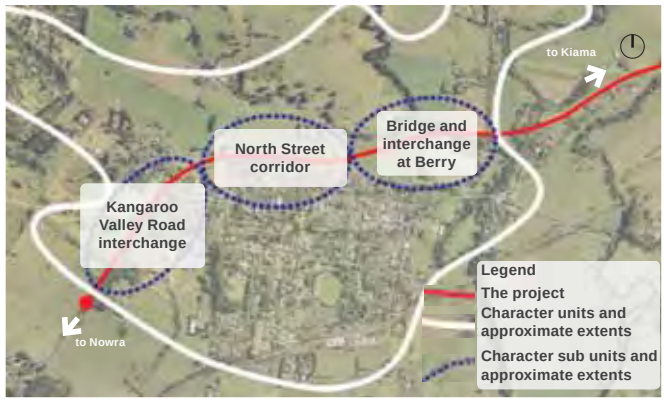


Figure 5.10 - Landscape sub - character units within the Berry landscape unit

5.6 Contextual and landscape character analysis: summary of findings

The key findings from the contextual analysis are:

- Within the study area the combination of the natural and cultural landscape forms a uniquely rich, engaging and tangibly enjoyable experience. This harmonious and attractive character is strongly identified with by local residents and widely recognised as a key regional asset.
- The surrounding landscape is strongly influenced both culturally and physically by the dairy industry. This activity has defined the general pattern of vegetation clearance, defined rural boundaries with linear cultural planting and influenced the distribution of rural houses and farm buildings.
- The nature of the terrain varies significantly between the four landscape character units, from the large extent of steep slope on Toolijooa Ridge, through to the flat floodplain of Broughton Creek, to the quickly changing and variable north Berry slopes and the flatter flood prone land around the northern and western sides of the Berry township.
- Berry is recognised as the first truly rural town south of Sydney and with its rich heritage, it is a very popular stopover point and destination for tourists and travellers.
- Presently the town can be considered as having three component parts, these being:
  - Original Berry or the Pullman Street Heritage Precinct.
  - Established Berry.
  - West Berry, where the majority of future expansion and growth will occur.
- The northern section of Berry is defined by North Street which forms a clear delineation of the northern edge of town, with adjacent rural landscape to the north and sporting grounds to the east. This provides for uninterrupted views across the rural landscape to the ridges and escarpment beyond.
- The existing Princes Highway alignment runs just north of original Berry and along established Berry's main street (Queen Street) with the resulting traffic generally creating a negative influence on the amenity of the town centre.
- The significance of the natural and cultural landscape has been widely acknowledged and recorded. 'The Foxground and Berry Bypass – Princes Highway Upgrade: Cultural Heritage Assessment (Non-Aboriginal) Report' (NOHC, 2011) report describes in detail the recorded cultural landscape framework and history.

- To the north and west, the forested ridgelines and escarpment have a prominent visual presence from many locations along the existing highway and within Berry. They provide a strong connection with the surrounding natural environment influencing the character of the town (particularly that of Queen Street).
- The route constantly interacts with existing creeks and drainage lines with crossings proposed at a number of locations.
- Corridors of native vegetation are often retained along drainage lines within the pastureland, while isolated native trees, particularly larger specimens of fig, remnant gum trees and cabbage tree palms, also occur. There are five dominant tree species which occur along the route. These include:
  - *Ficus macrophylla* (Moreton Bay Fig).
  - *Eucalyptus pilularis* (Blackbutt).
  - *Eucalyptus salignus x botryoides* (Blue Gum).
  - *Casuarina cunninghamiana* (River She Oak).
  - *Livistona australis* (Cabbage Tree Palm).
- The extent of vegetation cover appears much more substantial when experienced from ground level rather than viewed in plan. This is likely due to the scale of the existing trees many of which are mature and greater than 15 metres in height.
- With broad valleys, stately trees and rolling green pasture the landscape reflects a richness and vitality that constantly engages the road user. This is illustrated in **Figure 5.12.**
- The road user also experiences constantly changing open and enclosed views including broad expansive pasture, well vegetated portals and valley tunnels. This is illustrated in **Figures 5.13** and **5.14.**
- The immediate built form context of the route includes a number of small working farms/rural residences and the town of Berry.
- The study area can essentially be broken into four landscape character units, each of which are closely interrelated:
  - Toolijooa Ridge.
  - Broughton Creek.
  - North Berry.
  - Berry.
- Within the Berry landscape character unit three sub-units have been identified:
  - Bridge at Berry.
  - North Street corridor.
  - Kangaroo Valley Road interchange.

Fig Tree - *Ficus macrophylla*

Remnant cabbage tree palms - *Livistona australis*

Remnant existing Eucalyptus specimens

Existing River She Oaks - *Casuarina cunninghamiana*

Figure 5.11 - The dominant creek line vegetation contrasts sharply with the open pasture land across the Broughton Creek floodplain

Figure 5.13 - Remnant areas of closed forest form portals and contrast with long views over pasture

Figure 5.12- The combination of open undulating pasture, cultural planting, creek line vegetation and remnant open and closed forest combines to form an aesthetically pleasing landscape

Figure 5.14 - Open areas of rolling pasture often occurring on slopes greater than 20 per cent

6

Landscape character and visual impact assessment

6 Landscape character and visual impact assessment

6.1 Methodology

The methodology for the landscape character and visual impact assessment is based on the 'Environmental Impact Assessment Guidance Note: Guidelines for Landscape Character and Visual Impact Assessment: EIA-N04' (RTA, 2009b). The impact grading matrix for the relevant levels of impact is illustrated in **Table 6.1.**

The assessment has been divided in two parts, the first is an overall assessment of the project and the second is an assessment of the four key landscape character units. The four landscape character units as described in **Section 5.0** assessment are:

- Toolijooa Ridge.
- Broughton Creek.
- North Berry.
- Berry.

The following methodology was used in assessing landscape character and visual impact for each of those units:

- A description of the project components within each of the four landscape units.
- Assessment of existing landscape character.
- Descriptions of the impacts of the project.
- Description of the visibility of the project.
- Assessment of sensitivity to proposed change.
- Assessment of the magnitude of proposed change.
- The overall assessment of the impact.
- The recommended mitigation strategies.

These are supported by figures that illustrate the following:

- The context of the landscape unit and visual catchment of that landscape unit in relation to the project.
- The existing landscape context of the landscape character unit.
- The project design (generated from the 3D model of the project).

Artist's impressions from a series of selected viewpoints are included illustrating the likely final built outcome including suggested mitigation measures. The artist's impressions are represented with before and after images in **Section 6.7**.

It is assumed that viewers include road users and local residents. All of the visual assessments in the field were taken from publicly accessible land.

The visibility analysis was undertaken using a GIS based view shed analysis. Viewpoints were selected on the basis that they are vantage points or represent concentrations of people. Visual envelope maps were then produced illustrating the area of likely visual impact associated with the project to represent the range of views to the study area, including points both within and outside of the study area. View sheds for each of the selected viewpoints were mapped using GIS to illustrate the overall visual catchment.

6.2 Landscape character and visual assessment: overall project

General

Each landscape character unit is assessed in detail in **Section 6.3** through to **Section 6.6**. The overall ratings for sensitivity to change and magnitude of the proposed change are a consolidation of the detailed findings for each of the landscape units assessed.

Existing landscape character

The immediate study area associated with the project is set within what is widely recognised as a harmonious coastal hinterland/pastoral landscape. The existing landscape is a rich mosaic that balances cultural and natural patterns forming an intimate and engaging experience. The topography varies greatly from flat to undulating graduating through to relatively steep slopes on the west side of Toolijooa Ridge. In the valleys and adjacent to the highway, strong cultural patterns in the landscape associated with ownership and the agricultural and pastoral land use dominate.

Detailed project description

Refer to **Section 3.2** for a detailed description of the project design elements.

Impacts

Interventions associated with the project that would have a landscape character and visual impact on the four landscape character units would include:

- The relative scale of the project, this includes the footprint (width), structures (bridges and overpasses), significant lengths of new alignment and its increased elevation (flood mitigation measure).
- The introduction of large fill embankments and cut slopes.
- The potential for a reduction in amenity for the residents of Berry and west Berry/ Kangaroo Valley Road .
- The potential visual and physical separation for residents of west Berry (along the Kangaroo Valley Road corridor) from established Berry and Queen Street.
- The visual impact of eight new bridges.
- The scale of infrastructure required for the new town access points and access points along the alignment.
- The loss of existing roadside vegetation.

Visibility

Based on the generally open nature of the landscape and the variation in the localised topography, the project is within areas that have medium to high visibility. Visibility and viewer sensitivity to the project and modifications required for the project were analysed from the perspective of assumed viewer groups. These are primarily adjacent rural residents and users of the corridor itself.

Table 6.1 Landscape character and visual impact grading matrix - source RTA (2008)

Potential visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

Sensitivity to proposed change

As discussed in **Section 5.0**, the existing highway and its setting and integration with the existing landscape character are inseparable. The development of the cultural landscape interface at the edges of the existing road has evolved over many years. A large number of residences directly access the highway, many with defined hedge rows, avenue plantings, fencing types and entry gates. Agricultural plots come right up to the road edge in some cases while in others remnant stands of vegetation occupy the thin strips of road verge and in some places completely envelop the highway. These interactions are all important contributors to the overall landscape character and experience of the place, providing immediate detail and framing broader district views.

There is also the need to recognise the greater level of separation that residents along the highway may feel as additional highway width may increase the sense of severance that may exist. The larger, broader experiences would still be evident, including visual engagement with the ridges and escarpments, but the rich detail presently experienced would be reduced in some places.

For Berry the impacts are at the same time positive and negative. The removal of traffic from the centre of town would improve the amenity for residents and town users of Queen Street. The visual impacts for the North Street corridor would be significant on the visual connection to the open pasture land and ridges and escarpment beyond. This is discussed in further detail in **Section 6.7.**

The viewer/user sensitivity (adjacent rural residents and road users) to the proposed change within the area is expected to be medium to high.

Magnitude to proposed change

Closely aligned with the impacts on the sensitivity of the place to proposed change, the impacts from the magnitude of the change generated by the project would be significant. The magnitude of upgrading from a two lane highway with a speed limit of 80 kilometres per hour to a four lane highway with central median and a speed limit of 100 kilometres per hour requires significantly more footprint than the existing highway. Much of the intimate landscape interactions presently experienced in the vicinity of the highway (by both residents and road users) would be either lost or greatly modified.

The scale of the upgraded highway would result in changes to residents' interactions with the highway from day to day direct highway access, agricultural operations and neighbourly connectivity, to larger scale physical relationship with alterations including potential house relocation, internal property circulation, cultural planting and visual outlook.

There is also the need to consider the likely timeframes for construction and the requirement for ancillary facilities during the construction period, which are all likely to add to the magnitude of change, especially in the short term.

Assessment of impact

The overall impact assessment was based on the average assessments completed for each of the four landscape character units:

- Toolijooa Ridge.
- Broughton Creek.
- North Berry.
- Berry, which includes the sub units of:
  - The bridge at Berry.
  - North Street corridor.
  - Kangaroo Valley Road interchange.

The impacts are summarised in **Table 6.2**.

For the detailed assessment of each of these impacts, refer to **Section 6.3** through to **Section 6.6**.

Based on the overall scale of the proposed intervention and the relative distance that the majority of users would experience these interventions from, the overall impact is rated as high to moderate.

Overall rating - High to Moderate.

Mitigation strategy

The recommended mitigation strategies to minimise impacts to the landscape and visual character of the project include:

- Minimise the apparent width of the corridor through reinforcement of the existing landscape patterns and integration of the project with the existing landscape context.
- Integrate new vegetation with the existing landscape character and vegetation communities.
- Ensure that the appropriate footprint is developed as part of the project, including consideration of the construction footprint versus the final footprint.
- Integrate large fill embankments and cut slopes through reestablishing pasture grasses and culturally relevant planting.
- Define minimum design standards for the bridge structures.
- Engage adjacent land owners and community groups in assessing whether early works mitigation (eg.; landscape planting) can be achieved to help soften or decrease likely impacts of the project.

Table 6.2 Landscape and visual impact summary table

Potential landscape and visual impact summary table				
Category	Character unit			
	Toolijooa Ridge	Broughton Creek	North Berry	Berry
Sensitivity	High to Moderate impact	High to moderate impact	High to moderate impact	High to Moderate impact
Magnitude	Moderate impact	High to moderate impact	High to moderate impact	High impact
Overall	High to Moderate impact	High to moderate impact	High to moderate impact	High impact
Overall (All units)	High to moderate impact			

6.3 Landscape character and visual impact analysis - Toolijooa Ridge

Existing landscape character

Travelling south west from Gerringong, the open pastoral landscape extends to the north and south of the existing highway which makes its way along an eastern spur of Toolijooa Ridge. Here the ridge contains the view and separates the coastal plain from Broughton Creek further to the west. There are isolated clumps of trees on steeper slopes separated by rolling pasture grasses. A small number of rural residences are located mostly to the north of the existing highway.

Project components

The project includes the continuation of the Gerringong upgrade two lane dual carriageway and involves the following components within the Toolijooa Ridge landscape character unit:

- A new alignment through Toolijooa Ridge for a separated dual carriageway.
- A new over bridge at Toolijooa Road.
- Large cut batters through Toolijooa Ridge (up to 25 metres in depth).
- Allowance for northbound and southbound climbing lanes.
- A northbound climbing lane from Broughton Creek.

Impacts

Interventions associated with the project that would have a landscape character and visual impact on the Toolijooa Ridge landscape character unit would include:

- A new alignment through Toolijooa Ridge.
- Large cut batters.
- Loss of some vegetation associated with corridor widening.
- Introduction of infrastructure into a landscape where there presently is none.

Visibility

To the east of Toolijooa Ridge the project would travel up a ridge line from Toolijooa Road within an open landscape before entering into a cutting. The nature of the surrounding terrain has low visual exposure to surrounding rural residents.

The main points of visibility to the cutting would be from the existing highway near the Foxground bends and north (towards Foxground). For road users, the cutting would be a visually dominant element and it would frame vistas both to the west (the escarpment) and to the east (Gerringong and the Tasman Sea).

Figure 6.1 illustrates the visibility of the Toolijooa Ridge landscape character unit proposal. **Figure 6.2** shows the overall existing landscape character of the Toolijooa Ridge landscape character unit, while **Figures 6.3** through **6.8** illustrate the project.

Sensitivity to proposed changes

The views to Toolijooa Ridge are mostly experienced by road users and an isolated number of rural residents. Residents south of Gerringong can also access distant views. The new cutting, while substantial, would run perpendicular to the ridge, minimising the extent of exposure to the east and west (location of most viewers). The cuttings would be large and would have an impact within the landscape, however considering viewer distance, the sensitivity to change would be moderate.

Rating - Moderate.

Magnitude of proposed changes

The topography of Toolijooa Ridge results in it being the divide between the immediate coastal landscape and the broader rural valley and escarpment. It is to be expected that this transitional experience will be maintained but that the scale of the intervention will cause moderate change to the Toolijooa Ridge profile and visual form.

Rating - Moderate.

Assessment of impact

Based on the overall scale of the proposed intervention and the relative viewer distance, the overall impact is rated as moderate.

Overall rating - Moderate impact.

Refer to **Table 6.3** for the impact assessment.

Mitigation strategy

The recommended mitigation strategies to minimise impacts to the landscape and visual character of the Toolijooa Ridge character unit include:

- Close to vertical cuttings in the suitable rock.
- Keeping the cutting benches at a consistent profile that matches the elevation of the roadway.
- Enclosing the view at the end of the cutting to frame views.
- Establishment of vegetation to the top of the cutting to ensure integration with the adjacent landscape.

For the application of these mitigation strategies and the concept design illustrated in **Section 3.0** refer to **Figure 3.2** through to **Figure 3.27**.

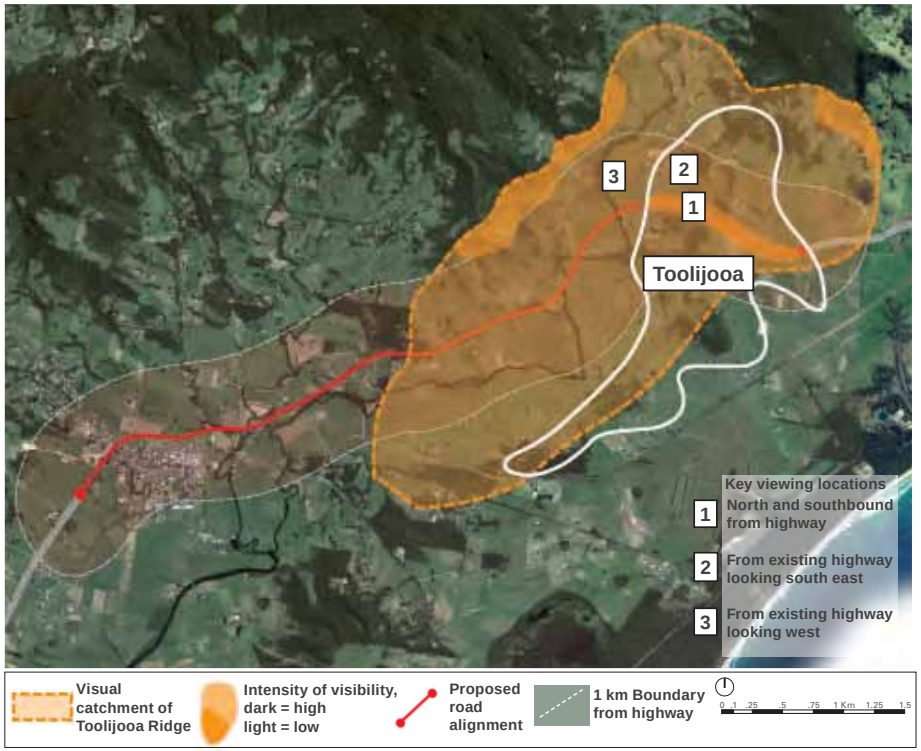


Figure 6.1 Visual catchment and key viewpoints of the Toolijooa landscape character unit

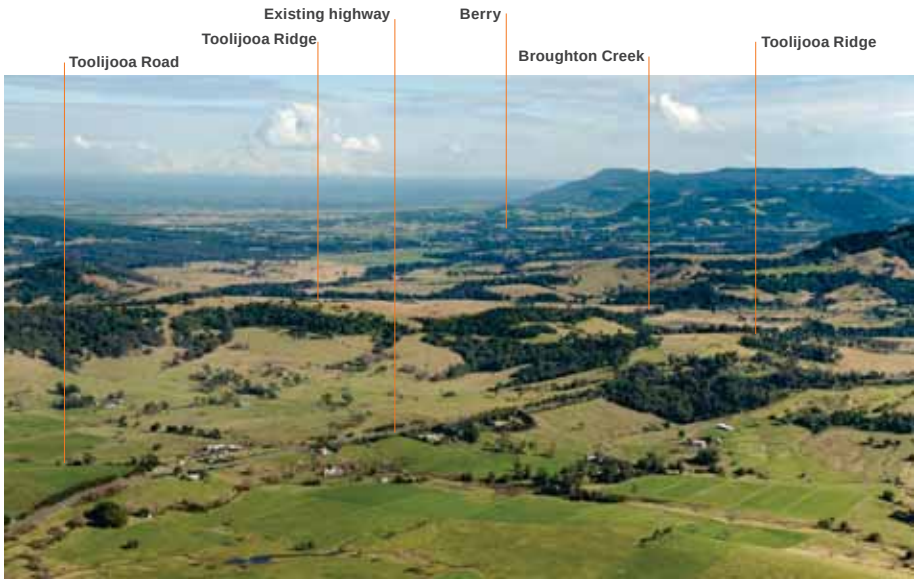


Figure 6.2 Toolijooa landscape looking south east

Figure 6.3 Significant cutting at Toolijooa Ridge

Figure 6.4 Travelling southbound on the eastern side of Toolijooa Ridge

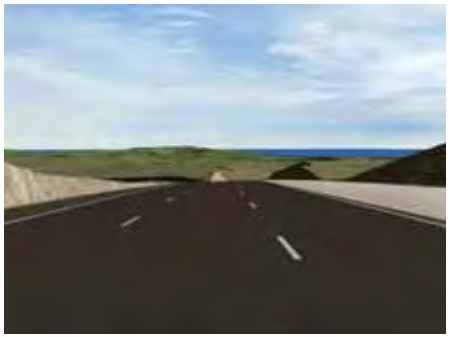


Figure 6.5 Travelling northbound on the eastern side of Toolijooa Ridge toward Gerringong

Figure 6.6 Travelling northbound across the eastern side of Broughton Creek

Table 6.3 Impact assessment table for the Toolijooa landscape character unit

Toolijooa Ridge landscape character unit potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

6.4 Landscape character and visual impact analysis - Broughton Creek

Existing landscape character

Broughton Creek and its adjacent floodplain is located between the western slopes of Toolijooa Ridge and the eastern slopes of Broughton Village. The Broughton Creek valley runs in a north south direction, while the creek line meanders back and forth across the floodplain.

The landscape is generally open pasture with vegetation (trees) mostly present along the creek corridor where mature *Casuarina cunninghamiana* form large walls to the open pasture. To the north is the upper catchment around Foxground with the valley opening up to the south. There are small numbers of rural residences and working farms along the floodplain, many of which contain cultural planting including hedges, avenue driveways, and windbreaks.

Project components

The project involves the following components within the Broughton Creek landscape character unit:

- A new road alignment across the Broughton Creek floodplain.
- Large embankments near Toolijooa across the floodplain.
- Three new bridges across Broughton Creek.

Impacts

Interventions associated with the project that would have a landscape character and visual impact on the Broughton Creek landscape character unit include:

- Introduction of infrastructure into a landscape where there presently is none.
- Introduction of large embankments (up to 16 metres) into a generally flat landscape.
- A large bridge over Broughton Creek (up to 200 metres) long and visible from the existing highway.
- The prominence of the elevated embankment across the floodplain between bridges one and three (providing the route with 1:100 year flood immunity).

Visibility

The visual catchment of Broughton Creek is contained by the western slope of the Toolijooa Ridge and the slopes south of Broughton Village. The project would be highly visible due to its elevation. The number of viewers within this landscape however is relatively low. The third bridge over Broughton Creek would be very visible from the existing highway and would have a significant impact on a private property adjacent to the alignment. For road users the dominate visual experience would be the surrounding landscape and bridge crossings as this whole section of highway would be elevated above the existing landscape.

Figure 6.7 illustrates the visibility of the Broughton Creek landscape character unit proposal. **Figure 6.8** shows the overall existing landscape while **Figures 6.9** through to **Figure 6.11** illustrate the project.

Sensitivity to proposed changes

The project at this point would bypass Foxground and would be furthest away from the existing alignment than at any other point along the project. This alignment results in the severance of some larger working properties.

There are no major stands of significant vegetation that would be impacted other than those associated with the three creek crossings of Broughton Creek (classified as a class one waterway) where some existing riparian vegetation would be removed.

Local residences with existing views of the upper Broughton Creek floodplain would be impacted in terms of visual amenity. The third crossing of Broughton Creek would require a bridge of up to 260 metres long and would be clearly visible from the existing highway.

Rating - High to moderate.

Magnitude of proposed changes

The impact on the existing landscape at Broughton Creek is significant when considering the large footprint of the project in this area. The height of the embankments, the length of the bridges and the number of bridges would all introduce new and significant infrastructure into this open landscape.

Rating - High to moderate

Assessment of impact

Based on the scale of the proposed interventions and the relative distance from which the majority of users would experience these interventions, the overall impact is rated as high to moderate. With the successful implementation of the recommended mitigation strategies, it would be expected that over time the impacts would be reduced as the landscape establishes.

Overall rating - High to moderate impact

Refer to **Table 6.4** for the impact assessment.

Mitigation strategy

The integration of the project into the existing landscape would require a combination of strategies to mitigate any potential adverse outcomes. Suggested mitigation strategies include:

- The large embankments at the interface between Toolijooa Ridge and Broughton Creek should be decreased as much as is feasible.
- The three bridges over Broughton Creek should be designed with simple clean forms.
- Vegetation adjacent to the bridges should be reestablished to maintain the viability of existing fauna corridors and portal experience within the landscape.
- Batters across the floodplain should be flattened to between 10:1 - 4:1 instead of 2:1 to utilise surplus spoil from Toolijooa Ridge and reestablish pasture landscape as close to the road edge as possible. This may also remove the requirement for road safety wire rope.

For the application of these mitigation strategies and the concept design illustrated in **Section 3.0** refer to **Figure 3.2** through to **Figure 3.27**.

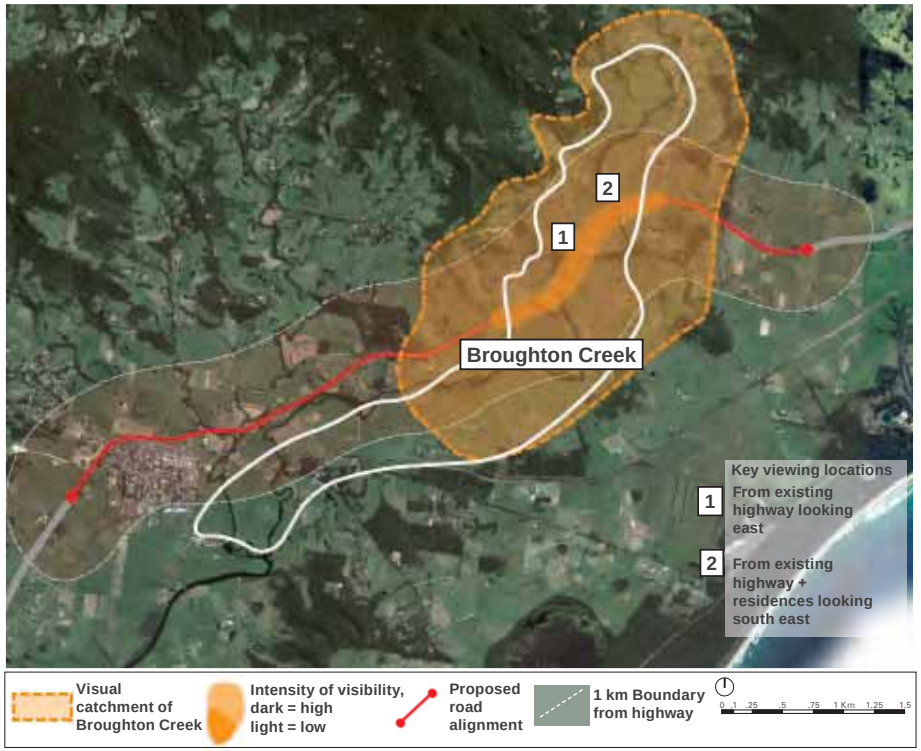


Figure 6.7 Visual catchment and key viewpoints of the Broughton Creek landscape character unit

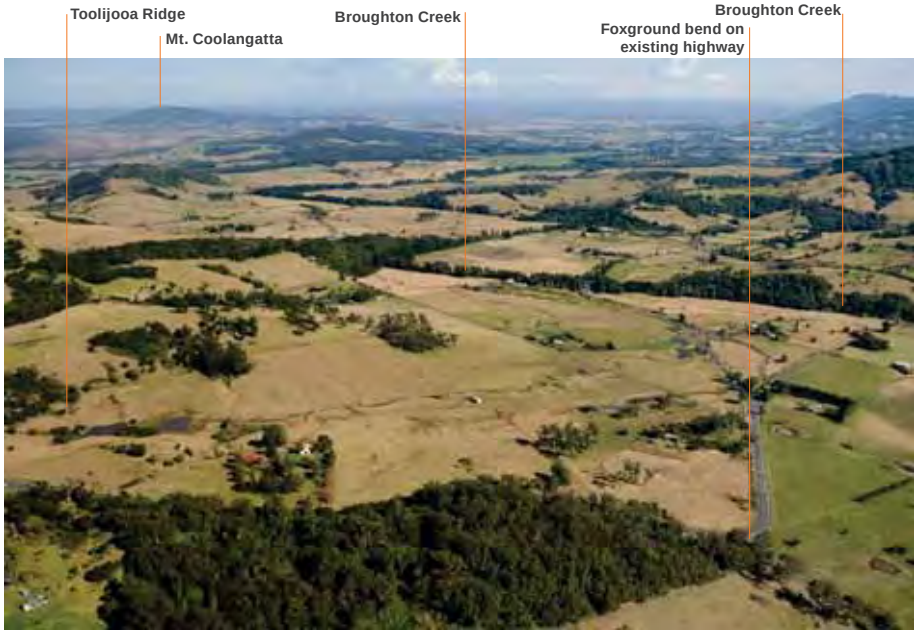


Figure 6.8 Broughton Creek landscape looking south west

Figure 6.9 Large embankments crossing the Broughton Creek floodplain

Figure 6.10 Travelling south bound (leaving the Toolijooa cutting) onto Broughton Creek floodplain

Figure 6.11 Broughton Creek Bridge in close proximity to the existing highway

Table 6.4 Impact assessment table for the Broughton Creek landscape character unit

Broughton Creek landscape character unit potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

6.5 Landscape character and visual impact analysis - North Berry

Existing landscape character

To the east of the Broughton Creek floodplain the road corridor follows the edge of the rolling hill and ridge line that separates the Broughton Creek drainage to the east and the Broughton Mill Creek drainage to the west.

This landscape is characterised by a mix of open rolling pastureland, isolated pockets of closed forest and undulating to steep terrain with views across the valley to the escarpment to the west. As the project gets closer to Berry the ridge line becomes narrower and views form to the east and south.

There are a number of isolated large Eucalyptus specimens (*Eucalyptus pilularis* and *Eucalyptus saligna x botryoides*) in open pastoral landscape that provide scale and frame views.

Figure 6.13 illustrates the existing landscape character of the North Berry landscape character unit.

Project components

The project involves the following components within the North Berry landscape character unit:

- A new interchange with the existing highway in the vicinity of Austral Park Road, including an over bridge.
- A new interchange at Tindalls Lane that makes use of the existing highway and includes an over bridge.
- Large extents of quickly transitioning cut and fill slopes.
- Left in / left out accesses along the highway allowing access to rural properties.

Impacts

Interventions associated with the project that would have a landscape character and visual impact on the North Berry landscape character unit include:

- Areas of significant earthworks required to improve the vertical alignment of the highway in a landscape that has many areas of slope at 30 per cent or steeper.
- The loss of roadside vegetation associated with the re-alignment and widening of the existing road corridor.
- The alteration to a number of property accesses along the existing route.
- Removal of vegetation along the ridge line just north of Berry.
- The potential visual impact of two over bridges on the tops of ridge lines at Austral Park Road and Tindalls Lane interchanges.
- Lighting - impacts at interchange intersections which would generally have ramp terminals, merge / diverge and weaving areas.

Visibility

The nature of the landform and vegetation cover combined with the relatively low number of adjacent rural residential viewers results in much of the highway not being highly visible. The primary viewing locations are from the existing highway itself and from a small number of local rural residences along the alignment. These are mostly clustered around the Austral Park Road area and Tindalls Lane. The increased footprint and loss of some large existing trees, as a result of the project, would likely result in the project being more visible particularly to the south-west. It is at this point that the ridge line narrows before entering into Berry and crossing Broughton Mill Creek.

Figure 6.12 illustrates the visibility of the North Berry landscape character unit proposal. **Figure 6.13** shows the overall existing landscape context.

Sensitivity to proposed changes

The project within the North Berry landscape character unit is generally a widening and or straightening of the existing highway alignment. Where the highway currently meanders and bends, a straighter alignment is proposed. The design also makes use of some of the residual existing highway to assist with safe access and circulation. The requirements for the vertical alignment would result in some large embankments that quickly transition from cut to fill through this undulating landscape.

Rating: Moderate

Magnitude of proposed changes

The existing highway alignment follows the undulating terrain very closely, but the design standards for a modern highway require flatter grades, the result being that large cut and or fill slopes follow in very quick succession. Additionally, areas of existing vegetation, including large trees would be impacted. As the project includes two new interchanges, a heavy vehicle rest stop and residual highway connections, the overall footprint on the landscape would be significant.

Rating: High to Moderate.

Assessment of impact

Based on the scale of the proposed intervention interfacing with the North Berry landscape character unit, the overall impact is rated as high to moderate.

Overall rating - High to Moderate impact.

Refer to **Table 6.5** for the impact assessment.

Mitigation strategy

The integration of the project into the existing landscape would require a combination of strategies to mitigate any potential adverse outcomes. Suggested mitigation strategies include:

- Consideration of in fill tree planting of the residual spaces between the existing highway and proposed highway.
- Reinstatement of vegetation along cuttings and embankments to help reduce the visual scale of the works, particularly close to ridge lines.
- The consideration of appropriate screening to adjacent rural residences.
- The planting of isolated single or small clumps of eucalypts to reinforce the broader landscape pattern.
- Rolling back the top of cut slopes to integrate with local topography and landform.
- Revegetation of any areas of existing highway left as residual landscape.
- Reinstatement of pasture grasses on flattened embankments where feasible.
- The use of farm style fencing in residual spaces between the existing highway and proposed highway to reinforce rural character.
- Integration of the water quality basins and swale systems within the landscape.
- Consistent detailing for the two over bridge structures.
- Vegetation to soften the sudden transitions from cut to fill slope.
- Lighting - all intersections are to be lit to ‘flag’ standard in accordance with ‘AS/NZS 1158 Code of Practice for Public Lighting’ and designed to avoid potential light spill impacts (measures to direct light source towards carriageway only).

For the application of these mitigation strategies and the concept design illustrated in **Section 3.0** refer to **Figure 3.2** through to **Figure 3.27.**

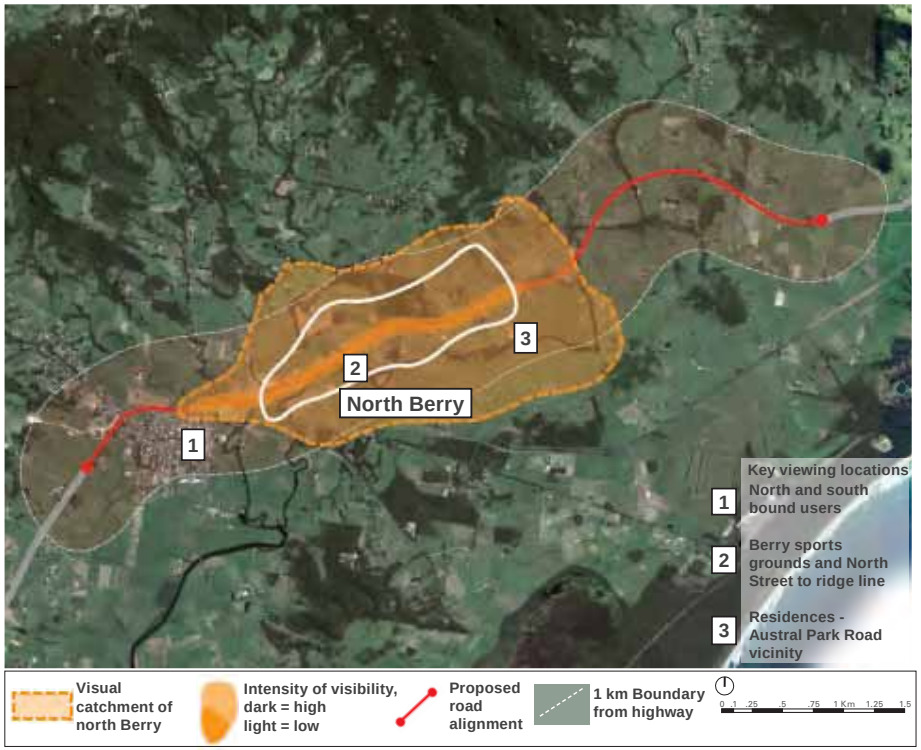


Figure 6.12 Visual catchment and key viewpoints of the North Berry landscape character unit

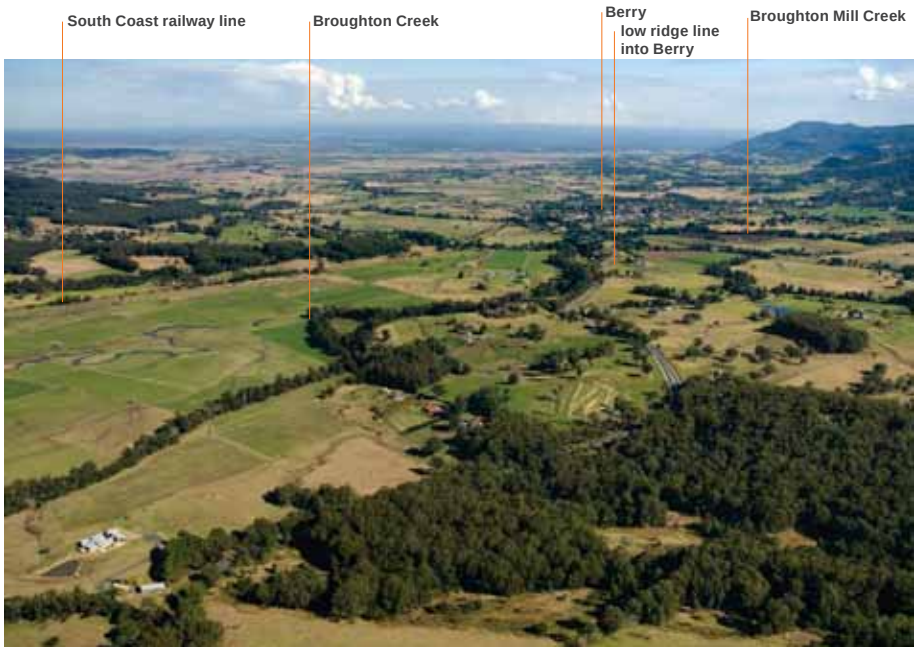


Figure 6.13 North Berry landscape looking south

Table 6.5 Impact assessment table for the North Berry landscape character unit

North Berry landscape character unit Potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

6.6 Landscape character and visual impact analysis - Berry

Existing landscape character

The township of Berry occupies the area of flat land just above the flood prone pasture of Bundewallah, Broughton and Broughton Mill Creeks. The town has clearly defined extents and strong visual connections with the surrounding rural landscape. The landscape within the town is a rich mix of traditional European cottage style gardens, hedges and isolated deciduous ornamental trees set against a back drop of remnant large Eucalyptus trees. The escarpment to the west and north is visually prominent and serves as a reference point within the town. To the west, the landscape of Berry's growth area is less formal in its street layout responding to existing topography.

Figure 6.15 illustrates the existing landscape character of the Berry landscape character unit.

Project components

The project would involve the following components within the Berry landscape character unit:

- A new interchange to the north of town that includes a southbound off ramp and a northbound on ramp.
- A new bridge over Broughton Mill Creek, Woodhill Mountain Road and Bundewallah Creek (approximately 600 metres in length) and up to 12 metres high.
- Significant new infrastructure along the North Street corridor.
- The diversion of Town Creek to the north of the highway to connect into Bundewallah Creek.
- A new interchange at Kangaroo Valley Road that includes southbound on and off ramps and northbound on and off ramps.
- A bridge over the highway at Kangaroo Valley Road.
- A new roundabout at the intersection of Woodhill Mountain Road and the existing Princes Highway.
- Closure of Victoria Street and the introduction of a cul-de-sac at the western end.
- South of Berry, on the western side of the upgrade, between the southern Berry interchange and Schofield's Lane a permanent variable message sign (VMS) that would service northbound traffic would be installed. The VMS would be around 6.1 metres in height and would be designed and constructed in accordance with the Guidelines for the location and placement of variable message signs.
- Noise walls located along the North Street corridor and adjacent to the northbound off ramp at the Southern Interchange for Berry.

Impacts

Interventions associated with the project that would have a landscape character and visual impact to the Berry landscape character unit include:

- A bypass of the township of Berry in close proximity to housing along North Street and Huntingdale Park Road including the introduction of new infrastructure where there presently is none.
- The bypass of Berry would be located within the area identified as the BTUCA. The BTUCA identifies a 'buffer zone' that seeks to protect the immediate rural setting along the North Street corridor. The proposed alignment of the bypass impacts directly on the distinct rural / urban boundary.
- A new interchange north of town located on a narrow ridge line requiring significant earthworks.
- Introduction of a significant bridge structure over Woodhill Mountain Road, Broughton Mill Creek and Bundewallah Creek.
- The loss of existing vegetation associated with the bridge at Berry.
- The loss of amenity along the North Street corridor and Huntingdale Park Road.
- The introduction of a new roundabout west of the existing Berry bridge.
- The potential 'perception of severance' in Berry by residents located west of the bypass alignment.
- Noise impacts and noise walls, to the residents of North Street and around Kangaroo Valley and Huntingdale Park roads.
- Some impact on vegetation and the amenity of Mark Radium Park.
- The loss of vegetation due to the road widening, works specifically:
  - Along the low ridge line at the entrance into Berry where the highway is at its widest point (including on and off ramps and the bridge abutment).
  - On the southern side of Berry where the bypass connects with the existing Princes Highway widening would require the removal of an existing row of Brush Box trees (*Lophostemon confertus*).
- Lighting - the interchange intersections would generally have ramp terminals, merge / diverge and weaving areas lit.
- South of Berry, the placement of the VMS introduces a large element into the western side of the road corridor.

Visibility

The key areas for viewing the project are from the North Street corridor, the Berry sports grounds, around Kangaroo Valley Road, Huntingdale Park Road, and Mark Radium Park.

The new interchange just north of Berry is large in scale and located on a narrow ridge and would be seen from a number of locations to the east, south and west.

The elevated nature of the bridge at Berry would have a visual impact, though this is somewhat mitigated by existing vegetation. North of town the longest unbroken visible elevation of the bridge would be from Woodhill Mountain Road.

Along North Street, the northern noise attenuation measures would be visible, with the highest intensity being toward the western end of North Street. The noise attenuation measures would be visible at the ends of each of the north-south streets. To the west the highway is closer to North Street before it goes underneath Kangaroo Valley Road in cut.

Along Huntingdale Park Road and the northbound off ramp, the noise attenuation measure located south of Kangaroo Valley Road would be visible. Proposed screening vegetation will help to mitigate this visibility. Refer CM+ design strategy in Appendix A.

Figures 6.16 through to **Figure 6.25** illustrate visual impacts from North Street towards the ridges and escarpment.

The Kangaroo Valley Road overbridge would be 21m wide.

The VMS would be around 6.1m high and would be located to ensure that conspicuity, legibility and comprehension are achieved.

Figure 6.14 illustrates the visibility of the proposal within the Berry landscape character unit. **Figure 6.15** shows the overall existing landscape context.

Sensitivity to proposed changes

The Berry sports ground, North Street corridor and Kangaroo Valley Road are all key elements of the landscape identity and functionality of the town and are very sensitive to intervention. The proximity, mass and scale of infrastructure present significant concerns with regard to visual and noise impacts. The Berry sports grounds are a focal community point as is the Camp Quality area located just north-west of the playing fields.

The North Street corridor is a quiet street that provides a delineation between the edge of town, the rural foreground and the background of the escarpment. This existing relationship would be significantly altered with the addition of the bypass.

The future expansion of Berry is restricted due to flooding, and currently predominantly occurs along the Kangaroo Valley Road corridor. Functionally, Kangaroo Valley Road is a continuation of Queen Street and with expansion to the west this connection will become more important. There is a requirement that the bypass not sever this key connection.

Rating - High to moderate.

Magnitude of proposed changes

The scale of the changes around the town are significant as would be expected with a bypass. The introduction of a large elevated bridge, potential noise attenuation measures, cuttings and over bridge as well as land acquisitions are all significant impacts.

Rating - High

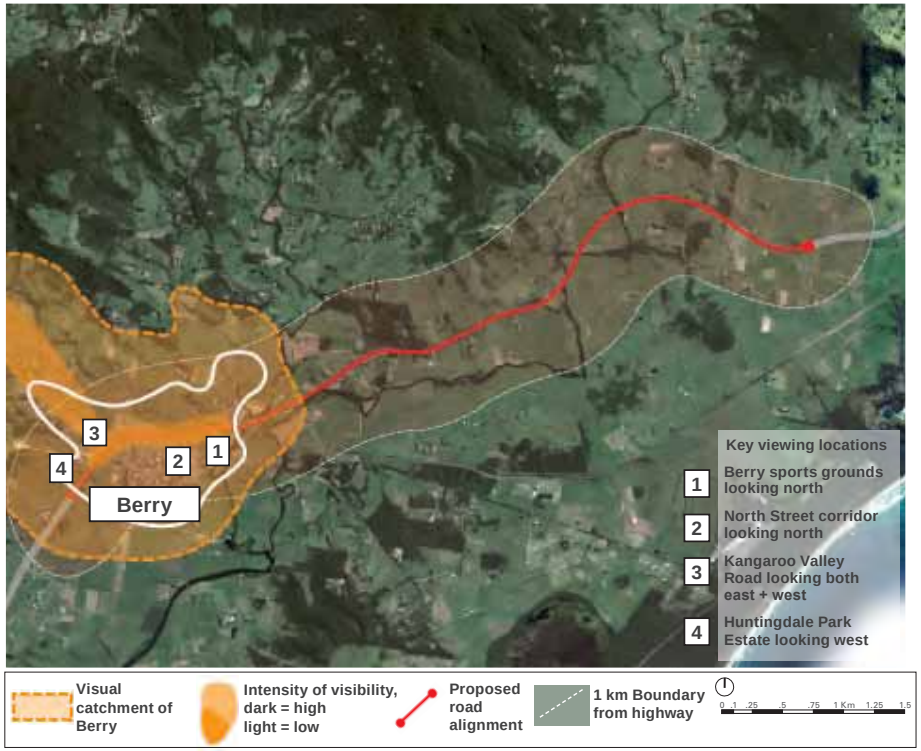


Figure 6.14 Visual catchment and key viewpoints of the Berry landscape character unit

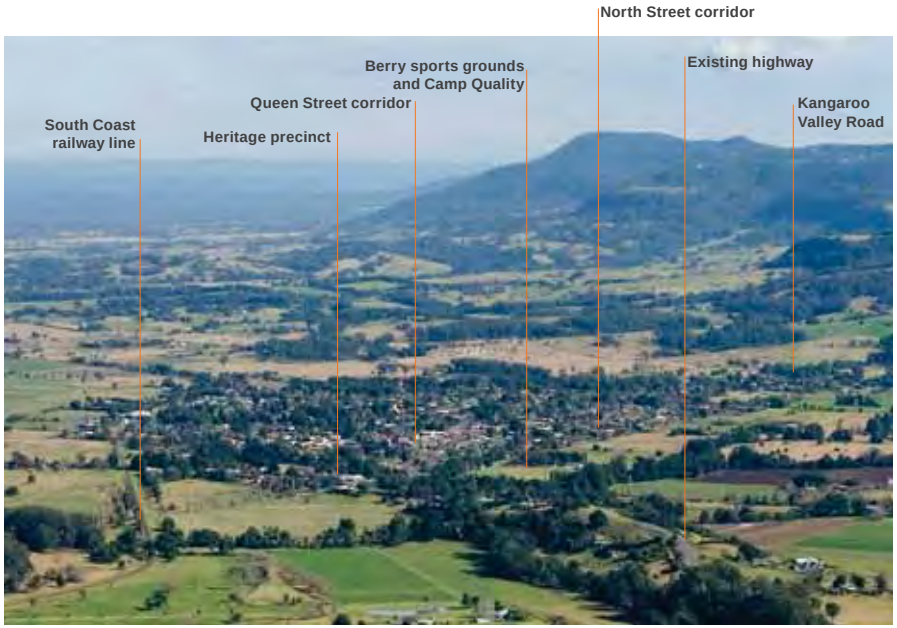


Figure 6.15 Berry landscape looking south west

Assessment of Impact

Based on the overall scale of the proposed intervention interfacing with the Berry landscape character unit, the overall impact is rated as high.

Overall rating - High impact.

Refer to **Table 6.6** for the impact assessment.

Mitigation strategy

Based on the High impact rating of the project on Berry, a series of focused community workshops and an independent urban design study was undertaken by CM+ and the findings of this have been incorporated into the concept design and the mitigation measures that follow. This study is documented in Appendix A.

The integration of the new highway alignment into the existing landscape would require a combination of strategies to mitigate any potential adverse outcomes. Consistent with the recommendations in RMS' 'Noise Wall Design Guidelines: Design Guidelines To Improve The Appearance of Noise Walls in NSW' (RMS, 2006), the recommendations for mitigation by considering;

- The existing landscape context and character.
- Utilising the space available for mounding.
- Proposing the use of locally relevant materials and planting.

Other suggested mitigation strategies for the Berry landscape character unit and sub units include:

- The bridge at Berry (sub unit):
  - Define the southbound town entry with culturally relevant planting and reinforce with an appropriate entry statement. This could be a suitable location for the Alexander and David Berry memorial.
  - Reinforce existing creek line vegetation to integrate the bridge within the landscape.
  - Minimise the number of columns for Berry bridge by maximising the span length (where feasible).
  - Utilise planting around the bridge abutments to blend the transition from bridge deck to embankment landscape.
  - Utilise background planting of Eucalyptus on the ridgeline at the interchange to soften the significant earthwork modifications.
- North Street (sub unit):
  - Blend the existing pastoral landscape up to the edge of the highway by reducing the steepness of the embankments.
  - Use a simple palette of low shrubs to screen the top of the sound attenuation wall, allowing the foreground landscape to blend in with the broader context.
  - Engage with the Berry community during the planning and design of the open space network.
  - Consider low screen planting to the northern side of the highway adjacent to the existing farming land and homestead.
  - Design planting within new roundabout at Queen Street and reinforce deciduous avenue planting that is consistent with the landscape garden character of Berry.
- Kangaroo Valley Road Precinct (sub unit):
  - Design planting within roundabouts and landscaped verges to the bridge that reinforce the landscape garden character of Berry.
  - At the north bound exit into town establish cultural tree planting consistent with that proposed at the northern interchange.
  - Consider the street lighting (scale and rhythm) and ornamental tree planting to unify the existing local road network with the new bridge and roundabouts.
  - Continue to engage with the Berry community during the planning and design of the open space network.
  - Lighting - all intersections are to be lit to 'flag' standard in accordance with AS/NZS 1158 Code of Practice for Public Lighting and designed to avoid potential light spill impacts (measures to direct light source towards carriageway only).
- Variable Message Sign
  - Consider locating the VMS between chainage 18650 and 18700 to;
  - Minimise impacts of any effects associated with silhouetting against the sky, between these chainages there is a very gradual down slope that will reduce any silhouetting
  - Minimise impacts on any vistas or views
  - Minimise impacts on any existing or planned built form
  - Maximise distance away from the interchange, signage and lighting that will be associated with the Kangaroo Valley Road Precinct.

For the application of these mitigation strategies and the concept design illustrated in **Section 3.0,** refer to **Figures 3.2** through to **Figure 3.28,** and CM+ study, Appendix A.

Table 6.6 Impact assessment table for the Berry landscape character unit

Berry landscape character unit potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

6.7 The ridges and escarpment - impact

A key requirement of the project DGRs is to:

"*Assess the visual significance of the area, including the escarpment and ridges and the township of Berry, and impact of the proposed alignment*'".

This requirement requires the assessment of:

- The visual connection to the ridges and escarpment.
- The visual significance of the township of Berry.

The escarpment and ridges and the township of Berry

As the escarpment and ridges are well outside the study area the assessment focuses on the loss of the visual connection to the escarpment and ridges due to the project concept design. The ridges and escarpment form a constant backdrop to the north, north west and west of the project. The only area where they cannot be seen is immediately east of Toolijooa Ridge. The ridges are almost exclusively heavily forested and form a dramatic contrast to the more 'managed' agricultural landscape of the rolling hills and floodplains below.

The township of Berry sits within two layers of landscape. The first is the immediate, generally open pasture and flood prone land, all set against the second broader Broughton Mill Creek valley defined by the ridges and escarpment.

The proposed alignment along North Street would introduce a third and significant element into this landscape setting of Berry. With its close proximity to North Street the visual interface would be significantly altered.

The impacts to views of the ridges and escarpment from Berry are due to two main factors. The first is the introduction of the bypass as a new element with a significant foot print into the area north of North Street. The second is the requirement for noise mitigation to the residents of Berry in the vicinity of North Street. Based on the concept design for the project, modelling indicates that a four metre high barrier would be required to mitigate the expected noise impacts.

There are six prominent points along the ridges and escarpments which are visible from Berry town; these are identified in plan in **Figure 6.16** and from aerial perspective in **Figure 6.17** and **Figure 6.18**. These points will provide a method of measuring the project's visual impact of views towards the escarpment.

Methodology

Through the assessment of various viewpoints along the east west aligned streets including North Street, Albert Street and Queen Street and the north south aligned streets including George, Edward, Albany and Alexandra Streets, a relative impact intensity map was produced to show level of impacts on the views to the ridges and escarpments to the west and north of Berry.

To further illustrate this, three viewpoints where selected to assess the relative impact on the visual connection to the ridges and escarpment. The three viewpoints selected were:

- Point A, from the eastern end of North Street near the intersection with Edward Street (refer **Section 6.7.1**).
- Point B, from the intersection of Albert Street and Edward Street (refer **Section 6.7.2**).
- Point C, from the intersection of Queen Street and Edward Street (refer **Section 6.7.3**).

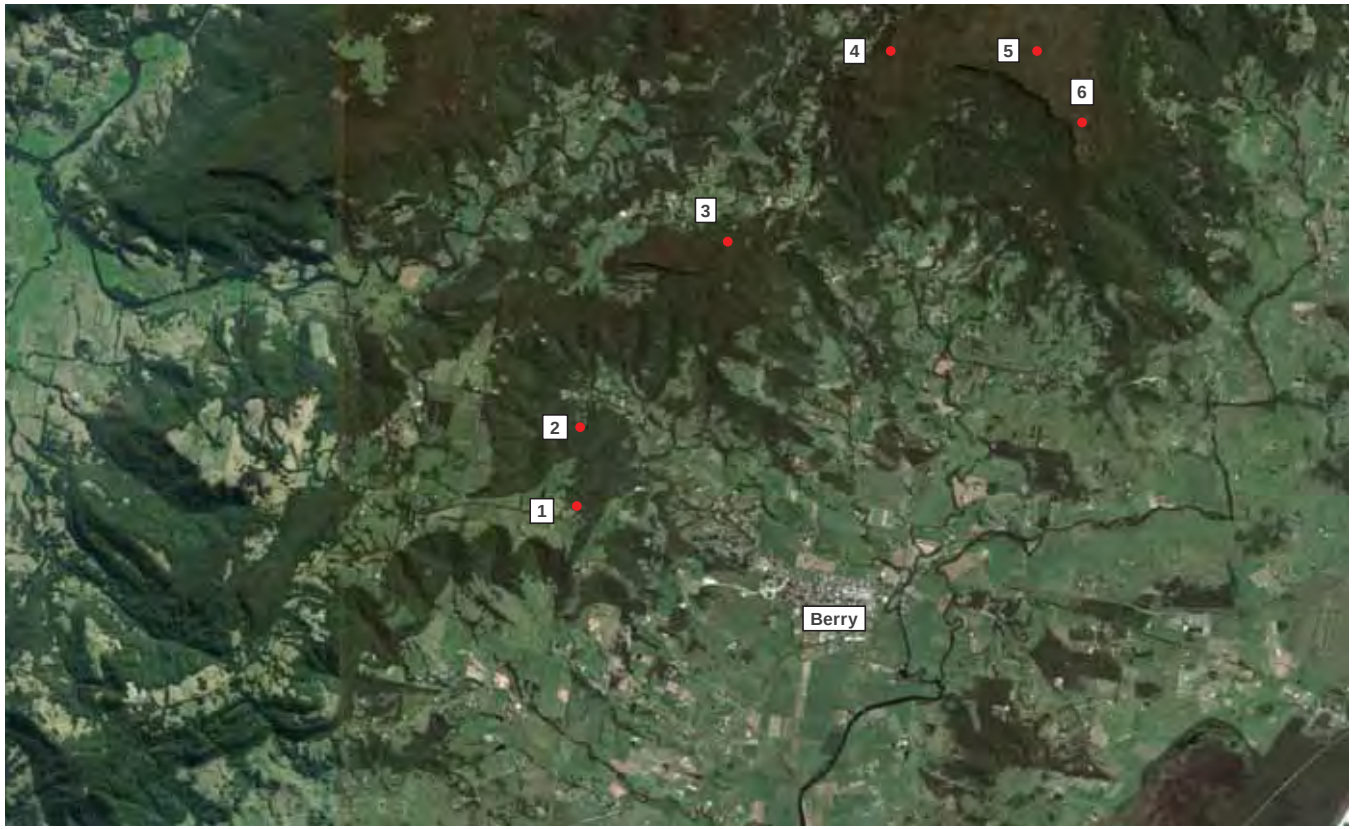


Figure 6.16 Aerial image locating the identified significant escarpment landforms (Image Source: Google)

Figure 6.17 Elevated view west to escarpment overlooking Berry township, highlighting significant points 1 and 2

Figure 6.18 Elevated view north to escarpment overlooking Berry township, highlighting significant points 3, 4, 5, and 6.

6.7.1 North Street view towards escarpment: Observer location A: North Street

Observer location A is sited on North Street near the intersection of Edward Street as shown in **Figure 6.19**. Potential noise attenuation measures at this location would be located along the southern side of the bypass of Berry. A noise attenuation wall treatment of up to four metres in height would impact the visual amenity looking north from this location. **Figure 6.20** demonstrate the potential impact of the noise attenuation treatment as viewed from eye level (1.6 metre height). Residents in this proximity would fall into what has been classified as Zone One for impacts as illustrated in **Figure 6.21**.

Assessment

For Zone One (refer **Figure 6.21**), North Street residents, the sensitivity and magnitude of change are both considered moderate. There would be only very minor impact on views to the ridges and escarpment, the more significant impacts would be on the foreground and middle ground pastoral views. This is clearly illustrated in **Figure 6.20**.

Overall rating - Moderate impact.

Refer to **Table 6.7** for the assessment table.

Summary

With regard to the impacts on views to the ridges and escarpments and the visual significance of township of Berry, the project would:

- Have moderate impacts for residents and users of the western end of North Street especially on foreground views. Views to the ridges and escarpments would not be impacted.
- The landscape setting and relationship of the interface on the north side of Berry would be impacted because of the proximity of the proposed highway to the western end of North Street.

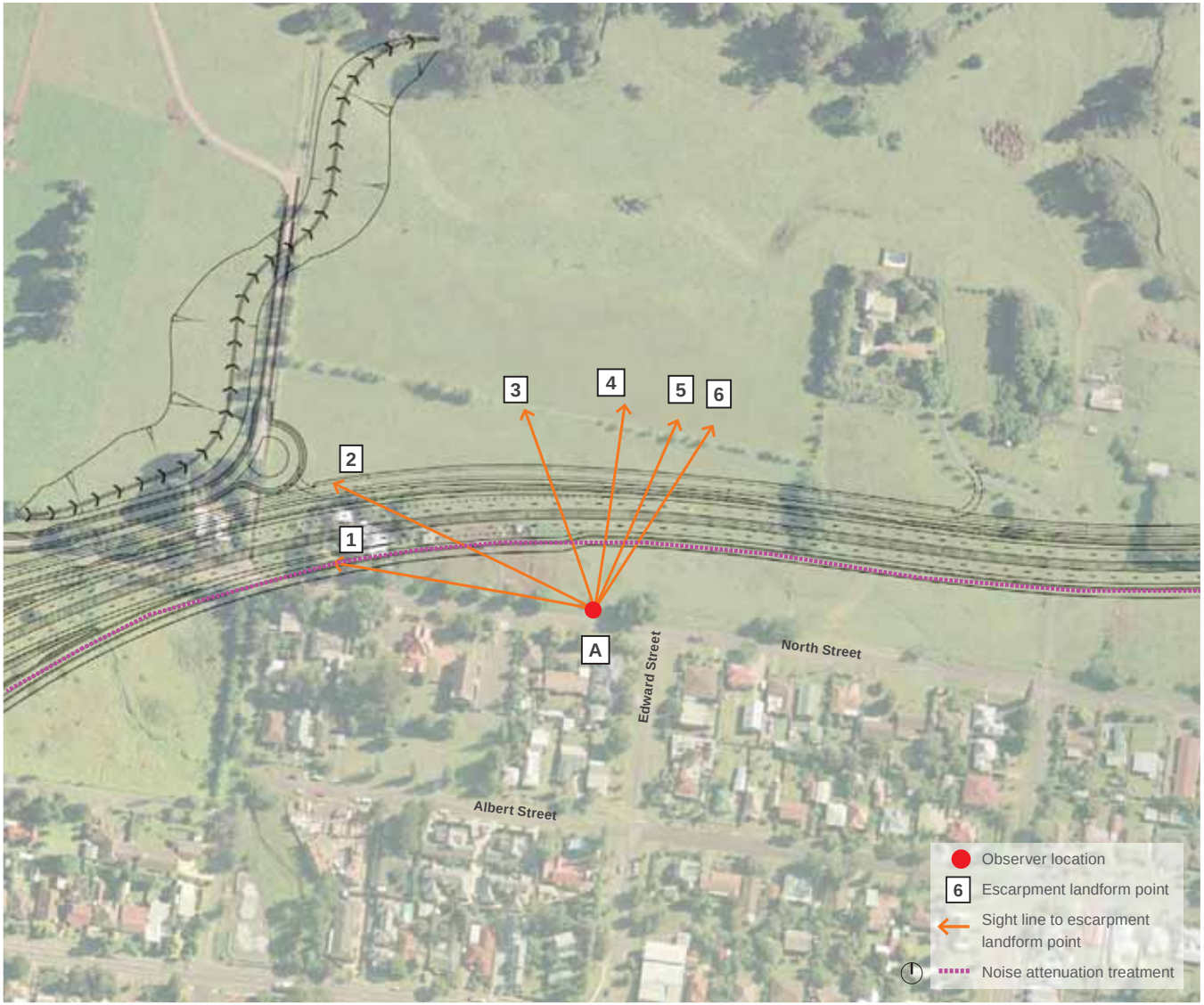


Figure 6.19 Observation location A on North Street showing sight lines to the significant points along the escarpment

Figure 6.20 Observer location A comparison, North Street

Table 6. 7 Impact assessment table for North Street - Zone 1

Berry (North Street Zone 1) potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

Legend

- Zone 1: moderate impact, impacts on foreground views but ridges and escarpment visible
- Zone 2: moderate to low impact, minor impacts on foreground views, no impact on views to ridges and escarpments
- Zone 3: low impact, very minor to no impacts on foreground views, no impact on views to ridges and escarpments
- Noise attenuation wall, indicative
- Proposed alignment
- Commercial core
- Impact assessment observer location points (A,B,C)

Figure 6.21 Ridges, escarpment, and foreground landscape views zones of impact from proposed bypass alignment

6.7.2 Albert Street view towards escarpment: Observer location B

Observer location B is sited at the intersection of Albert and Edward Streets as shown in **Figure 6.22**. Potential noise attenuation measures located along the southern side of the bypass at Berry would impact the visual amenity looking north along Edward Street. This impact is reduced as the observer location is further away from the noise mitigation measure (165 metres +/-). **Figure 6.23** demonstrate the potential impact of the noise attenuation treatment as viewed from eye level (1.6 metre height). Residents in this proximity would fall into what has been classified as Zone Two for impacts as illustrated in **Figure 6.24**.

Assessment

For Zone Two (refer **Figure 6.24**), Albert Street residents and some residents of George, Edward, Albany and Alexander Streets, the sensitivity and magnitude of change are both considered moderate to low. For the majority of this zone there would be some impacts on foreground views and no impact on views of the ridges and escarpment.

Foreground views, while not as much as a feature of North Street, would also be impacted at the cross street intersections. These impacts are clearly illustrated in **Figure 6.23.**

Overall rating - Moderate to low impact.

Refer to **Table 6.8** for the assessment table.

Summary

With regard to the impacts on views to the ridges and escarpments and the visual significance of township of Berry the project would:

- Have moderate to low impact on residents and users of Albert Street. Views to the ridges and escarpment would not be impacted but foreground views would experience some impact, especially at the north - south cross streets.

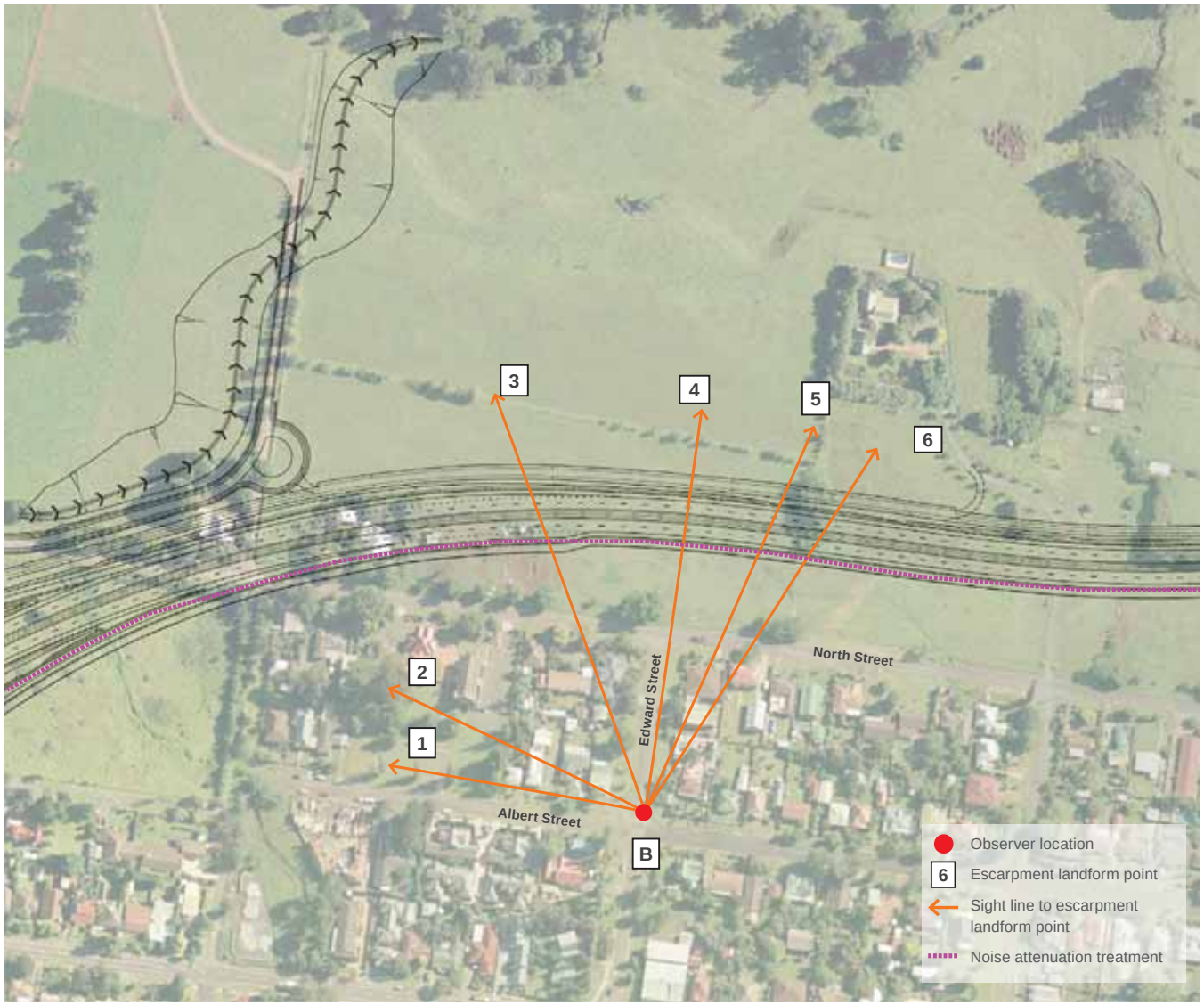
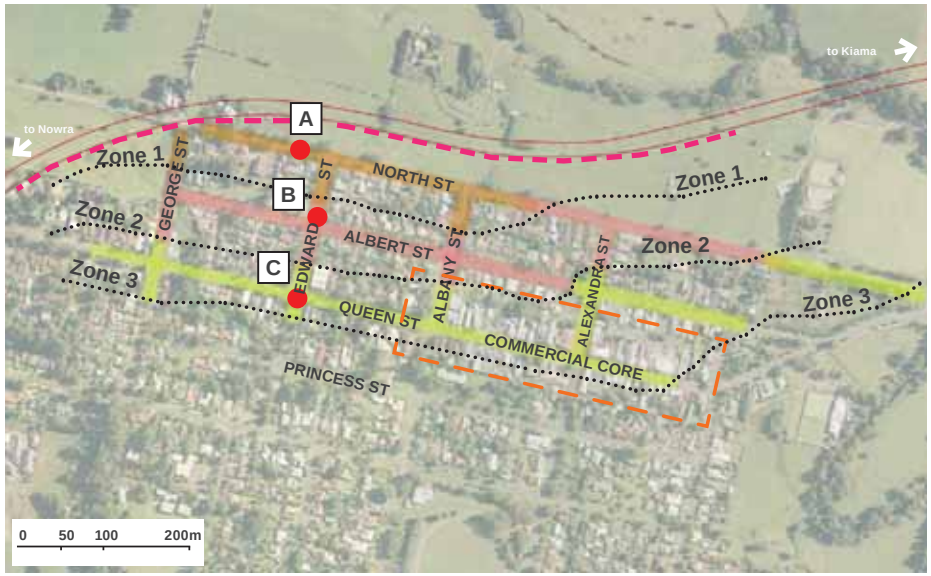


Figure 6.22. Observation location B on Edward Street showing sight lines to the significant points along the escarpment

Figure 6.23 Observer Location B comparison, Albert Street

Table 6. 8 Impact assessment table for Albert Street - Zone 2

Berry (Albert Street Zone 2) potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact



Legend

- Zone 1: moderate impact, impacts on foreground views but ridges and escarpment visible
- Zone 2: moderate to low impact, minor impacts on foreground views, no impact on views to ridges and escarpments
- Zone 3: low impact, very minor to no impacts on foreground views, no impact on views to ridges and escarpments
- Noise attenuation wall, indicative
- Proposed alignment
- Commercial core
- Impact assessment observer location points (A,B,C)

Figure 6.24 Ridges, escarpment, and foreground landscape views zones of impact from proposed bypass alignment

6.7.3 Queen Street view towards escarpment: Observer location C

Observer location C is sited at the intersection of Queen and Edward Streets as shown in **Figure 6.25**. Potential noise attenuation measures located along the southern side of the bypass at Berry would impact the visual amenity looking north along Edward Street. This impact is reduced further as the observer location is at a greater distance away from the noise mitigation measure (270 metres +/-). **Figure 6.26** demonstrate the potential impact of the noise attenuation treatment as viewed from eye level (1.6 metre height). Residents in this proximity would fall into what has been classified as Zone three for impacts as illustrated in **Figure 6.27**.

Assessment

For Zone three (refer **Figure 6.27**), Queen Street residents and commercial core, the sensitivity and magnitude of change are both considered low. From the majority of this Zone three area there would be no impact on the views of the ridges and escarpment.

There is some minor impact on the open views/vistas along the north south streets as they would be terminated by a noise attenuation wall. This would include George, Edward, Albany and Alexandra Streets. From Queen Street the impact however would be relatively minor as illustrated in **Figure 6.25.**

Overall rating - Low impact.

Refer to **Table 6.9** for the assessment table.

Summary

With regard to the impacts on views to the ridges and escarpments and the visual significance of township of Berry, the project would have low impact to residents, commercial property owners and users of Queen Street and the commercial core. There would be no impact on views to the ridges and escarpment.

When considered on a block by block basis, the level of impact decreases significantly as you move further south and further east.

Figure 6.25 Observation location C on Edward Street showing sight lines to the significant points along the escarpment

Table 6. 9 Impact assessment table for Queen Street - Zone 3

Berry (Queen Street Zone 3) potential landscape character and visual impact		Magnitude of change				
		High	High to moderate	Moderate	Moderate to low	Low
Sensitivity	High	High impact	High impact	High to moderate impact	High to moderate impact	Moderate impact
	High to moderate	High impact	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact
	Moderate	High to moderate impact	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact
	Moderate to low	High to moderate impact	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact
	Low	Moderate impact	Moderate impact	Moderate to low impact	Moderate to low impact	Low impact

Figure 6.26 Observer location C comparison, Queen Street

Legend

- Zone 1: moderate impact, impacts on foreground views but ridges and escarpment visible
- Zone 2: moderate to low impact, minor impacts on foreground views, no impact on views to ridges and escarpments
- Zone 3: low impact, very minor to no impacts on foreground views, no impact on views to ridges and escarpments
- Noise attenuation wall, indicative
- Proposed alignment
- Commercial core
- Impact assessment observer location points (A,B,C)

Figure 6.27 Ridges and escarpment and foreground landscape views zones of impact from proposed bypass alignment

6.8 Artist's impressions

Artist's impressions have been developed throughout the design process to:

- Help define the likely visual impacts.
- Inform the assessment of design options.
- Help clearly communicate and illustrate the landscape and urban design concepts.

To support the concept design, a series of artist's impressions are included in the following pages. Refer to **Figure 6.31** through to **Figure 6.51.**

Figure 6.28 identifies the locations.

Viewpoints one through seven are taken from locations along the existing highway.

The aerial perspective images A-C, have been produced to illustrate the design in locations where it is difficult to see the overall impact from ground level. These also use before and after figures for comparison.

Due to the sensitive nature of the bypass of Berry, four viewpoints were selected along the North Street corridor. These artist's impressions were developed in consultation with residents in the community review group. These artist's impressions were prepared by CM+ and the targeted urban design assessment undertaken with the local community.

Figure 6.29 identifies the location of the artist's impressions along the north Street corridor.

Viewpoint locations

1. From existing Princes Highway looking south west to the Toolijooa Ridge cutting.
2. From Broughton Creek looking north east across the creek to the west side of Toolijooa Ridge.
3. From existing Princes Highway looking east to Broughton Creek.
4. From existing Princes Highway just north of Austral Park Road looking east to Broughton Creek.
5. From Woodhill Mountain Road looking south to Bundewallah Creek and the proposed bridge at Berry.
6. From Bong Bong Road, looking south towards Berry.
7. From the intersection of North Street and Woodhill Mountain Road looking north across Berry sports grounds.

Aerial perspective images

- A • North of residual highway interchange near Austral Park Road looking south west towards Berry.
- B • Tindalls Lane interchange looking south west towards Berry.
- C • West of Mark Radium Park looking north east to the south Berry interchange.

Figure 6.30 describes the image sequence for the artist's impressions.

North Street viewpoint locations

8. View from North Street (near Edward Street) looking north west.
9. View from the corner of North Street and Albany Street looking north west.
10. View from the corner of North Street and Alexandra Street looking north west.
11. View from the corner of North Street and Prince Alfred Street looking north west.

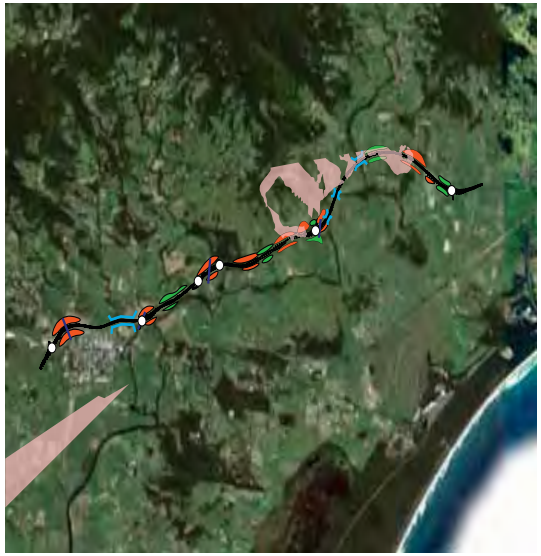
Figure 6.29 illustrates the viewpoint locations for the North Street artist's impressions.

Figure 6.28 Locations of artist's impressions 1 through 7, and aerial perspective location A,B, and C, along the route

Figure 6.29 North Street enlargement area, showing locations of artist's impressions along North Street image provided courtesy of CM+ (2011)

Step 1 Legend illustrating the elements of the project captured in the artist's impression and the visual catchment from the photo location point

1 Photo location [number]
Intersection/interchange
Proposed road design
Overpass/underpass
Bridge
Major embankment
Major cut
Area of visual catchment



Visual assessment location showing view shed coverage

Step 2 Existing site condition

Existing View

Step 3 The road engineering design model (wireframe) is inserted into the existing view, illustrating the approximate extent of the proposed construction works

Location #01: The viewpoint has been taken overlooking the west side of Toolijooa Ridge.
Location Lat: -34.742909° Long: 150.772193° Elev: 98 m (asl) Facing: South West

Site photo showing extent of proposed construction works (wireframe) / 12D model

Step 4 Artist's impression illustrating the likely outcomes including recommended mitigation and management measures

Figure 6.30 Image sequence for artist's impressions

6.8.1 Artist's impression one - Toolijooa Ridge

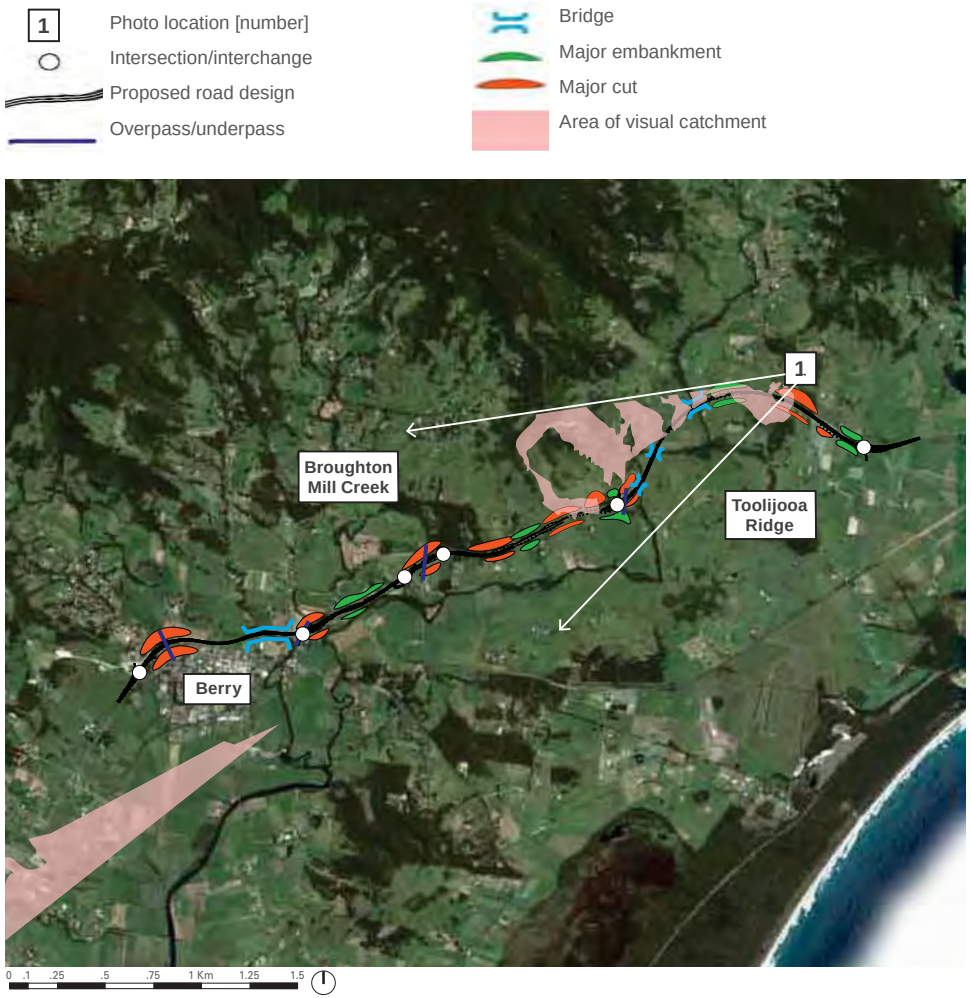


Figure 6.31 Visual assessment location 1 showing view shed coverage

Location 01: The viewpoint has been taken from the existing Princes Highway looking south west to the Toolijooa Ridge cutting.
Location Lat: -34.742909° Long: 150.772193° Elev: 98 m (asl) Facing: South West

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

Figure 6.32 Artist's impression from viewpoint 1 (Note: vegetation shown with approximately 10-15 years of growth)

6.8.2 Artist's impression two - Broughton Creek

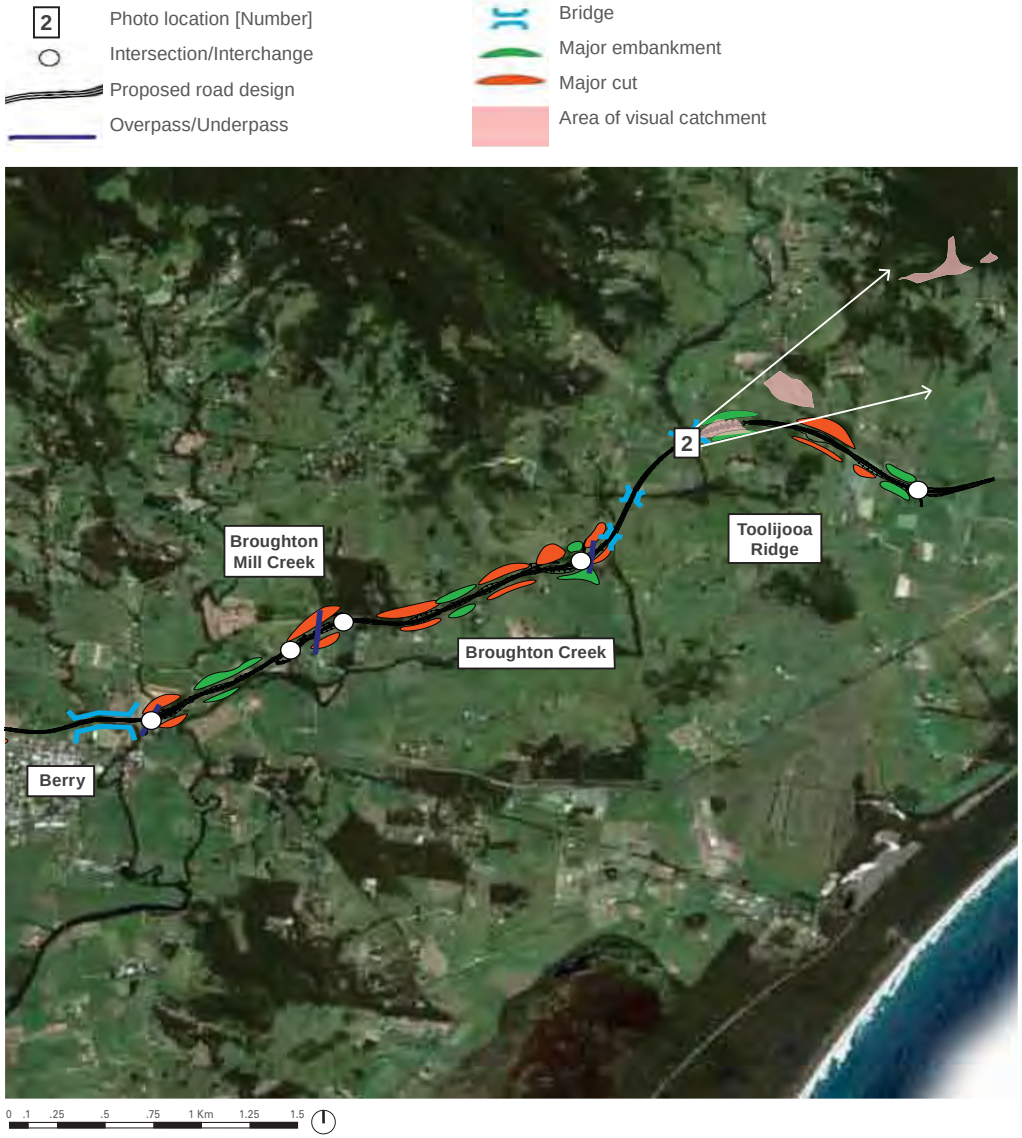


Figure 6.33 Artist's impression location 2 showing view shed coverage

Location #02: The viewpoint has been taken from Broughton Creek looking north east across the creek to the west side of Toolijooa Ridge.
Location Lat: -34.746335° Long: 150.760087° Elev: 36 m (asl) Facing: East North East

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

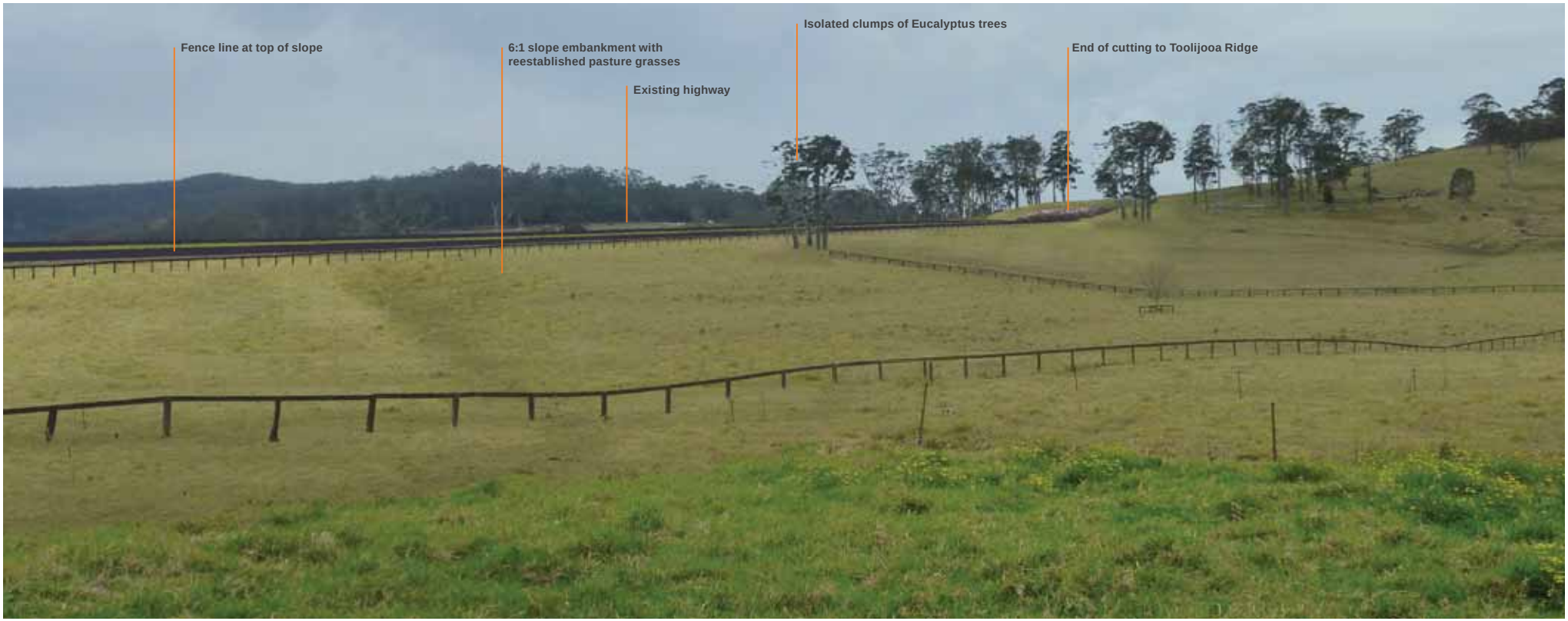


Figure 6.34 Artist's impression from viewpoint 2 (Note: vegetation shown with approximately 10-15 years of growth)

6.8.3 Artist's impression three - Bridge two over Broughton Creek

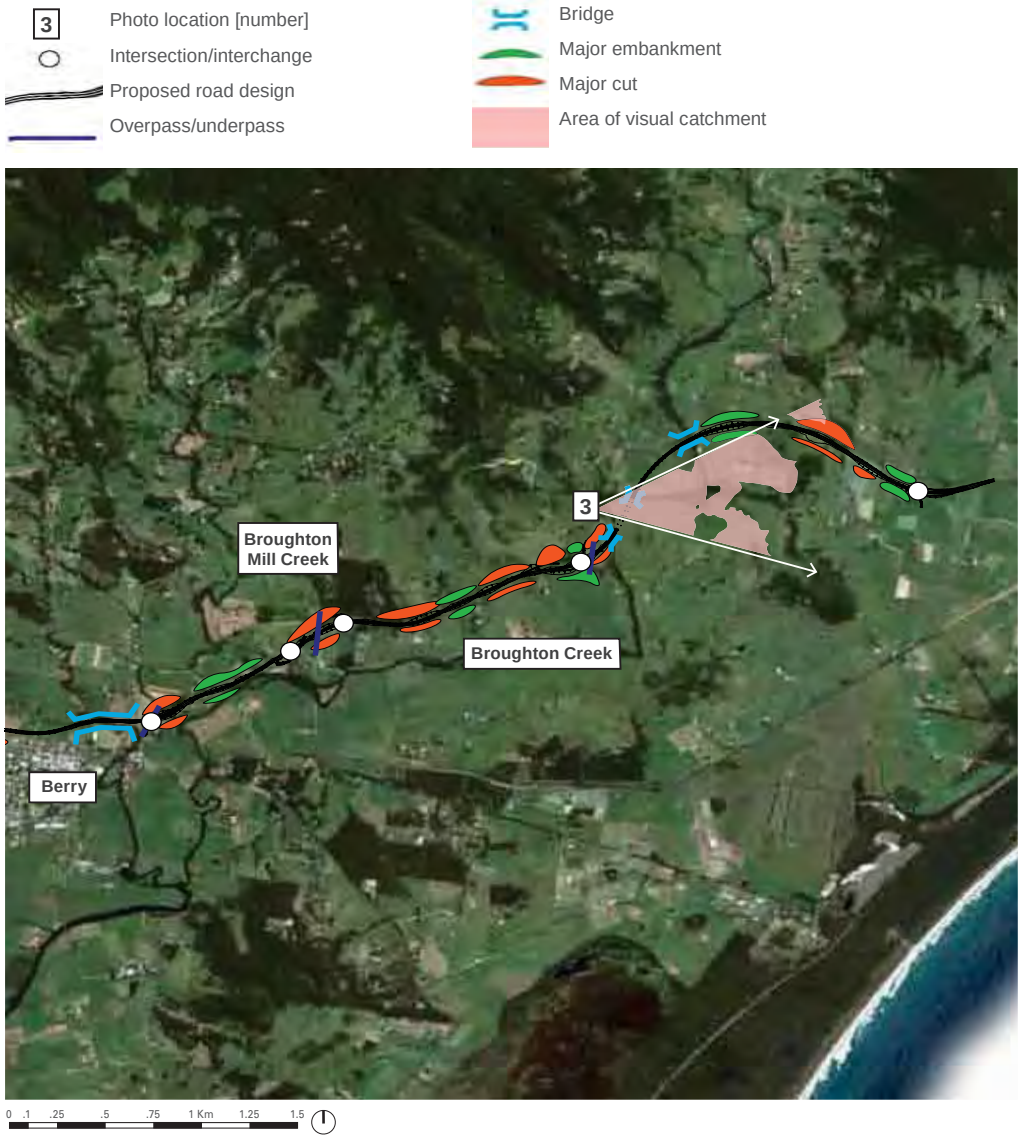


Figure 6.35 Artist's impression location 3 showing view shed coverage

Location 03: The viewpoint has been taken from the existing Princes Highway looking east to Broughton Creek.
Location Lat: -34.752235° Long: 150.749788° Elev: 54 m (asl) Facing: East

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

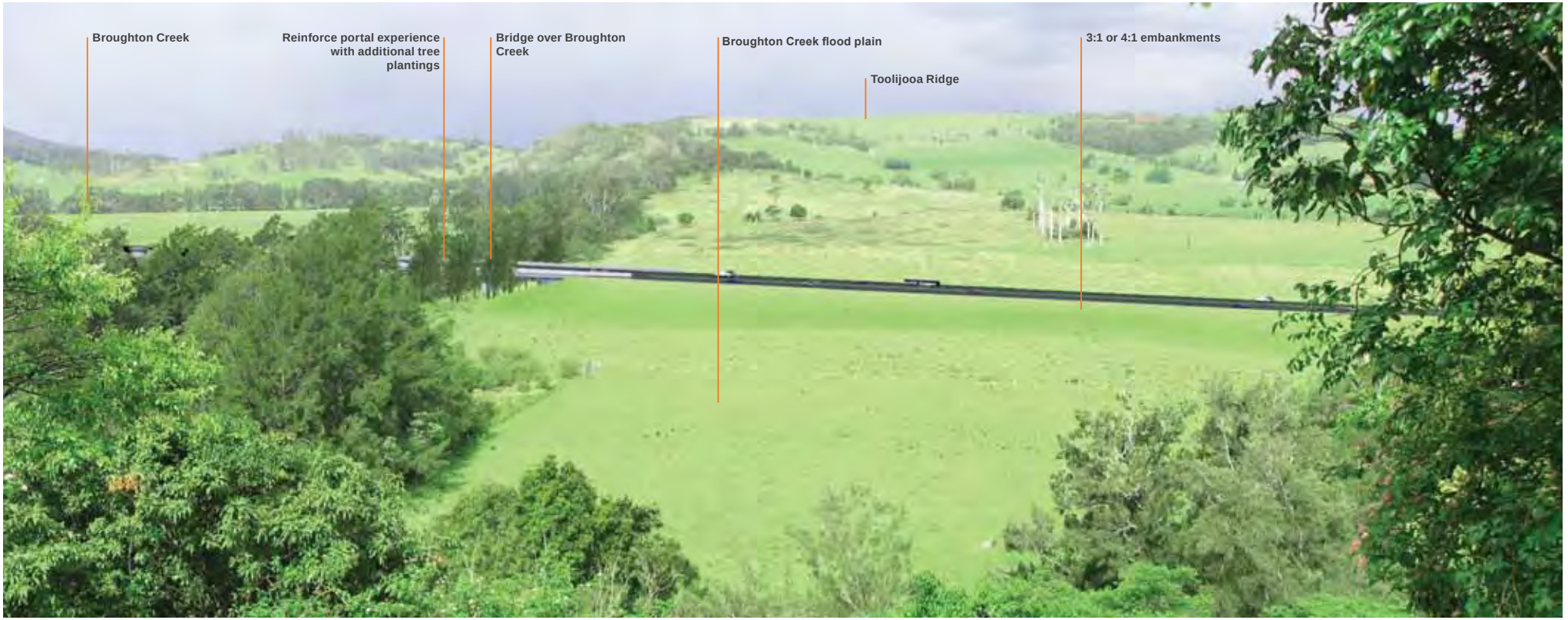


Figure 6.36 Artist's impression from viewpoint 3 (Note: vegetation shown with approximately 10-15 years of growth)

6.8.4 Artist's impression four - Bridge three over Broughton Creek

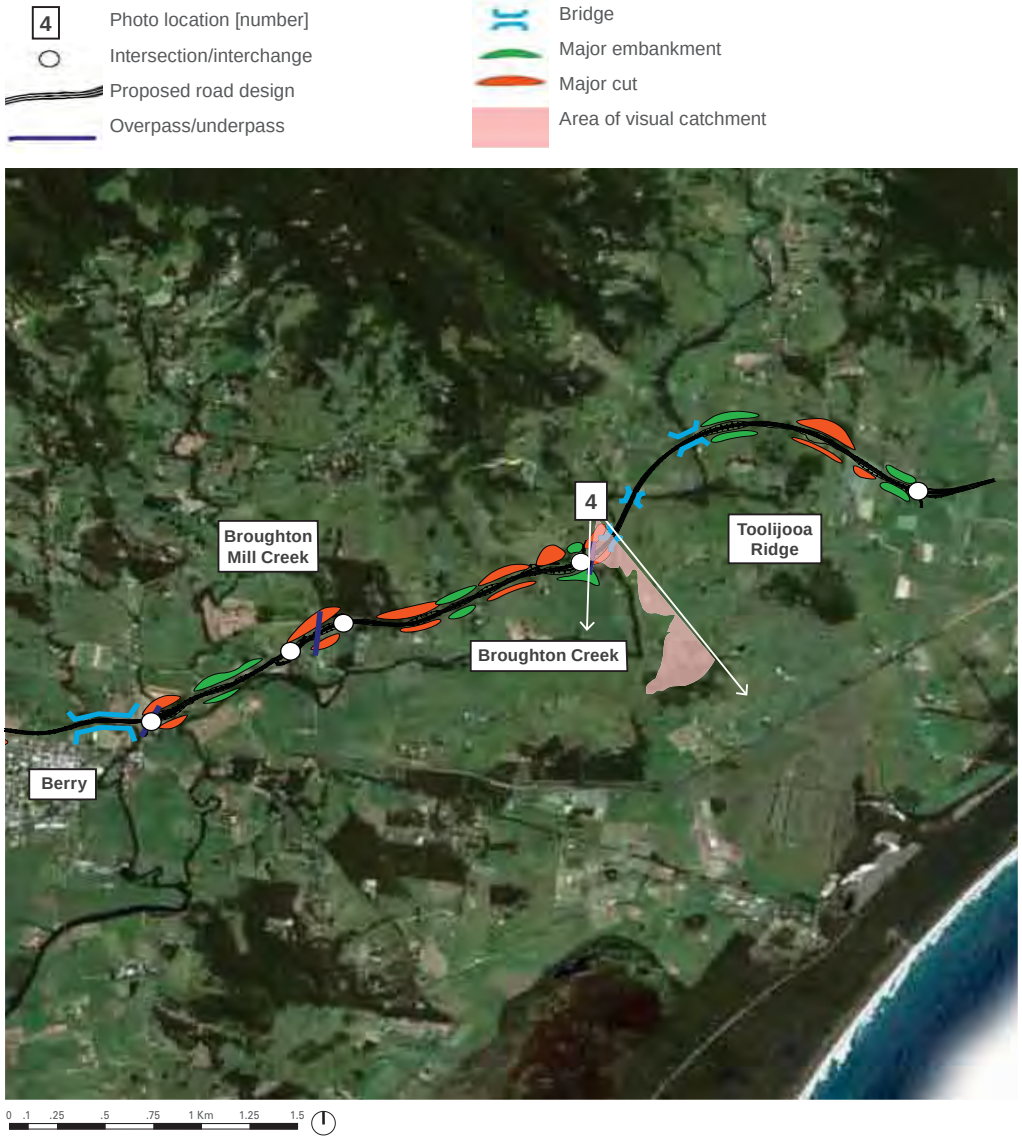


Figure 6.37 Artist's impression location 4 showing view shed coverage

Location 4: The viewpoint has been taken from the existing Princes Highway just north of Austral Park Road looking south east to Broughton Creek.
Location Lat: -34.754075° Long: 150.749562° Elev: 38 m (asl) Facing: South east

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

Figure 6.38 Artist's impression from viewpoint 4 (Note: vegetation shown with approximately 10-15 years of growth)

6.8.5 Artist's impression five - looking south to the bridge at Berry

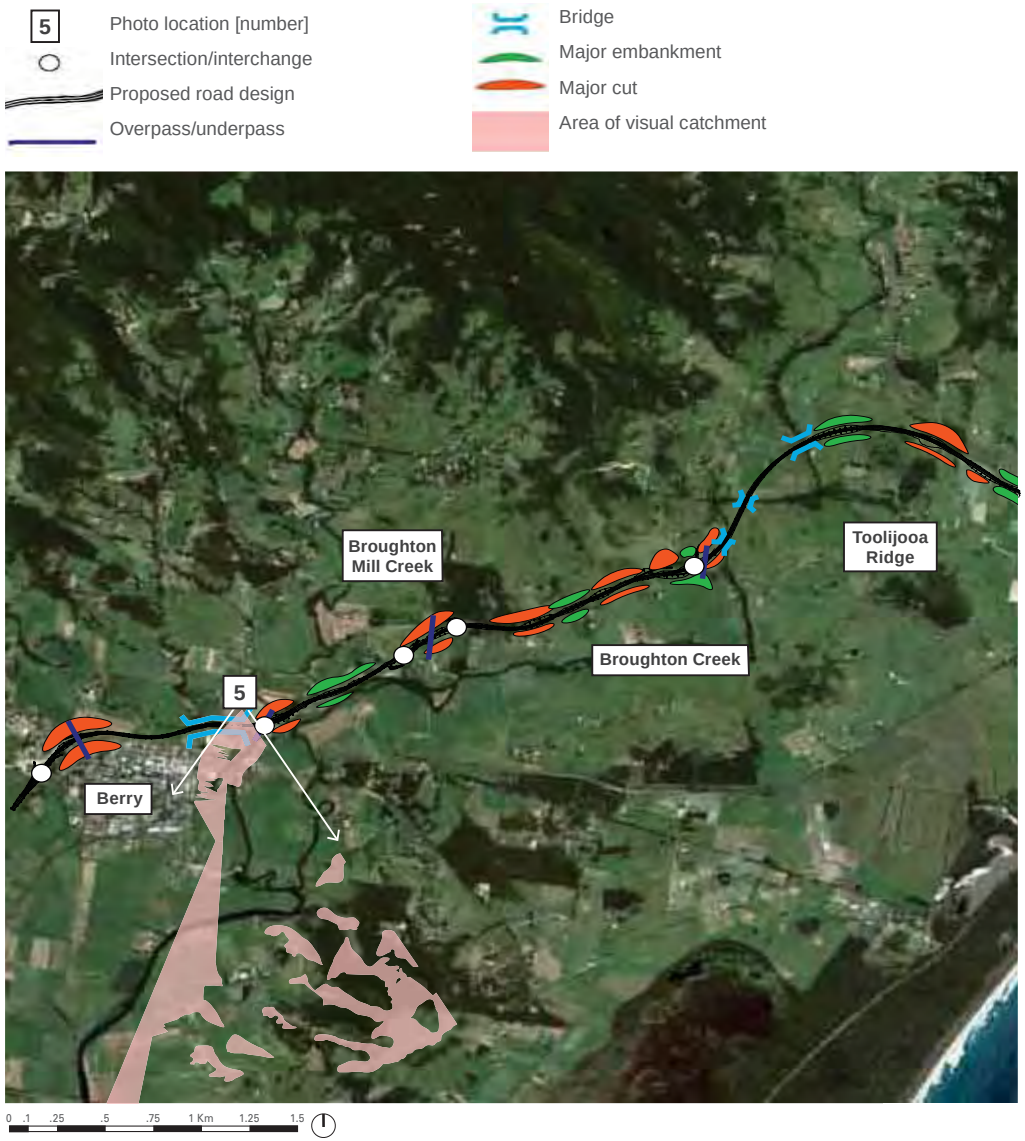


Figure 6.39 Artist's impression location 5 showing view shed coverage

Location 5: The viewpoint has been taken from Woodhill Mountain Road looking south to Bundewallah Creek and the proposed bridge at Berry.
Location Lat: -34.770440° Long: 150.703588° Elev: 9 m (asl) Facing: South

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

Figure 6.40 Artist's impression from viewpoint 5 - Bypass of Berry

6.8.6 Artist's impression six - looking south to Berry bypass

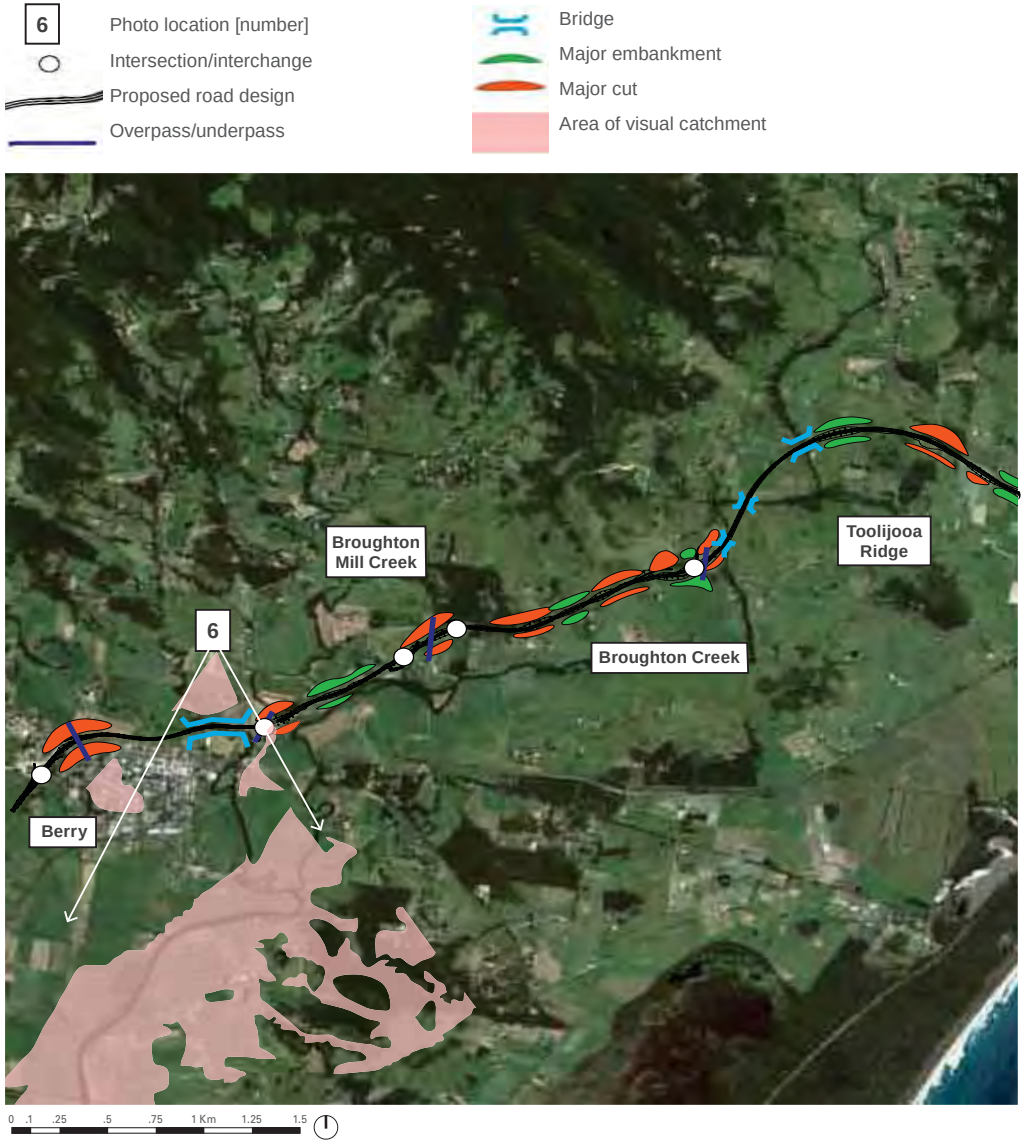


Figure 6.41 Artist's impression location 07 showing view shed coverage

Location 6: The viewpoint has been taken from Bong Bong looking south towards Berry.
Location Lat: -34.764212° Long: 150.701495° Elev: 13m (asl) Facing: south

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

Figure 6.42 Artist's impression from viewpoint 6

6.8.7 Artist's impression seven - Berry sports grounds looking north

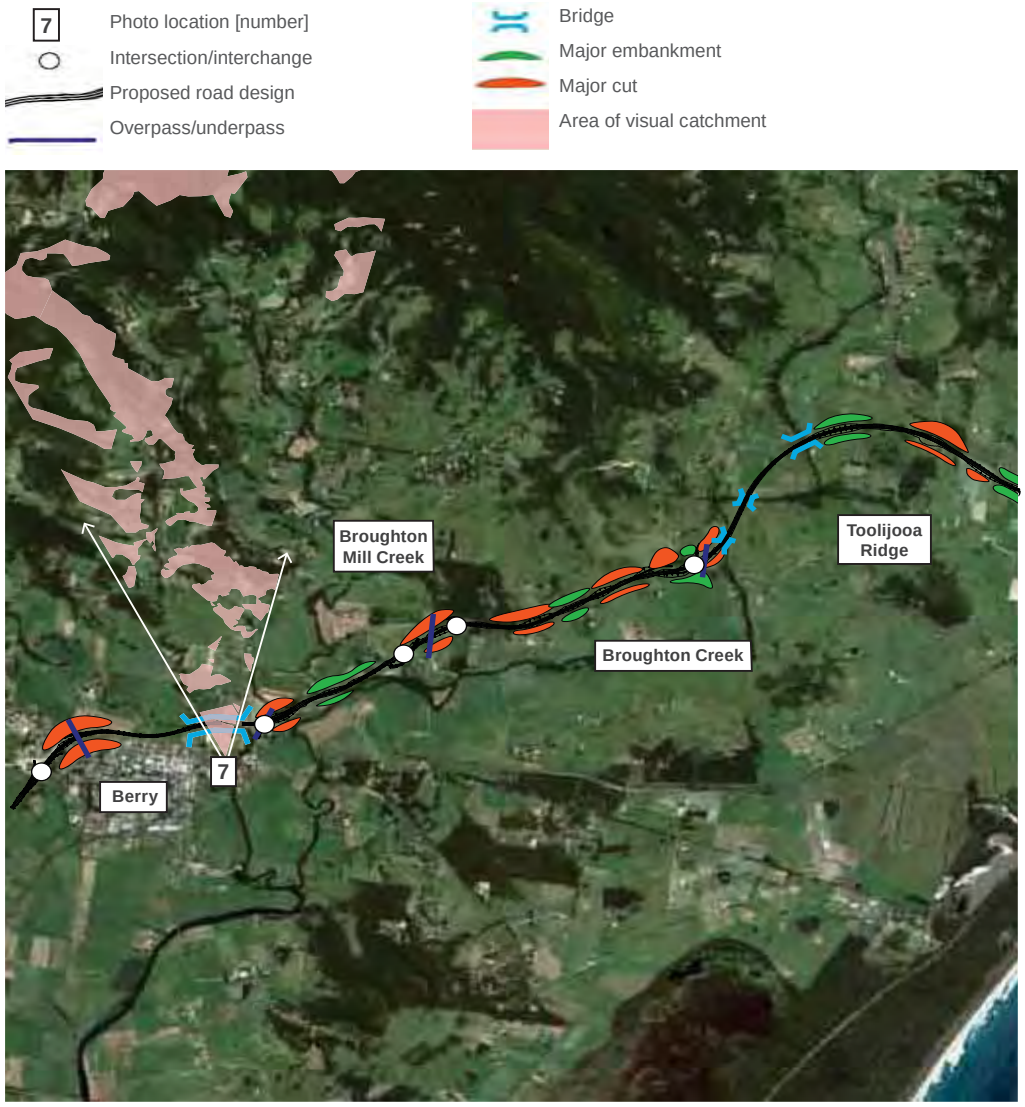


Figure 6.43 Artist's impression location 8 showing view shed coverage

Location 7: The viewpoint has been taken from intersection of North Street and Woodhill Mountain Road looking north across Berry sports grounds.
Location Lat: -34.773992° Long: 150.702185° Elev: 9m (asl) Facing: north

Existing view

Site photo showing extent of proposed construction works (wireframe) / 12D model

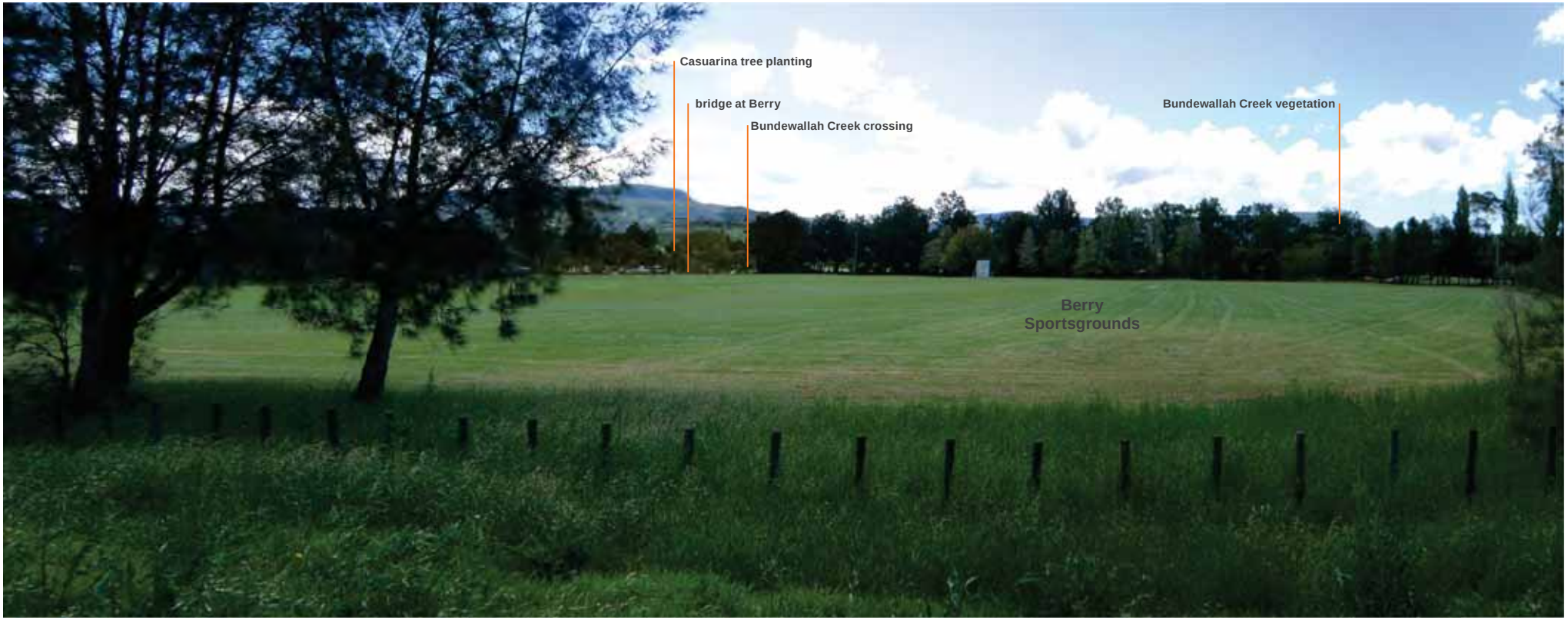
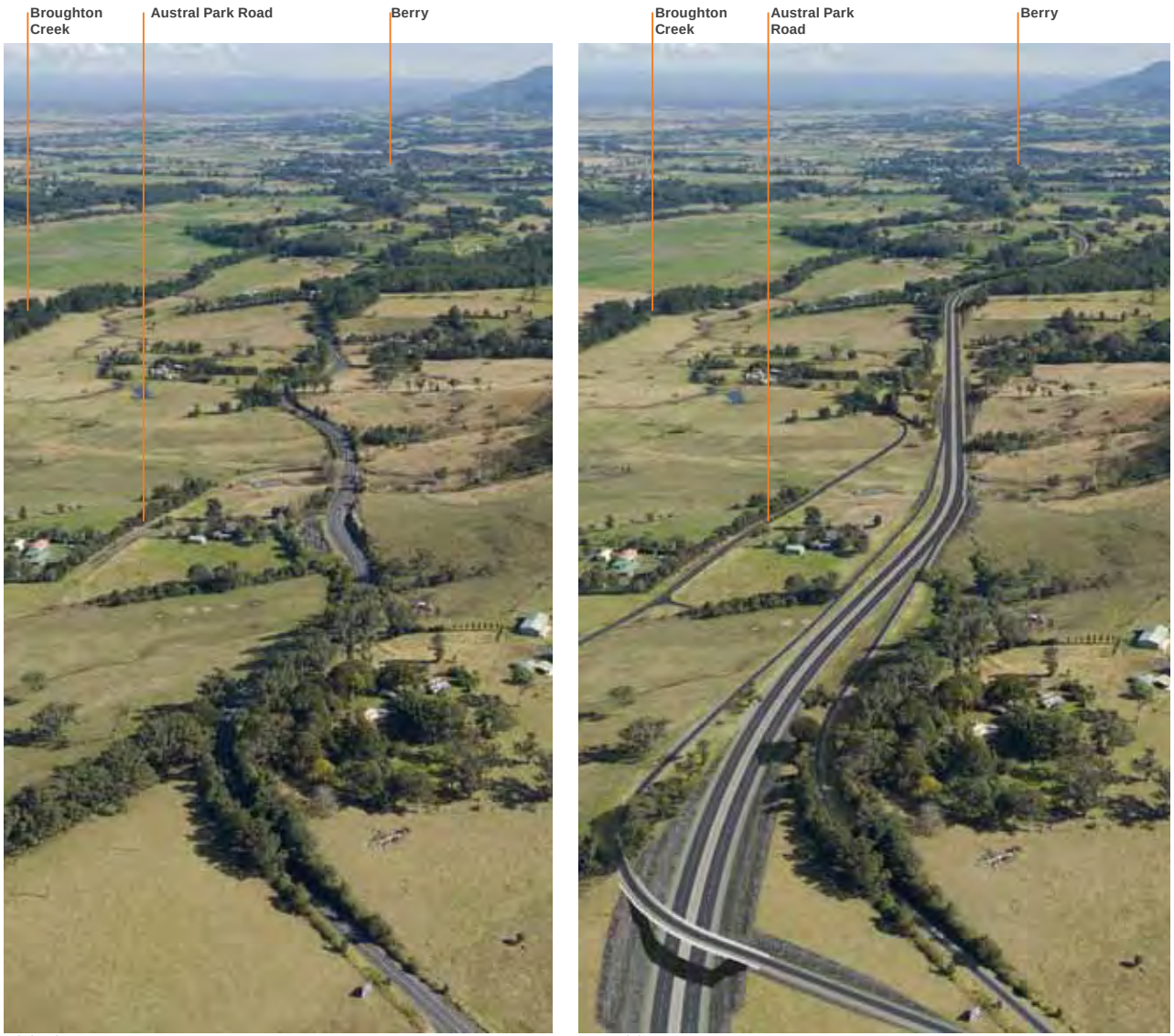


Figure 6.44 Artist's impression from viewpoint 7 (Note: vegetation shown with approximately 10-15 years of growth)

6.8.8 Aerial artist's impression #A - Austral Park Road

Location #A: North of residual highway interchange near Austral Park Road looking south west towards Berry.



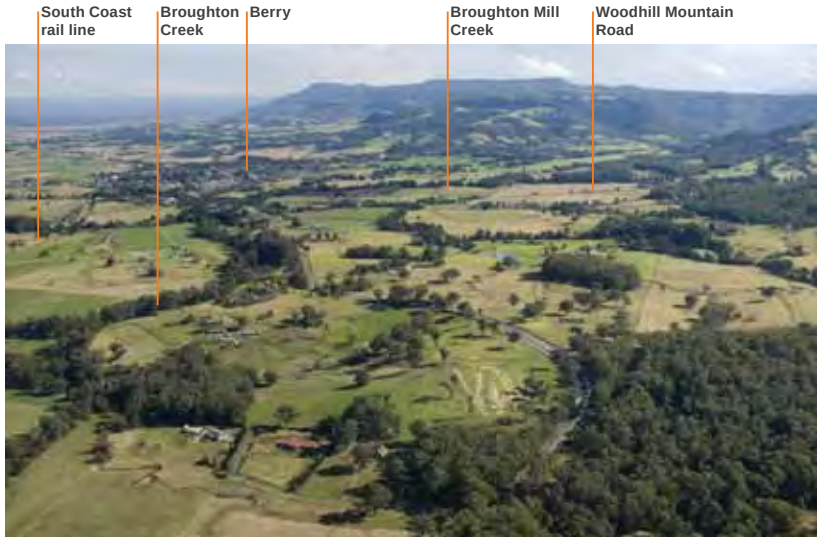
Existing view

Proposed view

Figure 6.45 Before and after illustrations of the project at Austral Park Road (Note: vegetation shown with approximately 10-15 years of growth)

6.8.9 Aerial artist's impression #B - Tindalls Lane

Location #B: Tindalls Lane interchange looking south west towards Berry.



Existing view

Proposed view

Figure 6.46 Before and after illustrations of the project at Tindalls Lane (Note: vegetation shown with approximately 10-15 years of growth)

6.8.10 Aerial artist's impression #C - Southern Berry interchange

Location #C: West of Mark Radium Park looking north east to south Berry interchange.

Existing view

Proposed view

Figure 6.47 Before and after impressions of the project at Kangaroo Valley Road

6.8.11 Artist's impression eight - North Street near Edward Street

Existing view (refer to Figure 6.29 for location on North Street)

Proposed view - without landscape treatment

Figure 6.48 Artist's impression from location eight showing established landscape. Image provided courtesy of CM+ (2012)

6.8.12 Artist's impression nine - North Street and Albany Street

Existing view (refer to Figure 6.29 for location on North Street)

Proposed view - without landscape treatment

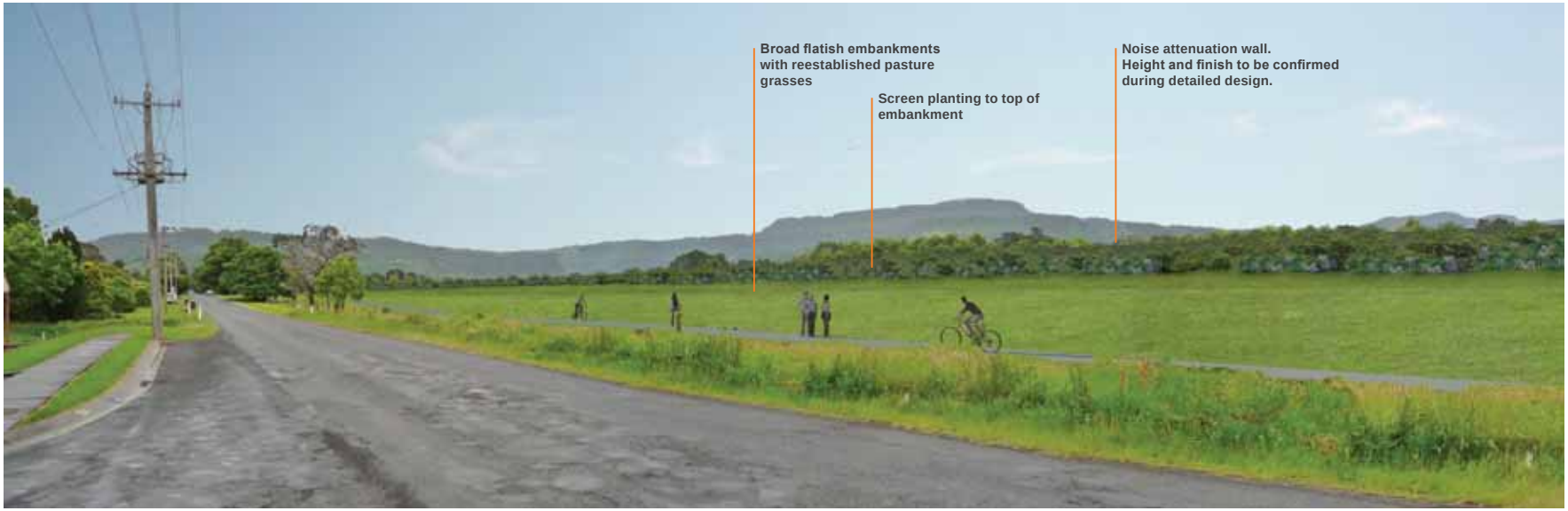


Figure 6.49 Artist's impression from location nine showing established landscape. Image provided courtesy of CM+ (2012)

6.8.13 Artist's impression ten - North Street and Alexandra Street

Existing view (refer to Figure 6.29 for location on North Street)

Proposed view - without landscape treatment

Figure 6.50 Artist's impression from location ten, showing established landscape. Image provided courtesy of CM+ (2012).

6.8.14 Artist's impression eleven - North Street and Prince Alfred Street

Existing view (refer to Figure 6.29 for location on North Street)

Proposed view - without landscape treatment

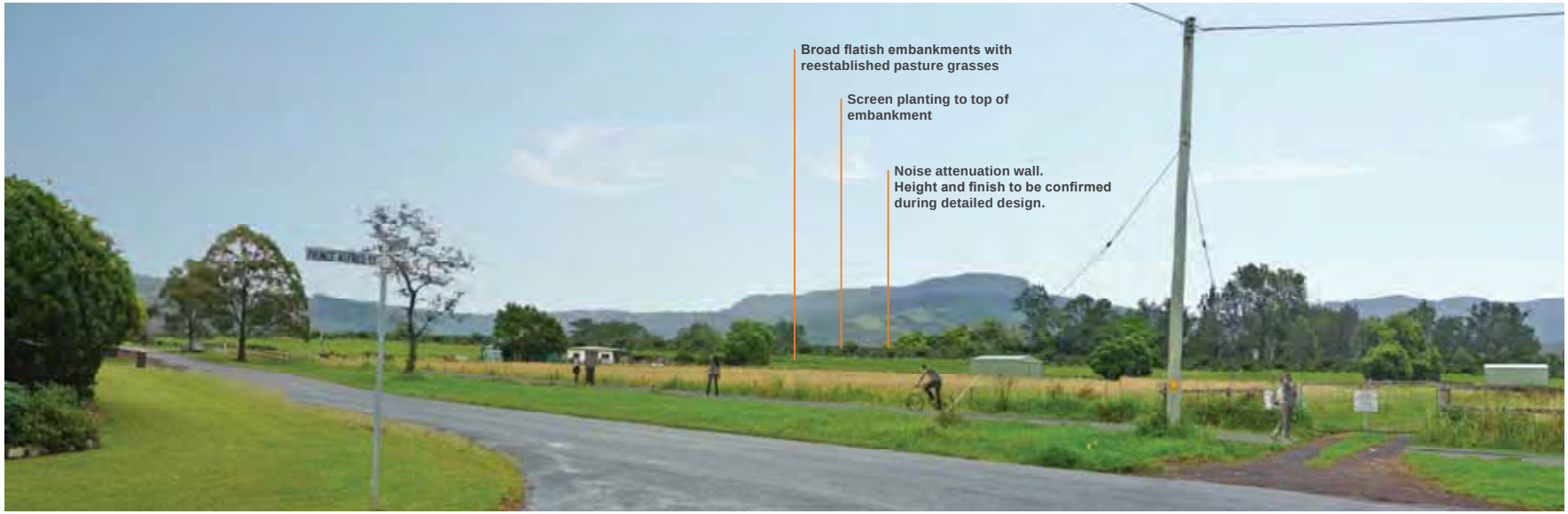


Figure 6.51 Artist's impression from location eleven, showing established landscape. Image provided courtesy of CM+ (2012).

7

Mitigation and management measures

7 Mitigation and management measures

Landscape character impacts and visual impacts from the project are described in **Section 6.0** with recommended mitigation measures outlined. In this section, actual mitigation and management strategies to be applied to the project are identified in response to the impacts that arise from the project. In general, the mitigation measures would seek to:

- Reduce the physical impacts of the project to the minimum required to achieve the project objectives.
- Facilitate landscape and urban design outcomes that resolve other project opportunities and constraints including:
  - Balancing cut and fills.
  - Utilising RMS owned land along the corridor to facilitate increasing the short term footprint of the project to reduce the long term footprint and therefore maintenance requirements (primarily through the return to pasture land).
- Integrate new vegetation with the existing landscape character by using culturally relevant species planted to existing patterns.
- Engage with the local community to gather feedback as the design develops, foster broader community support and ownership for the design outcome and facilitate integration with existing pedestrian access mobility plans (PAMP) for the township of Berry.
- Clearly define where the transition points occur between the highway and local street networks.
- Design retaining wall structures, cut embankments, fill slopes and bridges and associated elements in accordance with the Urban and Landscape Design Strategy (refer to **Section 4.0**).
- Engage adjacent land owners to assess whether early works mitigation (eg. landscape planting) can help reduce or soften the visual impacts of the project.
- Clarify minimum reference design requirements of the following project components:
  - The eight bridges within the project.
  - The embankments across Broughton Creek west of Toolijooa Ridge.
  - The noise mitigation measures required along the North Street corridor and at Huntingdale Park Road.

Table 7.1 sets out the specific mitigation and management measures that would be implemented in response to the impacts at the eight viewpoints analysed in **Section 6.0** and through the community engagement and the outcomes of that process captured in Appendix A.

These mitigation measures are implemented in the Concept Urban Design plan in **Section 3.0,** within the artist's impressions for each of the eight viewpoints in **Section 6.0.**

It is assumed in this assessment that all of the relevant environmental management requirements relating to sound, dust control, minimum buffer distances, noise and vibration will be met. The landscape and urban design recommendations are focused on requirements that would integrate with and support the proposed environmental management strategies.

7.1 Reference design parameters

Reference design elements

During the concept design process it was determined that the following components of the project would be required to meet a set of minimum reference design requirements. These components include:

- The first two bridge crossings of Broughton Creek.
- The third bridge crossing of Broughton Creek.
- The two overpasses of the proposed highway at Austral Park Road and Tindalls Lane.
- The bridge at Berry.
- The noise mitigation measures to North Street and the North Street corridor.
- The Kangaroo Valley Road interchange and bridge and noise attenuation, at the northbound off ramp.

Table 7.2 outlines the reference design parameters for each of the proposed bridge structures.

Table 7.3 outlines the reference design considerations for the North Street sound attenuation and south Berry interchange.

Table 7.1 Mitigation and management measures

Landscape unit and Artist's impression viewpoint no:	Potential impacts identified in landscape character and visual impact assessment	Design responses mitigation and management measures
VP 1 Looking north east from existing highway to proposed highway and cutting. Landscape unit - Toolijooa.	• Large intervention in the landscape where there is currently no infrastructure. • Relative open nature of the landscape means that the cutting is clearly visible.	• Steepen rock batters at base of cutting. • Keep benching levels consistent and in parallel with the vertical geometry of the highway. • Roll out top of cutting and reestablish pasture grasses and scattered tree planting. • Establish tree planting across the top of the cutting to provide visual integration with adjacent landscape and to satisfy environmental requirements for fauna corridor connectivity.
VP 2 Looking north east from existing highway to proposed highway and cutting. Landscape unit - Broughton Creek.	• Large 2:1 batter slopes up to 16 metres in height contrast strongly with the existing landscape. • Open landscape means that new infrastructure is clearly visible.	• Flatten embankments and widen project footprint, which would be returned to pastureland following construction. • Reestablish pasture grasses and rural fencing to top of embankment slopes, maximising pastoral landscape. • Plant isolated clumps of Eucalyptus trees consistent with the immediate local context.

Landscape unit and Artist's impression viewpoint no:	Potential impacts identified in landscape character and visual impact assessment	Design responses mitigation and management measures
VP 3 Looking east from existing highway to proposed second bridge over Broughton creek. Landscape unit - Broughton Creek.	• Large intervention in the landscape where there is currently no infrastructure. • Flood immunity requirements result in elevated road and adjacent batter slopes that impact on agricultural landscape.	• Reinforce portal landscape at creek crossing. • Flatten batter slopes (where possible) from 2:1 to 4:1 to 10:1. • Reestablish pasture grasses and rural fencing as high as possible on embankment slopes, maximising agricultural and pastoral landscape. • Clearly identify construction works areas to reduce the extent of vegetation removed along the banks of Broughton Creek.
VP 4 - Looking east from existing highway to proposed third bridge over Broughton Creek. Landscape unit - Broughton Creek.	• Large elevated bridge would be clearly visible from the existing highway. • Removal of some existing creek line vegetation. • Bridge located in very close proximity to an existing residence. • Bridge abutment at southern end interfaces with a steep slope.	• Clearly identify construction works areas to reduce the extent of vegetation be removed along the banks of Broughton Creek. • Reinstate creek line vegetation to satisfy both environmental and aesthetic requirements. • Provide supplemental planting to the southern bridge abutment to reinforce the existing vegetation. • Provide minimum reference design requirements for the bridge. • Consult with property owner and consider relocation of residence.
VP 5 View of bridge at Berry from Woodhill Mountain Road. Landscape unit - Berry.	• Large piece of elevated infrastructure in close proximity to the town. • Heritage trees (Poplars) along Woodhill Mountain road screen the bridge in part but the northern elevation is relatively unbroken by existing vegetation. • To the east existing vegetation does help screen and reduce the overall bulk of the structure as it descends from the ridge line east of Berry.	• Consider early planting works to reduce visual impact of bridge structure. • Provide minimum reference design requirements for the bridge. • Provide *Casuarina cunninghamiana* planting at and around the abutment and adjacent embankments of the bridge landing. • Locate clumps of planting to reduce unbroken elevation of the bridge around Bundewallah Creek crossing point. • Minimise the loss of vegetation at the point where the bridge crosses Bundewallah Creek.
VP 6 North Street corridor looking south towards Berry from North of Bundewallah Creek. Landscape unit - Berry.	• There is little to no visual and or landscape character impact from this location.	• Consistent with the those recommended mitigation measures for the bridge at Berry and bypass from other viewpoint locations.
VP 7 Looking north from the corner of North Street across the sports ground to the Bridge at Berry. Landscape unit - Berry.	• Large piece of elevated infrastructure in close proximity to the town. • Proximity to sports grounds would result in visual and potential noise impacts. • Existing vegetation would help screen and reduce the overall bulk of the structure. • Bridge would be at its lowest elevation at the western end adjacent to proposed pedestrian linkages and the existing Camp Quality grounds.	With reference to the findings of the CM+ Urban Design Study outlined in Appendix A; • Consider early planting works to reduce visual impact of the bridge structure. • Provide minimum reference design requirements for the bridge. • Provide Casuarina planting at and around the abutment and adjacent embankments of the bridge landing. • Locate clumps of planting to reduce unbroken elevation of the bridge around Bundewallah Creek crossing point. • Minimise the loss of vegetation at the point where the bridge crosses Bundewallah Creek. • Engage with the local community to gather feedback as the design develops, foster broader community support and ownership for the design outcome and facilitate integration with existing PAMP for the township of Berry.
VP 8, VP 9, VP 10 and VP 11 North Street, looking north across to Bundewallah Creek and the ridges and escarpment. Landscape unit - Berry.	• Large piece of infrastructure in relative open flat landscape. • Potential to reduce viability of existing farmland. • Proximity to North Street would reduce amenity and outlook. • Visual impacts from noise attenuation walls.	With reference to the findings of the CM+ Urban Design Study outlined in Appendix A; • Use extensive mounding with maximum slopes of 4:1 to reduce the overall free standing height of noise walls. • Use planting to the top of mounding to screen the exposed facades of noise wall. • Engage with the local community to gather feedback as the design develops, foster broader community support and ownership for the design outcome and facilitate integration with existing PAMP for the township of Berry.

Table 7.2 Reference design requirements for proposed bridges

The project Bridge Reference Design requirements:								
Bridge Id	Bridge 1 Underpass at Toolijooa Road.	Bridge 2 Broughton Creek 1	Bridge 3 Broughton Creek 2	Bridge 4 Broughton Creek 2	Bridge 5 Overpass 1 Austral Park Road	Bridge 6 Overpass 2 Tindalls Lane	Bridge 7 Bridge at Berry	Bridge 8 Kangaroo Valley Road Bridge
Context	Open	Creek crossing open landscape with dense vegetation over creek line only .	Creek crossing open landscape with dense vegetation over creek line only.	Creek crossing and landing onto a steep hill in open landscape.	Open	Creek crossing open landscape with dense vegetation over creek line only.	Open pastoral landscape and well vegetated creek line.	Within the town of Berry, bridge over road cutting with highway below.
Visibility	Medium (open landscape in exposed location).	Low	Low	Medium to high.	Low to medium (high for road users).	Low – medium (high for road users)	Medium - due to overall length	Medium to high
Objectives	Make the bridge simple and elegant to complement the landscape. Keep consistent with other underpasses on the network upgrade (Gerringong upgrade).	Make the bridge as unobtrusive as possible to hide it in the landscape.	Make the bridge as unobtrusive as possible to hide it in the landscape.	Make the bridge as simple and elegant as possible to complement the landscape.	Make the bridge as simple and elegant as possible to complement the landscape.	Make the bridge as simple and elegant as possible to complement the landscape.	Make the bridge as simple and elegant as possible to complement the landscape.	Integrate the bridge into the existing urban arrangement and function of the township of Berry. Make the bridge as simple and elegant as possible to complement the landscape.
Bridge Type	Continuous super T – 1500mm deep	Continuous super T – 1500mm deep.	Continuous super T – 1500mm deep.	Continuous super T – 1500mm deep or alternative cast in place voided slab girder.	Cast in-situ box girder – single span.	Continuous super T – 1200mm deep.	Continuous super T – 1800mm deep.	Cast in-situ post tension voided slab.
Bridge Dimensions								
Approximate Width (m)	25	24	24	2.4	9.5	12.9	26.5	20
Approximate deck length (m)	32	16.7	7.6	19	55.2	60	600	47.8
Approximate Spans (m)	Single span	4 spans max 36 x 2 - min 24.5 x 2	3 spans max 36, x 1 - min 20 x 2	6 spans max 36, x 6 - min 23 x 2	Single span	3 spans max 40 x 1 - min 10 x 2	19 spans	Single span
Design elements								
Abutment	Spill through – equal proportion Stone pitched embankment underneath on 1.5:1 slope	Spill through – equal proportion Stone pitched embankment underneath bridge on 2:1 slope	Spill through – equal proportion Stone pitched embankment underneath bridge on 2:1 slope	Spill through – equal proportion Stone pitched embankment underneath bridge on 2:1 slope	Spill through – equal proportion. Stone pitched embankment underneath on 1.5:1 slope.	Spill through – equal proportion. Stone pitched embankment underneath bridge on 2:1 slope.	Spill through – equal proportion. Stone pitched embankment underneath bridge on 2:1 slope at southern end.	Reinforced soil wall, precast concrete panels. Stone pitched embankment underneath bridge on 1.5:1 slope.
Pier form and dimensions	Not applicable	Twin 'Y' shape, 3000 x 1800 with typical fillet of 600 millimeters	Twin 'Y' shape, 3000 x 1800 with typical fillet of 600 millimeters	Twin 'Y' shape, 3000 x 1800 with typical fillet of 600 millimeters	Not applicable.	Twin 'Y' shape, 3000 x 1800 with typical fillet of 600 millimeters .	3 x circular column pier, 1200 millimeter diameter.	Not applicable.
Parapet / Bridge Barriers	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail	Standard RMS integrated concrete barrier and double rail to south side, pedestrian railing integrated with safety screen to north side
Headstocks (exposed)	Not applicable	None	None	None	Not applicable.	None	Expressed	None/not applicable.
Safety screens	Not required	Not required	Not required	Not required	Required	Not required	Not required	Required
Lighting	Not required	Not required	Not required	Not required	Not required	Required	Not required	Required to be setout symmetrically with the bridge spans.
Noise screens	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Colour	Natural concrete	Natural concrete	Natural concrete	Natural concrete	Natural concrete	Natural concrete	Natural concrete	Natural concrete

Table 7.3 Reference design requirements for North Street sound attenuation and South Berry interchange

North Street - Sound attenuation requirements
Consistent with the requirements of RMS' 'Noise Wall Design Guidelines: Design Guidelines To Improve The Appearance of Noise Walls in NSW' (RMS, 2006), and with reference to the findings of the CM+ Urban Design Study outlined in Appendix A, the detailed design of the noise attenuation measures along the North Street corridor would:
• Use mounding to reduce the free standing height of the noise wall. The mounding would have a maximum slope of 2:1 at pinch points with a preferred maximum of 4:1.
• Establish a rhythm with the noise attenuation wall and its planting that reflects the Berry street grid.
• Use planting on the northern side of the wall, consistent with RMS planting guidelines, a canopy and ground cover species consistent with the local landscape character.
• Use planting on the southern side of the noise wall consistent with the existing character along North Street.
• Engage with the local community to gather feedback as the design develops, foster broader community support and ownership for the design outcome and facilitate integration with existing PAMP for the township of Berry.
South Berry interchange / Kangaroo Valley Road precinct
With reference to the findings of the CM+ Urban Design Study outlined in Appendix A, the detailed design of the Kangaroo Valley Road bridge precinct would:
• Consider the broader context of the project including the roundabouts and the connections into Queen Street and Kangaroo Valley Road.
• Allow for a 2.5 metres wide shared path on both sides of the bridge that connects with the broader PAMP plan for Berry.
• Include a landscape verge between the shared path and carriageway across the bridge.
• Include landscaping to the roundabouts that is consistent with the landscape character of Berry.
• Use street lighting arranged to compliment the rhythm of the bridge and of a scale consistent with the local road network.
• Use ornamental tree planting to define and identify the space as a continuation of the Queen Street / Kangaroo Valley Road corridor.

Appendix A

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Conybeare Morrison

Berry Bypass Urban Design Strategy

October 2012

Conybeare Morrison International
52 - 58 William Street
East Sydney, NSW 2011
T. +612 8244 8888 F. +612 8244 8877
E. mail@cmplus.com.au
www.cmplus.com.au
12001

Conybeare Morrison

Berry Bypass Urban Design Strategy

Ocotober 2012

Prepared for Roads and Maritime Services

Conybeare Morrison International
52 - 58 William Street
East Sydney, NSW 2011
T. +612 8244 8888 F. +612 8244 8877
E. mail@cmplus.com.au
www.cmplus.com.au

12001

Revision	Date	Description	By	Chk	App
01	10/08/12	Final Report	DA/CT	EC	DC
02	16/08/12	Final Report - Client comments	DA/CT	EC	DC
03	20/08/12	Final Report - Aecom comments	DA/CT	EC	DC
04	30/10/12	Final Report - Update	DA		

Glossary

Carriageway
Road surface used by vehicles, including both traffic lanes and shoulders.

CLD
Context Landscape Design

CRG
Community Reference Group.

CPTED
Crime Prevention Through Environmental Design - the design of the built environment which can lead to a reduction in fear of crime and incidence of crime.

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Cycle Path
A path dedicated for cyclist use.

EA
Environmental Assessment.

Footpath
Pavement for use by pedestrians and the disabled.

Footway
Zone between road kerb and road reservation boundary, typically incorporating a footpath and/or nature strip.

LGA
Local Government Area.

Parapet
Traffic crash barrier at the edge of a bridge, viaduct or tunnel portal structure.

Road Reservation
Corridor for road carriageway, footways, batter slopes, etc.

RMS
Roads and Maritime Services, NSW

SCC
Shoalhaven City Council

Shared Path
Pathway shared by both pedestrians and cyclists.

Shoulder
The portion of a carriageway beyond the traffic lanes adjacent to, and flush with, the pavement surface.

The Proposal
Works associated with the proposed Foxground and Berry Bypass, including associated parks, local road, pedestrian and cyclist facilities.

Type F Barrier
Tapered, redirective, concrete traffic safety barrier.

Undercroft
Area under a bridge without access to direct sunlight and rain.

Verge
Part of a road formation, not sealed, with a carriageway, footpath or cycleway.

Visual Catchment
The area from which an object is viewed.

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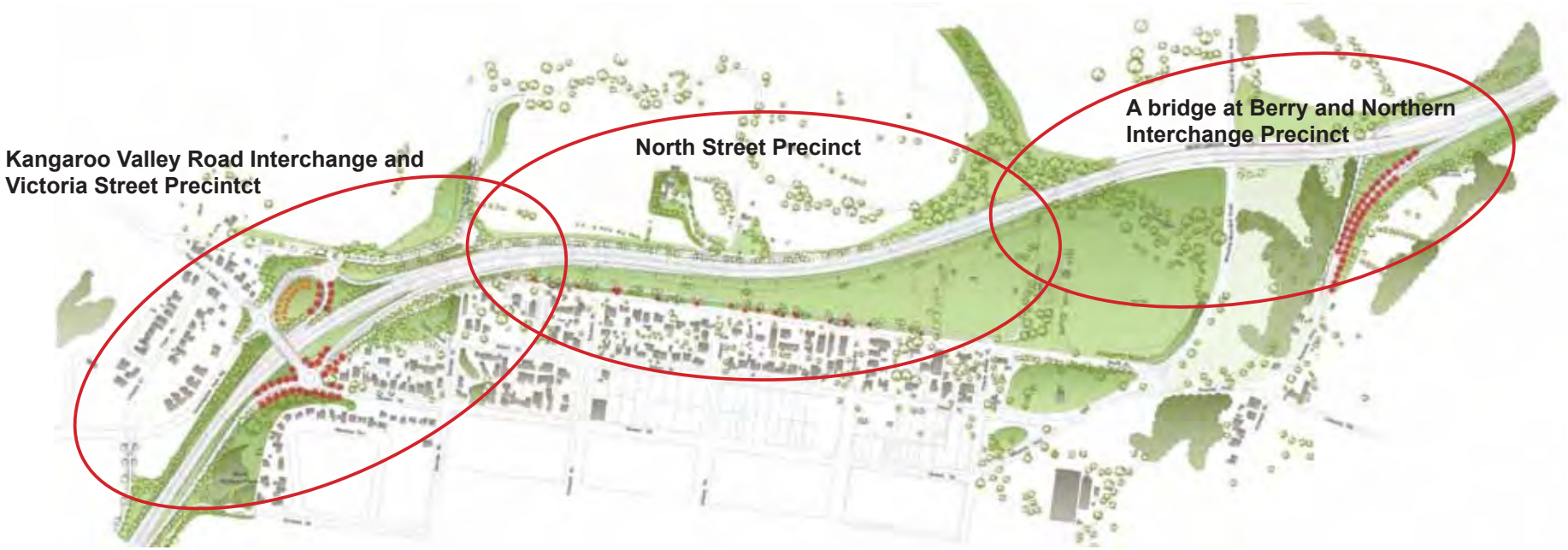

Figure 1: North Berry bypass route study precincts.

1.0 Introduction

1.1 Purpose

This report describes the Urban Design Strategy for the bridge at Berry and Northern Interchange Precinct, the North Street Precinct, and the Kangaroo Valley Road and Victoria Street Precinct, of the Foxground and Berry Bypass project. Refer to Figure 3.

1.2 Study objectives

The study objectives are to:

- Establish an integrated urban design vision for the Foxground and Berry Bypass.
- To develop an urban design strategy report for Berry that is consistent with and supports the overall Urban Design Report, Landscape Character and Visual Impact Assessment for the Foxground and Berry Bypass project.
- To identify urban design opportunities and concepts for adjoining Berry streets and interfaces that are consistent with community feedback and any existing pedestrian access and mobility plans (PAMP).
- To prepare a suite of preferred urban design mitigation measures that informs the setting of reference design parameters for future detailed design works.

1.3 Scope

The study focuses on the approximately 2.5km section of the Foxground and Berry Bypass (FBB) route that is proposed to the north of Berry, in the vicinity of the township, extending from the Northern Interchange to the northeast of Berry, to the Kangaroo Valley Road Interchange to the west.

The study area includes the bridge at Berry and Northern Interchange Precinct, the North Street Precinct, the Kangaroo Valley Road and Victoria Street Precinct, and all associated works required to integrate the project with the local street network, property access, pedestrian and cyclist connections, and includes the urban and landscape design of 'residual land parcels' that would be utilised for the agistment of stock or for public open space.

1.4 Consultation - a collaborative design process

The development of the Urban Design Strategy has involved an iterative working process - identifying urban design opportunities, developing concept design options, and testing these through 3D modelling and photomontage.

The urban design process has benefited from the feedback provided from a community engagement process commenced in 2011 and followed by a series of community workshops held in Berry in 2012. Also from meetings with key stakeholders such as Shoalhaven City Council (SCC) and through the review of fellow design professionals - a collaborative design process, working with the RMS Project Design Team, including the RMS Project Manager, Environmental Assessment (EA) Manager and Urban Design Manager, including the design engineers at Aecom and the specialist Bridge Designers of the Aurecon Group.

1.5 Study precincts

The Berry Bypass Urban Design Strategy encompasses three interconnected study precincts:

Refer to Figure 1.

- A bridge at Berry and Northern Interchange Precinct
- North Street Precinct
- Kangaroo Valley Road Interchange and Victoria Street Precinct

This report and the associated community consultation groups are structured, based on these three interconnected precincts.

Opportunities

1. Township street grid and North Street integrity
2. Berry north-south streets
3. Maximise views to the Cambewarra Escarpment
4. Recreational green space
5. Celebrate Berry arrival/departure
6. Minimise the visual prominence of the bypass and noise mitigation barriers
7. A new pedestrian/cycle circuit
8. Facilitate viable dairy farming
9. Preserve existing stands of trees
10. Improve Town Creek environment

Figure 2: Urban design opportunities.

2.0 Opportunities and constraints

2.1 Key Constraints

During the analysis phase of the project the following bypass urban design constraints were identified:

Flooding, drainage and water table

Drainage issues, due to the high water table, limit the potential for the bypass to be significantly depressed.

Homestead curtilage and farm viability

The bypass alignment and footprint has in part been guided by the need to establish a reasonable visual curtilage of the existing homestead and garden (to the north of North Street), to provide alternate vehicular access, and sufficient flood-free high ground for regular pastureland for a viable dairy farm.

Berry township urban integrity and legibility

The Berry township street grid and development blocks should be retained wherever possible, and the alignment of the Berry Bypass should respect the existing street and development pattern.

North Street streetscape integrity

The integrity of the North Street streetscape should be retained and strengthened through urban and landscape design improvements.

Bypass user safety (engineering geometry standards)

A safe Bypass roadway at 100km/hour speed limit is a mandatory design requirement. This includes ensuring minimum radius road curvatures and a horizontal rise and fall necessary to achieve sightline and safety requirements.

Construction factors

There would be a significant increase in road construction cost if the bypass alignment was to encroach north of Bundewallah Creek into flood prone areas.

Berry sports field

Berry sports field provides an important recreational facility for the Berry community. The field and surrounding landscape backdrop to the north should be protected.

Maintain escarpment views

The height of the Bypass road level and associated noise mitigation devices should be carefully designed, in order to maximise views from North Street to the Cambewarra Escarpment.

CRG agreed major road alignments

The bypass alignment, as agreed with the Community Reference Group (CRG) in 2011, is now established.

Noise attenuation requirements

Noise attenuation barriers would be necessary at various locations along the bypass alignment.

2.2 Opportunities

The following bypass urban design opportunities were been identified: (refer to Figure 2)

(1) Township street grid and North Street integrity

Preserve existing street corridor and improve streetscape definition and amenity through the design of recreational green space and street trees.

(2) Berry north-south streets

Provide a fitting northern, physical and visual, resolution of the Berry township north-south oriented streets: George, Edward, Albany, Alexandra and Prince Alfred Streets.

(3) Maximise views to the Cambewarra Escarpment

Lower the alignment as much as drainage requirements would allow and explore noise mitigation measures that maximise views to the escarpment.

(4) Recreational green space

Provide an ‘arc’ of connected recreational green spaces along the southern edge of the bypass, extending from Berry sports field in the east to Mark Radium Park and potentially further to the southwest.

(5) Celebrate Berry arrival/departure

Kangaroo Valley Road Interchange (and Queen Street, west) and the Northern Interchange are opportunities to incorporate special feature planting and high quality overbridge design to mark the arrival in Berry.

(6) Minimise the visual prominence of the bypass and noise mitigation barriers

Incorporate ‘Ha Ha’ landforms and landscaped mounds to integrate noise mitigation devices in the landscape, and to screen the bypass roadway from view - retaining escarpment views.

(7) A new pedestrian/cycle circuit

There would be an opportunity to establish a new walking/cycle route along the bypass corridor, extending from Mark Radium Park and Kangaroo Valley Road in the west along North Street to Berry sports field in the east.

(8) Facilitate viable dairy farming

Maintain conditions for viable dairy farming - maintaining sufficient flood free, high ground and general pastureland to the north of the bypass alignment.

(9) Preserve existing stands of trees

Consolidate existing trees to the north of Berry sports field (along Connolly’s Creek), at the Queen Street and Kangaroo Valley Road intersection and at Mark Radium Park.

(10) Improve Town Creek environment

Restore the upper reaches of Town Creek (to the south of the bypass), as the beginnings of a potential new recreational green space following the creekline.

Figure 3: Overall Berry Bypass plan.

3.0 Overall urban design strategy

The urban design approach has been one that pursues an integrated outcome. We understand there needs to be an overall urban design 'vision' for the future development of Berry (i.e. not simply a focus on the Bypass corridor in isolation). The design approach has been holistic in outlook, considering the urban design of the Berry Bypass in relationship to the urban structure, character and evolution of the Berry township as a whole. The strategy aims to achieve integrated urban planning outcome that would be forward looking, and serve Berry in the long term.

3.1 Overall urban design objective

The following overall urban design objective has guided the Urban Design Strategy:

3.1.1 A bridge at Berry and Northern Interchange Precinct

To integrate the bridge at Berry and Northern Interchange structures and earthworks within the picturesque rural landscape of northeast Berry.

3.1.2 Northern Precinct

To integrate the Berry Bypass within the northern township periphery and the picturesque rural landscape to the north of Berry.

3.1.3 Kangaroo Valley Road Interchange and Victoria Street Precinct

To integrate the Berry Bypass within the western edge of the township, including the Kangaroo Valley Road and Huntingdale Park communities, and within the picturesque rural landscape of Berry.

3.2 Coordinated project elements

The Urban Design Strategy seeks to realise a design outcome where all project elements are fully coordinated and contribute towards the overall project 'vision'. Project elements include:

- Interchanges, bridges and throw screens.
- Cut and fill batters, retaining walls, noise walls/mounds.
- Lighting, township place making signage.
- Corridor endemic and cultural landscape.

Figure 4: Overall Berry Bypass photomontage.

3.3 Berry recreational circuit and key pedestrian/cycle links

3.3.1 Township recreational circuit

To understand the broader town planning context of the Berry Bypass project, an analysis of the Berry township urban structure was undertaken. This study identified a potential future recreational opportunity for those who live and work in the township.

The shared path and footpaths proposed as part of the Berry Bypass works, could in the future become part of a more extensive recreational circuit around the township that would link major destinations such as Berry Oval and sports area, the commercial Main Street, the Lawn Bowls Club, Berry Railway Station, Berry Showground, several retirement villages, Berry Primary School, Mark Radium Park and the Huntingdale Park residential community.

The shared path circuit could be designed with gradients and radii that accommodate retiree's motorised scooters, and would attract local families for recreational cycling, joggers, and school children. The recreational circuit would potentially be of community health and social benefit. Visitors to Berry may also be attracted to hiring a bike and sightseeing, if a well laid out and sign posted trail was established.

3.3.2 Key pedestrian links

The key pedestrian and cycle links proposed as part of the project include:

- Linking North Street to Kangaroo Valley Road.
- Linking the footpaths of the Berry Oval sports facilities, via North Street to the existing footpaths along Queen Street and in Mark Radium Park to provide access to an interconnected arc of green spaces.
- Linking the existing Queen Street footpaths to Kangaroo Valley Road and to the existing Huntingdale Park residential estate footpaths.

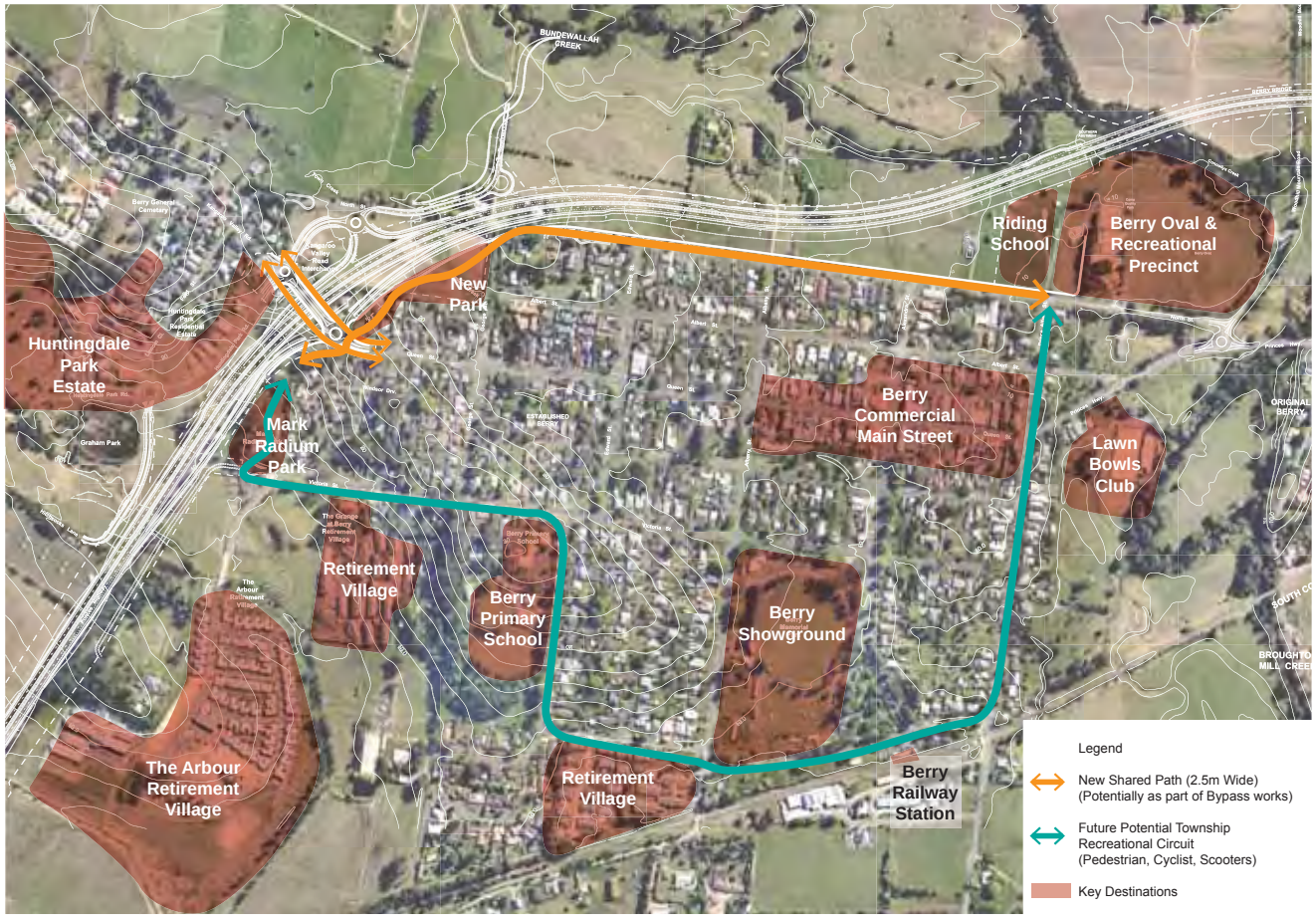

Figure 5: Recreation circuit and key links.

3.4 Interconnected green spaces

There would be an opportunity to utilise the residual open space that would remain following construction to establish a series of interconnected green spaces along the southern edge of the Berry Bypass. Current recreational open space includes the Berry Oval and sports facilities in the east and Mark Radium Park in the west. There would be potential to link these existing green spaces together, with a new strip of green space, as part of the Berry Bypass project.

These green spaces could be utilised as pastureland for agistment, for a relocated Riding School green, to establish a new local public park and for special event parking. SCC has stated that they do not wish to maintain in perpetuity large tracts of green space due to the maintenance costs involved. For this reason the proposed park (Town Creek Park) would be small in size and is envisaged as a simple low maintenance park landscape.

Figure 6: Arc of interconnected green space.

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3.5 Acoustic analysis outcomes

Acoustic analysis undertaken by Aecom consultants has established that two noise barriers would be necessary to achieve the NSW Environment Protection Authority (EPA) noise mitigation requirements. The extent of the two noise barriers is illustrated on the adjoining plan.

Figure 7: Acoustic analysis - noise barrier locations.

Figure 8: A bridge at Berry - in context.

4.0 A bridge at Berry and Northern Interchange Precinct

4.1 A bridge at Berry

4.1.1 A bridge at Berry - design process

In late 2011, Roads and Maritime Services engaged a number of industry specialists to critically review the concept design for the bridge at Berry and a number of community suggestions relating to the form and alignment of the bridge. The outcome of this review established the current concept design alignment for the Northern Route, including the bridge at Berry. The most significant change was the realignment of the northern section of the bridge by some 90metres away from the township at Woodhill Mountain Road and the lowering of the bridge by up to 6.4metres.

From February 2012 to May 2012, the design of the bridge at Berry was further developed through a collaborative process with the Berry community. Conybeare Morrison (CM^+) and Aurecon were engaged by RMS to work with the community, RMS and AECOM to review in more detail the following aspects of the bridge:

- Overall appearance of the bridge in its urban design context including development of options for the pier and traffic barrier form.
- Pier spacing and orientation.
- Bridge deck depth and height.

Refer to Figure 8.

4.1.2 Setting and vantage points

The bridge traverses, on the whole, a rural landscape of pastureland, turf farming, rural residential homesteads and properties, densely vegetated creek lines; and to the south, Berry sports field, recreational precinct and Camp Quality.

Apart from those driving over the bridge, the bridge at Berry would only ever be seen in parts. There would be no single vantage point where one would overview the whole of the bridge. This is due to the existing landforms and landscape (that would be retained), that would break potential views of the bridge into smaller partial views.

The main vantage points are from Woodhill Mountain Road: looking north from Bundewallah Creek and looking south to Bundewallah Creek. It would also be seen in part from a limited number of adjoining rural properties, inpart by northbound on-ramp users, and the south abutment would be seen up close by pedestrians utilising the parkland.

Refer to Figures 9 and 10.

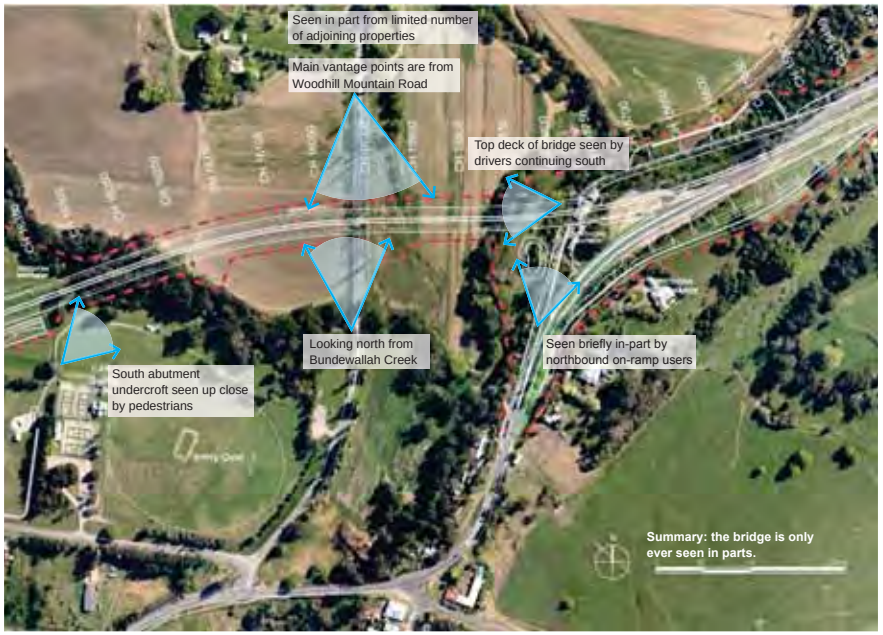


Figure 9: Vantage points.

Figure 10: A bridge at Berry - Aerial view from northeast.

4.1.3 Design philosophy

The following urban design philosophy has guided the design of the bridge at Berry:

- The bridge should be appropriate to its place – the picturesque rural setting.
- In scale with the township, landforms and existing landscape.
- Not draw attention to itself – a grand statement is inappropriate.
- Emphasis should remain on the picturesque setting: the dramatic backdrop of escarpment, the attractive pastoral valley/floodplain and creek-line vegetation.
- There should be no 'tack-on' decoration.
- The bridge should have clean lines and neat detailing – should not be fussy or cluttered.
- The architectural expression of the bridge should be one of simplicity and of straightforward structural expression: of spanning elements and support structures.
- The design should respond to the creek and floodplain environment.
- The bridge would be 'naturally' viaduct-like in character – a rhythm of piers/columns (not a forest) is an appropriate response.
- The design of the columns/piers needs to consider how they pick up the natural light and shadow – reading as an appropriate built form in the landscape.
- The bridge should age and weather well - minimising maintenance. Design for self cleaning surfaces, and designout opportunities for graffiti or vagrancy.
- Get the details right: articulation of surfaces - consider the bridge 'architecture' of light and shade to provide articulation of form.

4.1.4 Urban design principles

The following urban design principles have guided the bridge design:

- Develop bridge architecture that complements the pastoral setting.
- Maximise retention of existing screening landscape.
- Minimise bridge piers and elevation profile.
- Keep undercroft areas open, ventilated and with access to light.
- Maintain a consistent bridge profile without awkward junctions, steps or faceting.
- Explore opportunities to reflect the unique character of Berry and the Shoalhaven.
- Utilise locally sourced stone for abutment linings and scour protection wherever appropriate.

4.1.5 Cultural and heritage response

In the design of the bridge at Berry the following principles have guided the response to the important physical and cultural heritage of Berry and its rural setting:

- The bridge alignment has been relocated further north, away from the township to respect the town's heritage curtilage.
- The new bridge would be screened from Berry by the existing vegetation that follows Bundewallah Creek.
- The Alexander/David Berry Memorial would be relocated to a suitable new setting accessible to residents and visitors.
- Mark the turn off into Berry with appropriate signage.
- Draw inspiration for the project finishes palette from locally available materials – such as stone and timber.
- Incorporate endemic landscape themes and cultural plantings.

4.1.6 RMS Bridge Aesthetics Guidelines

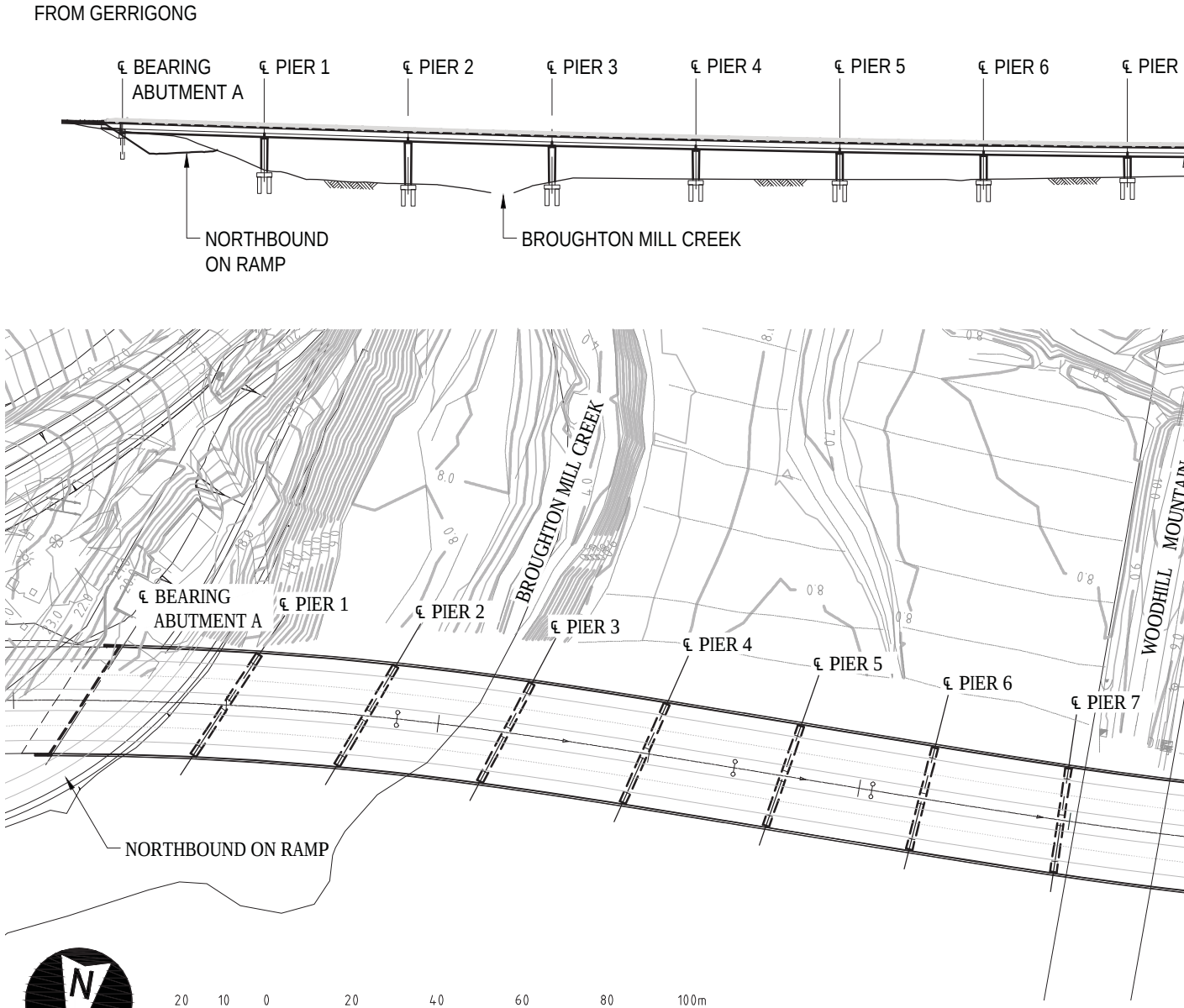
As part of the 'family' of bridges of the Foxground and Berry Bypass Project, and to be consistent with other bridges on the Princes Highway, the design of the bridge at Berry has been prepared with reference to the *RTA Bridge Aesthetic Guidelines, 2004*.

4.1.6 Bridge design overview

The bridge at Berry is designed to maintain 1:100 year flood free access to Berry. It is characterised by its overall gently sweeping, serpentine form. The bridge sweeps down off the ridgeline to then run almost parallel to the floodplain. The Super T primary structure provides a pleasing span and deck profile, leading to a sense of openness beneath the bridge, in keeping with the generally open pastureland along Woodhill Mountain Road.

The regular rhythm of support piers would provide a measured and refined architectural expression suited to the rural, floodplain context. The piers and abutments progressively vary in alignment to provide a comfortable relationship to the alignment of the northbound on-ramp, to Woodhill Mountain Road, and to the creeks and tributaries the bridge crosses. This 'fanning' effect should provide an attractive elevation when viewed from Woodhill Mountain Road, and a sense of openness when travelling beneath the bridge at the north abutment.

Refer to Figure 11.



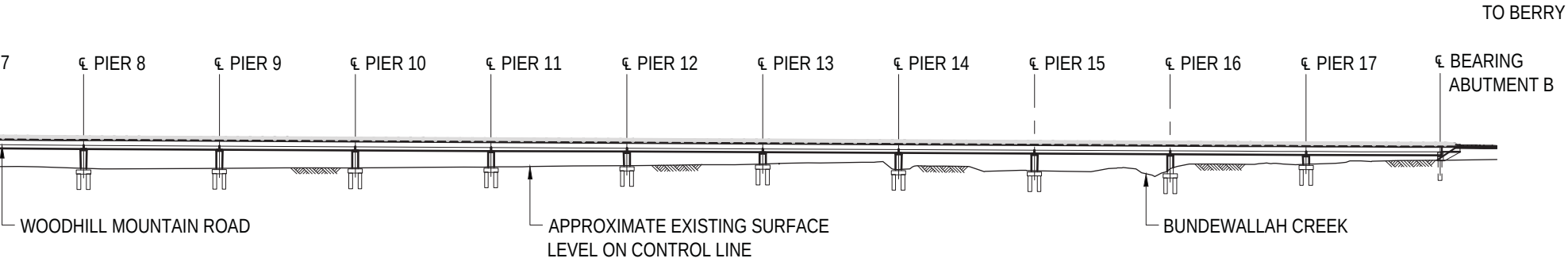


Figure 11: General arrangement

4.1.7 Technical criteria

Bridge Design Criteria	Parameter	Notes
Bridge length	600metres	Primary driver for the bridge length is to provide sufficient waterway opening in the event of a flood.
Overall bridge width	26.5metres	This width includes two traffic lanes for the northbound and southbound carriageways with provision to upgrade the bridge to carry three lanes in the future.
Bridge height from ground level to underside of bridge deck	5.3metres at Northern end 4.6metres at Woodhill Mountain Road 1.8metres to underside of deck	Driven by a 5.3metres clearance to the Bypass on-ramp that travels under the end span of the bridge. Minimum required road clearance to bridge structures. Minimum required clearance for maintenance
Distance between piers	33metres	This is a nominal dimension that changes across the length of the bridge to account for creek and road crossings. Maximising the spacing between piers creates a more open feel to the bridge structure. The 33metres bridge spans are also economical with regard to the supply and delivery costs of the Super-T girders.
Orientation of piers		Generally the piers are perpendicular to the road centreline, however in some locations the bridge piers are orientated parallel to the creeks and roads that pass beneath them.
Bridge deck type	Super-T girders	Super-T girders are precast bridge beams that are commonly used in Australia and provide a very high quality finish and durable product. A concrete deck slab is cast on top of the precast elements to enhance their strength.
Overall depth of bridge deck	1800millimetres	For the 33metres span length,1500millimetres deep Super-T girders with a 225 concrete slab would be provided. The bridge would then be covered by a 75millimetres thick layer of asphaltic concrete.

Bridge Design Criteria	Parameter	Notes
Substructure type	Reinforced concrete pier elements	Four separate pier options have been presented to the community. Pier options that accommodate the changing height from existing ground level to the bridge deck without taking away from the aesthetic were chosen.
Foundations	Cast in-place concrete bored piles	The piers would be supported on cast inplace bored piles that would be socketed into rock. These piles would be buried in the ground.
No. of expansion joints	3 or 4	Expansion joints would be a finger joint type in order to minimise joints across the bridge length. Finger joints have a better noise performance compared with compression seal type joints. The exact number of expansion joints would be determined at the detailed design stage following a detailed structural analysis. Typically a large spacing between the bridge expansion joints would result in a larger bridge bearing footprint to account for movements of the bridge due to transient load effects such as temperature changes. Larger bridge bearings also influence the width of the piers.
Traffic barrier type	Concrete barrier with twin galvanised steel railing	Height from road surface = 1300millimetres Overall height of concrete when viewed from ground level = ~ 1800millimetres. The geometry of the traffic barrier is driven by road safety on the inside face and aesthetics on the outside face. The overall height of the barrier on the outside is set to hide the longitudinal drainage pipes that run along the bridge deck to collect rainfall run-off from the road surface. The Northbound and Southbound Carriageways would be separated by a 1100millimetres high reinforced concrete barrier.
Noise barriers	Nil	Noise modelling has shown that no noise walls are required across the bridge.

4.1.8 Bridge design elements

The development of the bridge at Berry concept design involved a series of specific studies into the bridge components.

Pier design study

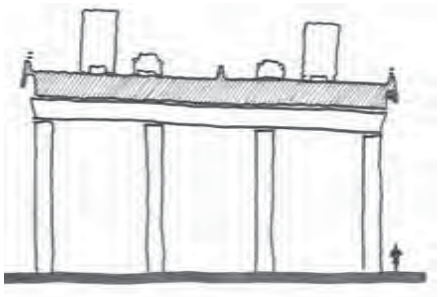
Initially six generic bridge pier options were investigated to establish the most appropriate. The types are illustrated in Figure 12.

The six generic pier options and the reasons for the subsequent shortlisting of types for further development was presented to the Berry Bridge and Northern Interchange Precinct Community Working Group for feedback in March 2012.

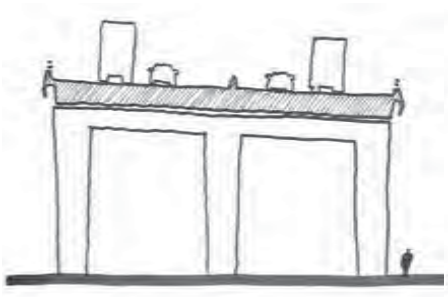
The three generic bridge pier types that showed the most promise for further development were:

1. Circular Columns – Integrated Headstock (developed as Option D)
2. Portal Frame – Integrated Headstock (developed as Options B and C)
4. Circular Columns – Expressed Headstock (developed as Option A)

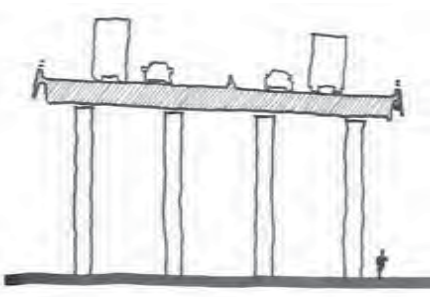
The reasons that generic bridge pier options 3, 5 and 6 were not developed further are as follows:



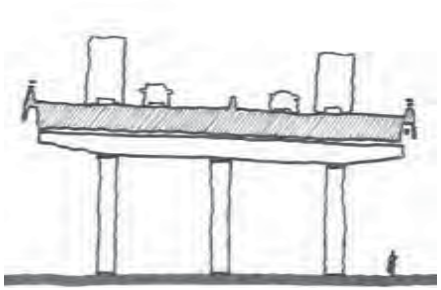
1. Circular columns - integrated headstock.



2. Portal frame ('m' shaped) – integrated headstock.

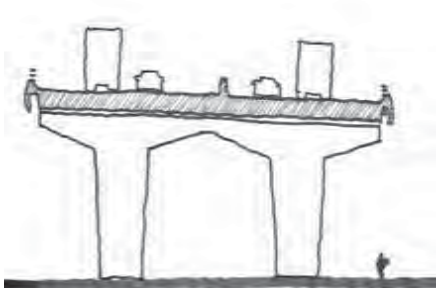


3. Circular columns – recessed headstock.



4. Circular columns - expressed headstock.

5. Double 'V' shaped piers.



6. Double 'T' shaped piers.

Figure 12: Generic pier types.

Double 'V' shaped piers

- A visually 'low key' expression in the environment was sought - a simple rhythm of piers and spanning elements (creating light and shade) as the bridge traversed the picturesque floodplain landscape. This pier type has an unnecessarily complex form, drawing attention to itself and was therefore seen as an inappropriate type to pursue.
- It did not address the need for a pier type that on an aesthetic level, could successfully transition from two or three meters of clearance height, at either end, to as much as twelve meters at Broughton Mill Creek.
- This option, due to the complexity of formwork involved, was likely to be the most expensive to pursue – the Working Group agreed that a simple, elegant solution, at moderate cost was preferred.

Double 'T' shaped piers

- This pier type did not address the need to transition from two or three meters of clearance, at either end, to as much as twelve meters at Broughton Mill Creek. Whilst the 'T' shape would have attractive proportions for the three to four highest pier locations, for the majority of the bridge length the clearance would be much less and the 'T' shape would look squat, as if sinking. For as much as half the length of the bridge the pier would end up simply as a beam/wall. The bridge should be considered in its totality, and the relatively low clearance required did not suit this pier type.

Circular columns – recessed headstock

- The Working Group did not respond well to this option. It was seen as a somewhat unrefined structure without any architectural character or design response to location.
- This pier type required the Super T beams to have a step in their ends, and the RMS had highlighted cracking problems with this arrangement on other bridges in NSW.
- The 'recessed' cross beam required would need to be very wide – the inverted 'T' shape end of the headstock would be clearly visible in elevation. The flush alignment of the headstock end and the Super T faces on a curved horizontal and vertical alignment like this would be difficult to achieve. This concern was illustrated with a photo of a flyover ramp at Sydney Airport of similar construction.

Study Outcome

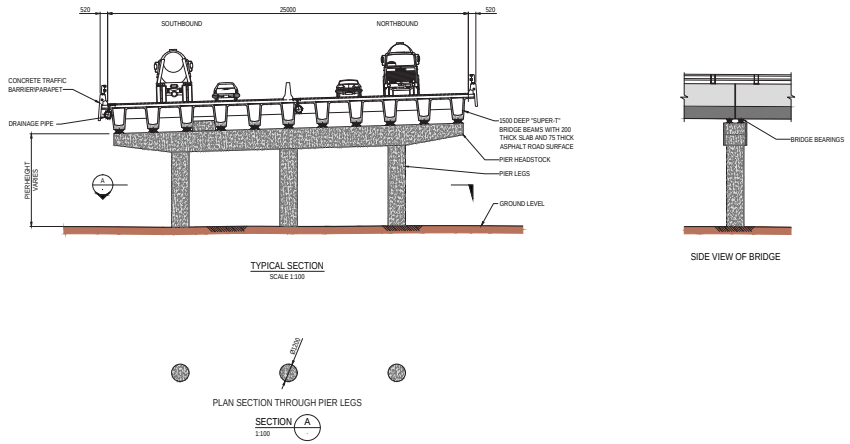
The three most promising generic pier type options were further developed into four shortlisted options that were then re-presented to the Working Group (and issued to the group in a draft report) and also published and exhibited to allow the broader community an opportunity to comment.

Short-listed bridge pier options

The following four pier types were short-listed for further consideration:

The short-listed bridge pier options were presented to the CRG for comment and were loaded onto the RMS website to provide an opportunity for further community feedback.

A - Original Pier Option – Refined



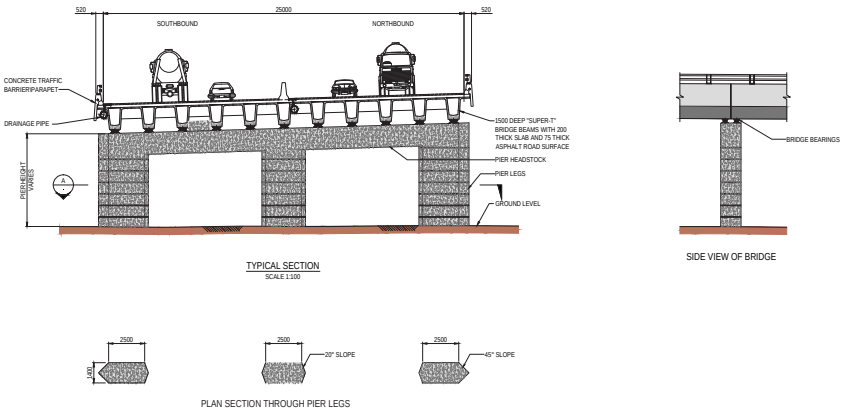
SIDE VIEW OF BRIDGE

CM+ 2012

CM+ 2012

Figure 13: A - Original pier option - refined.

B - Flood Plain/Expressed Coursing



SIDE VIEW OF BRIDGE

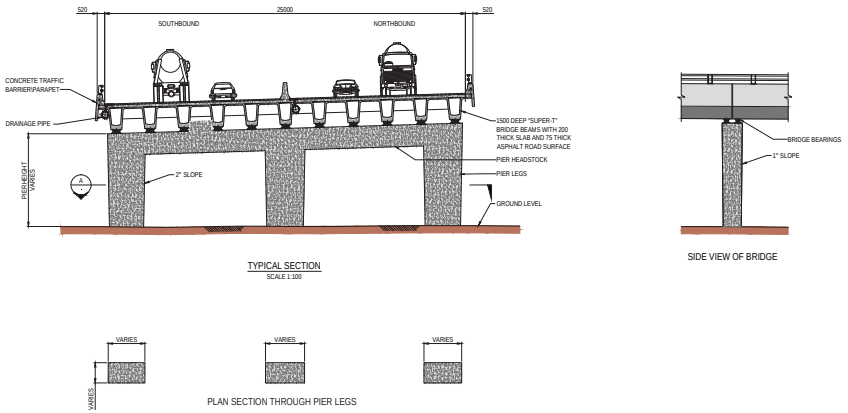
CM+ 2012

Figure 14: B - Flood plain/expressed coursing.

Example: Third Hunter River Crossing, Maitland.

CM+ 2012

C - Contemporary Portal Frame



SIDE VIEW OF BRIDGE

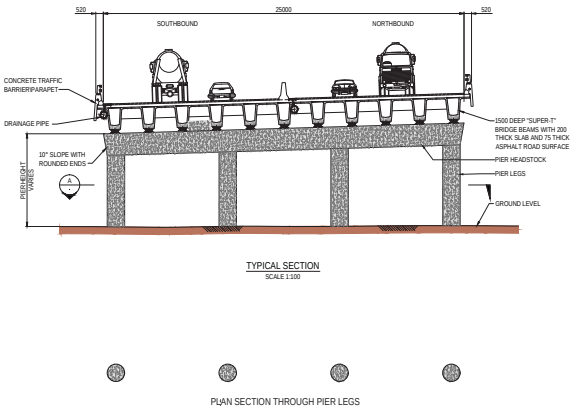
CM+ 2012

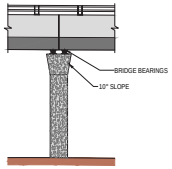
Figure 15: C - Contemporary portal frame.

Example: Mehi River Bridge, Moree.

CM+ 2012

D - Flared Capital/Integrated Headstock





SIDE VIEW OF BRIDGE

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Figure 16: D - Flared capital/integrated headstock.

Example: Pacific Highway, Bonville.

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Parapet options

Three parapet types were investigated. From a construction point of view, the selection of parapet type would be independent of pier type. However, some parapet types tend to suit the pier architecture more than others. The three pier types investigated were:

1. Straight Sloped Face

This option provides a simple, clean, modern expression.

2. Angled Face

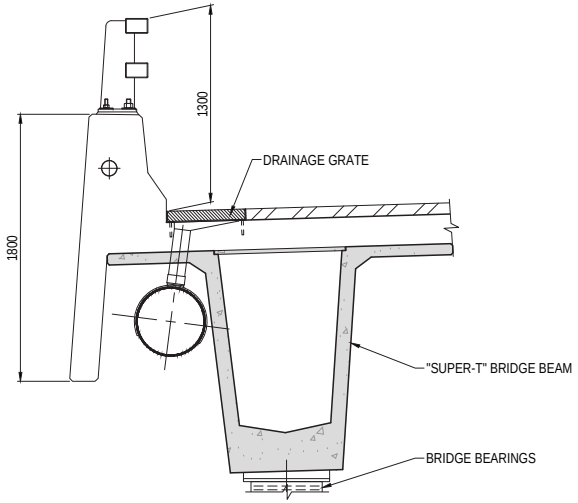
An angled parapet profile works well in conjunction with angled piers below.

3. Grooved Face

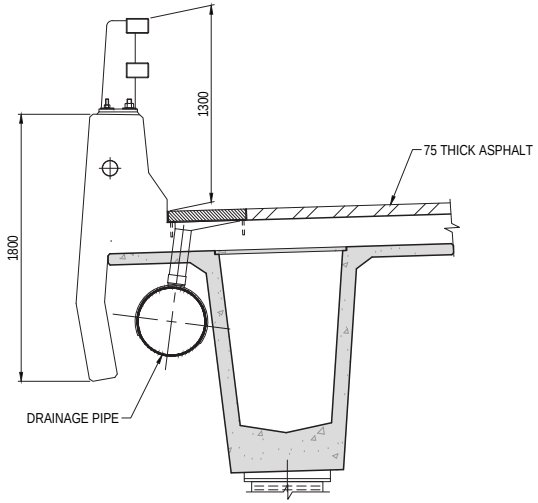
A horizontal groove introduces a 'false joint' shadow line, adding additional detail into the parapet panels.

All parapet types extend down the same length, on both north and south elevations, to screen the bridge drainage pipes when viewed from the side. They all incorporate twin rail safety barriers, provide an angled surface profile to catch the light and the top of the parapets slope away from the parapet face to avoid staining.

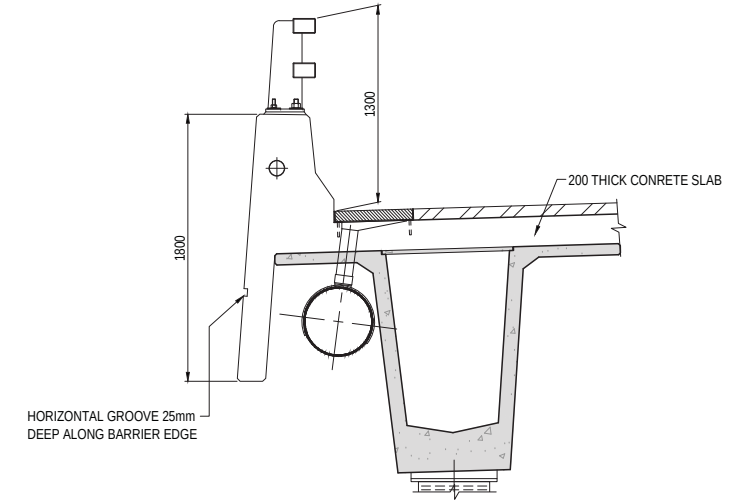
The three bridge parapet options were presented to the community working group for comment and were uploaded onto the RMS website to provide an opportunity for further community feedback.



BRIDGE BARRIER - OPTION 1



BRIDGE BARRIER - OPTION 2



BRIDGE BARRIER - OPTION 3

Figure 17: Parapet options.

Traffic barriers

Twin rail type safety barriers with a modified Type F concrete upturn arc are proposed for the outside edges of the bridge at Berry. This traffic barrier type:

- Reduces unnecessary parapet depth and heaviness.
- Provides a lighter and contrasting top profile.
- Emphasise the bridge's streamlining and horizontal lines.
- Provides a sense of openness and allows views.

An example of this barrier type in use, can be seen in the Sea Cliff Bridge, located at Stanwell Park/Coal Cliff.

Figure 18: Traffic barriers.

North abutment

The northern bridge abutment is proposed to be:

- A spill through type (this abutment type comprises a sloped embankment rather than a vertical wall).
- Is seen up close from the northbound on-ramp.
- Continues as a 2H:1V (a slope of the proportion two horizontal to one vertical) cut batter within the Northern Interchange.
- Would be rock faced in the bridge undercroft area (locally sourced stone).
- Would integrate maintenance access stair and landing in the abutment design.

Figure 19: Stone faced abutment.

Figure 20: View of north abutment from north bound on-ramp.

South abutment

The southern bridge abutment is proposed to be:

- A spill through type.
- Is seen close up by pedestrians using the adjoining sports/recreation precinct.
- Is angled to follow the creek alignment.
- Incorporates scour protection on embankment slopes (locally sourced stone).
- Would be rock faced in the bridge undercroft area (locally sourced stone).
- Would integrate maintenance access in the abutment design.

The southernmost bridge spans would maintain a clearance of 3.0metres (minimum 1.8metres for maintenance access), wherever possible, to:

- Deter graffiti.
- Deter vagrancy.
- Maximise light and rain penetration to undercroft and Connollys Creek.
- Properly ventilate.

If flood modelling necessitates the setbacks of the south bridge abutment from Connollys Creek, then bridge clearances may be achieved through local excavation, subject to an assessment of undercroft drainage levels.

Figure 21 : Stone faced abutment - showing maintenance access stair.

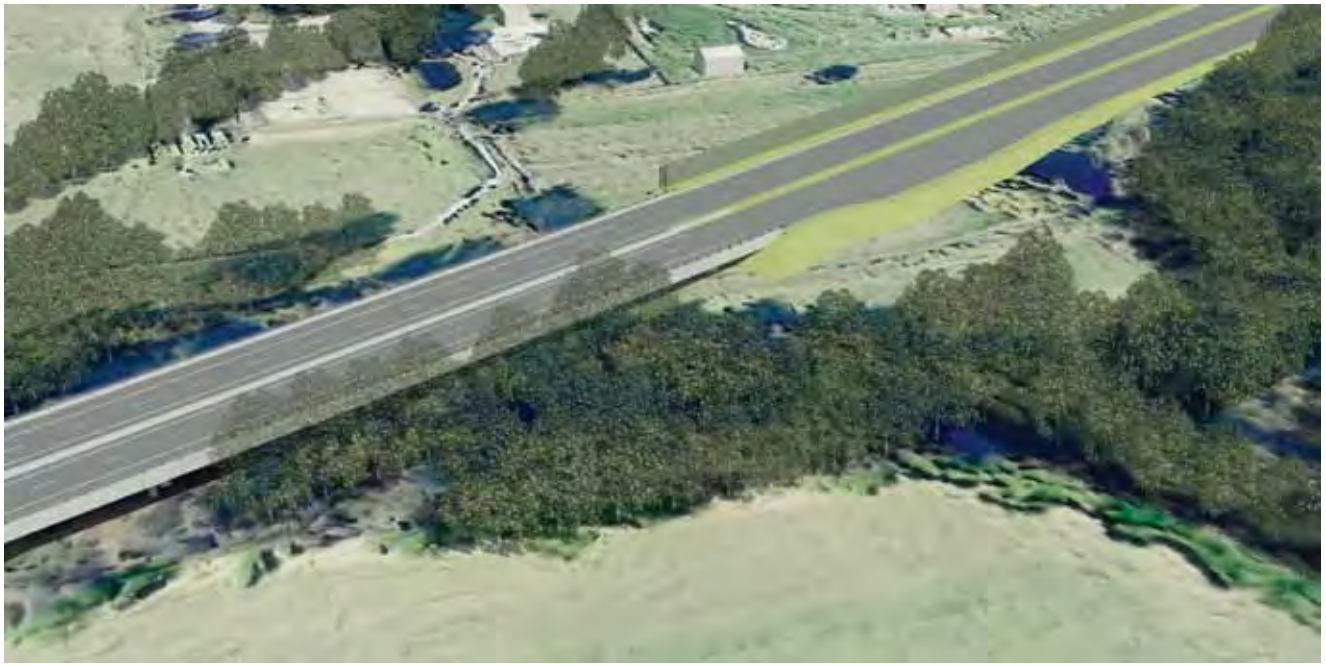


Figure 22: Aerial view of south abutment.

Lighting strategy

No lighting on the bridge at Berry is currently envisaged. The overhead power supply along Woodhill Mountain Road would need to be re-routed and local road lighting reassessed as the proposed alignment would interfere with the current service. Existing park lighting for the sport/ recreation precinct to the south of the bridge at Berry alignment may need to be reassessed in light of the need to ensure pedestrian safety.

4.1.9 Landscape design strategy

Where the bridge crosses over existing creeks, suitable riparian vegetation would need to be re-established, following the completion of bridge construction, in order to maximise the continuity of the creek ecology and habitat.

The historic Woodhill Mountain Road avenue of Poplar trees could be strengthened through the replacement of lopped trees and the inter-planting of gaps in the avenue, with new trees. The localised realignment of the power supply would prevent future lopping of trees by power supply utilities.

The 26.5metres wide bridge deck, combined with the lower height sections of the bridge (as low as 3.0metres) would result in an undercroft middle-zone that would not support pasture grasses – due to the rain shadow and lack of sunlight. Surface treatment suited to this microclimate would be an important consideration in order to avoid a ‘dead zone’ beneath these lower southern sections of the bridge.

Figure 23: Northern Interchange - setting.

4.2 Northern Interchange

The Berry Northern Interchange is located approximately 500metres to the northeast of the township, and connects into the Princes Highway continuing north to Sydney. The existing Princes Highway sweeps to the southwest, crossing Broughton Mill Creek before heading into town. The northbound on-ramp and the southbound off-ramp connect into this existing road that leads to the Main Street (Queen Street) of Berry. The bypass alignment sweeps westwards down across the floodplain, becoming the bridge at Berry. Refer to Figure 23.

4.2.1 Setting

A series of rural residential homesteads are located to the southeast and northeast of the interchange and are nestled within the bush vegetation of the ridgeline. A new driveway passing beneath the bypass carriageways at its northern extent would maintain vehicular access to those properties located west of the alignment.

4.2.2 Urban design principles

The following urban design principles have guided the interchange design:

- Minimise the visual presence of interchange structures.
- Minimise impacts on existing properties and access.
- Minimise the interchange footprint.
- Retain mature trees along the highway.
- Consider the sequential views on the northern approach to Berry.
- Contribute to the township arrival/departure experience and to legibility.
- Develop Berry township entry signage strategy.
- Frame rural and township views from elevated vantage points.
- Relocate Berry memorial sculptures.

4.2.3 3D study

A 3D computer generated model was prepared of the Northern Interchange to develop a better understanding of the experience of driving through the interchange from various directions, including the arrival sequence from the north into Berry; and also for continuing south on the bypass travelling on the bridge at Berry. Six views are illustrated with accompanying view location key plans.

View 1- View from Berry Bypass South Bound

N

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Berry Bypass Urban Design Strategy
Northern Interchange Views
March 2012
Dwg. No: 12001-SK027

View 2- View from Berry Bypass South Bound Exit Lane

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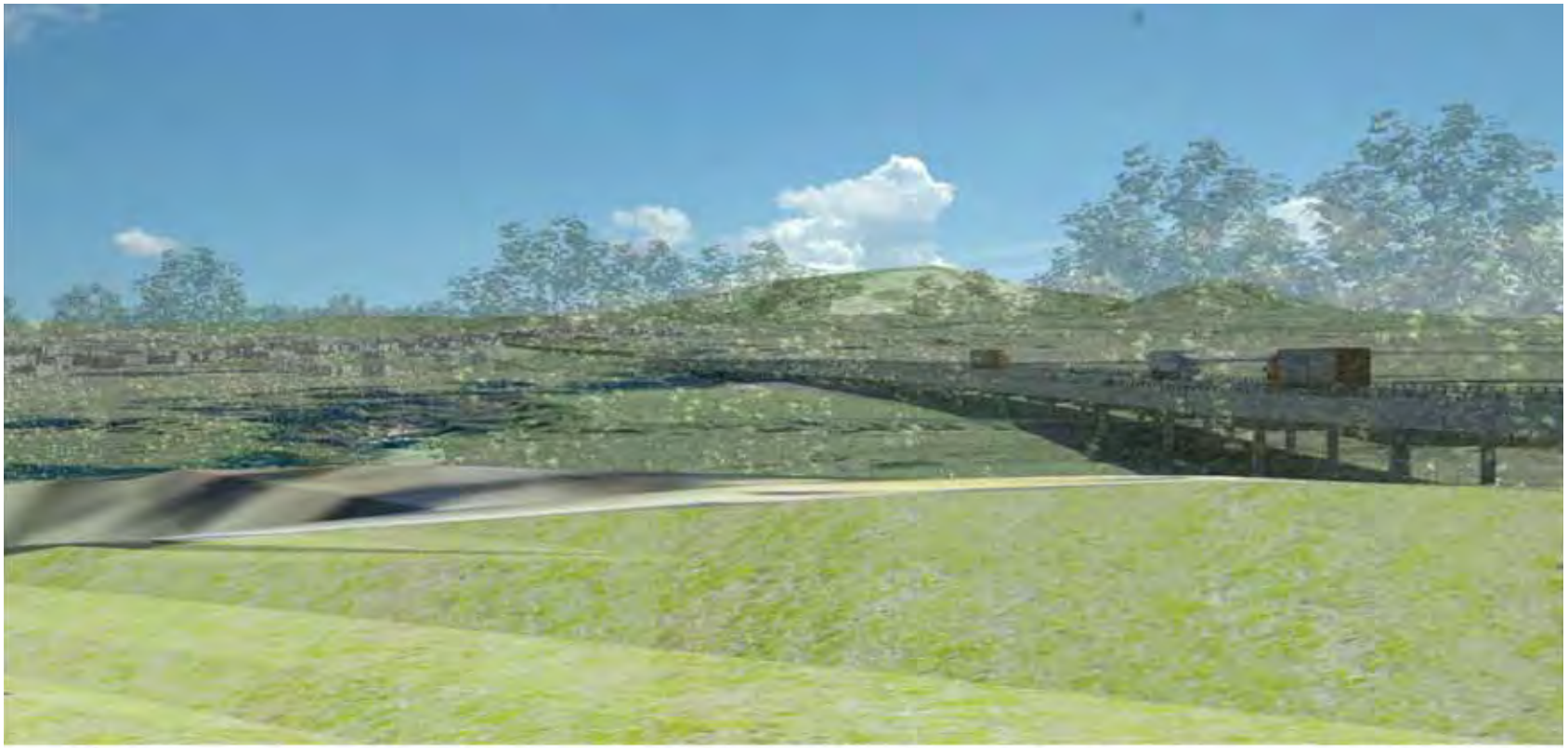
Berry Bypass Urban Design Strategy
Northern Interchange Views
March 2012
12001-SK028



View 3- View from Berry Bypass South Bound Exit Lane looking West

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Berry Bypass Urban Design Strategy
Northern Interchange Views
March 2012 **12001-SK029**

View 4 - View from Berry Bypass North Bound Entry Lane Looking North

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Berry Bypass Urban Design Strategy
Northern Interchange Views
March 2012 **12001-SK030**

View 5- View from Berry Bridge South Bound Lane at Ch 15800

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Berry Bypass Urban Design Strategy
Northern Interchange Views
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12001-SK031

View 6- View from Berry Bridge South Bound Lane at Ch 15925

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Berry Bypass Urban Design Strategy
Northern Interchange Views
March 2012
12001-SK032

4.2.4 Interchange design elements

The Northern Interchange would comprise the following component elements.

Cut and fill batters

The interchange sits atop a local ridgeline, the main alignment cutting into the ridge to the south, extending the existing cut batter of yellow-orange coloured, exposed, rock face. A further cut batter would be required to the east of the northbound on-ramp. This batter would be at a slope of 1V:2H and can therefore be planted out with suitable grasses, shrubs and scattered trees.

Retaining wall

Although most of the interchange main alignment and ramps follow the contours of the ridge landform, the levels are such that to the north of the interchange the northbound on-ramp necessitates a significant fill embankment. To prevent the toe of this embankment impinging upon the Turf Farm operation below, an approximately 100metres long retaining wall structure would be proposed.

Lighting

Sections of the interchange roadway would need to be illuminated to ensure compliance with road safety standards. The final light pole design is yet to be confirmed.

Figure 24: Northern Interchange - Aerial view from the west.

4.2.5 Landscape design strategy

The landscape design of the interchange and northern approach to Berry will choreograph the arrival sequence into Berry township. The landscape design will capitalise upon the potentially expansive views that will be possible from the elevated location atop the ridge, looking south and west across the rural valley landscape and new bridge at Berry, and to the escarpment beyond.

Typical cross sections

Three cross sections illustrate the new landform profile compared to the existing, and illustrate the opportunities for landscaping of the corridor to frame views along the highway, and then across the valley to provide a fitting arrival experience at Berry.

Refer to Figure 23 for location of cross sections.

Figure 25: Section A

Figure 26: Section B

Typical planting selections

Plantings that are endemic to the region are proposed that would suit the climate, soils and provide appropriate fauna habitat. The planting palette would be selected with the objective of achieving a low establishment and maintenance regime.

Figure 27: Section C

Northern interchange

The design of the landscape at the northern interchange would reinforce the landmark location and feature endemic tree plantings, natural rock embankments, colourful signature trees at the gateway to Berry and elevated views of surrounding fields from the bridge structure.

On the approach towards the interchange, the roadside embankments would be planted with native grasses, shrubs and copses of endemic trees to blend with the existing rural landscape.

As the cut embankments become higher and steeper (refer to Section B) the underlying rock surface would be exposed as a feature, with native trees planted at the top of the cuts to create a green ridgeline . The road median would be planted with native grasses and shrubs strategically placed to screen headlights at critical areas.

The turnoff to Berry will be distinguished by a colourful mix of native and exotic low shrubs framed by an avenue of Claret Ash (*Fraxinus oxycarpa aurea*)

The use of exotic species, highlighting the former heritage plantings in the town, would be echoed in the southern entry into Berry .

Where unaffected by earthworks within the road corridor, the existing landscape adjacent to the current Princes Highway alignment will be retained and reinforced with similar indigenous tree and shrub plantings. Existing drainage areas and dams will be retained and highlighted with riparian species to blend with the rural landscape character.

Proposed species:
Eucalypt trees to reinforce existing trees, which would be retained.

Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)
Hakea dactyloides
Melaleuca linarifolia

Possible exotic highlight trees:
Fraxinus oxycarpa aurea (Claret Ash)

Refer to Figures 28 to 30.

Figure 28: North Interchange typical landscape plan.

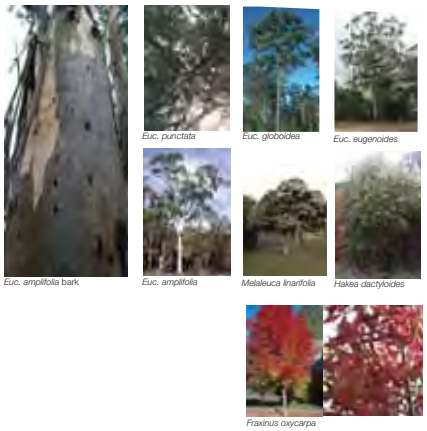

Figure 29: Species selection.

Figure 30: Typical cross section.

Figure 31: North Street - West.

Figure 32: North Street - Centre.

Figure 33: Rural character - pasture for agistment.

Figure 34: North Street - East.

5.0 North Street Precinct

The North Street precinct is located at the north edge of the Berry township, and includes the North Street streetscape, the Berry Bypass alignment and the strip of rural land between. At the precinct's western extent are George Street, and a triangular parcel of grazing land. The proposed Kangaroo Valley Road Interchange adjoins this parcel to the northwest. In the east the precinct extends to Prince Alfred Street, the Berry sports facilities; that include tennis courts and skate park; Berry Oval and Camp Quality facilities.

5.1 Setting and streetscape character

The precinct benefits from spectacular panoramic views to the north, across picturesque pastureland to the dramatic backdrop of the Cambewarra Escarpment. Small creeks and tributaries wander across the floodplain and support strings of dense vegetation. The pasture to the north of North Street is currently utilised for agistment, with horses grazing a common sight.

North Street varies in character along its length. The west end (between George and Edward Streets), is quiet and intimate in scale, has a narrow central pavement, grassed swales (rather than kerb and gutter) and informal avenue tree planting along each side. The mature tree planting tightly frames views west along the street to the escarpment – defining a quintessential country laneway. A mix of native and exotic street trees is proposed. Natives predominate with the occasional burst of colour provided by lighter coloured exotic foliage or Jacarandas.

Between Edward and Alexandra Streets (the middle section) there is sparser street tree planting on both sides (occasional groups of trees), that open up views north to pastureland. The residential frontages change in character in this section. There are tended front lawns, overhead power lines, concrete driveways and typical suburban residential house construction, that tends to contrast with the attractive rural character of the north side of the street.

Between Alexandra Street and Prince Alfred Street (the eastern section) there are even fewer street trees and the streetscape is exposed and lacks definition. Residences are set back in this section and the mid-block southern frontage is defined by a section of dense planting.

The precinct forms the transition from urban to rural land uses - from the regular town grid of residential streets and blocks, to the expanse of rural pastureland.

Refer to Figures 31 to 34.

5.2 Design philosophy

The guiding urban design philosophy for the North Street Precinct, has been to maintain as much as possible the:

- Small scale 'country laneway' character of North Street.
- Rural outlook and character of the pastoral landscape to the north.
- Expansive views to the impressive Cambewarra Escarpment.

5.3 Urban design principles

The following urban design principles have guided the urban and landscape design of the North Street precinct:

- Enhance township green space connectivity and recreational opportunities.
- Maintain North Street pedestrian and cycle connectivity.
- Integrate noise mitigation structures within the landscape setting.
- Re-establish facilities valued by the community, such as the Riding School green, and attractive pastures for agistment.
- Provide an attractive journey and outlook for drivers on the Berry Bypass.
- Provide a safe pedestrian and cyclist environment for parks and walkways through adopting Crime prevention through Environmental Design (CPTED) principles.
- Develop an urban and landscape design that would be low maintenance, durable and that deters graffiti.
- Develop a materials and finishes palette that wherever practical incorporates elements of locally sourced stone and timber, and colour finishes that complement the natural colours of the environment.
- Generally utilise native plantings that are endemic to the region, whilst also incorporating cultural exotic plantings, when warranted, as highlight or feature plantings.

5.4 North Street pedestrian and cyclist connectivity

At the workshops held with the community working group, it was related that North Street is currently used as an informal jogging and cycling route, and that this access was important to the community. Subsequent 3D modelling and costing studies showed that pedestrian overbridges on or near the North Street alignment were expensive and would impinge on the northern views and outlook of residents along North Street. The scale of the structures that would be necessary was also of concern to North Street residents in attendance.

Due to the cost and likely low level of use, the readily available alternative route (via the proposed bridge connecting Kangaroo Valley Road and Queen Street), and in light of residents concerns relating to scale and impact on views and amenity, the RMS decided not to pursue a pedestrian overbridge at this location. The adjoining map illustrates the short additional distance of 100metres and small additional walking time of 1.25 minutes of the alternative pathway.

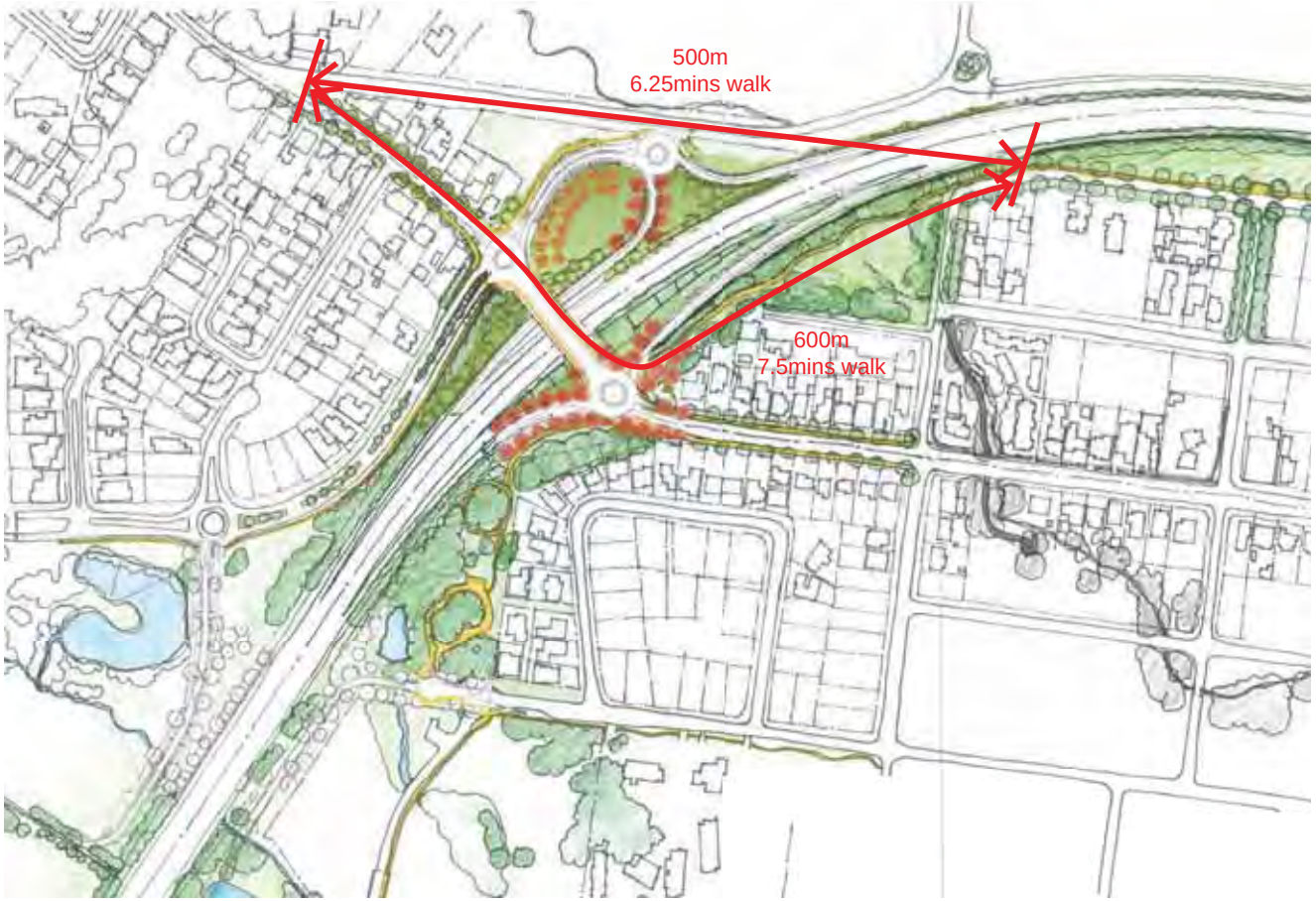

Figure 35: North Street access study.

5.5 Berry Bypass infrastructure

The Berry Bypass consists of a highway standard roadway, designed to a 100 kilometre/hour posted speed. Initially the bypass would be four lanes, with the capacity to expand to six lanes (built-in to the design and cross sectional footprint) if required in the future.

North Street (west) would be connected to Rawlings Lane to maintain vehicular access to the two farm properties located to the north of the Bypass.

A vegetated, noise reinforced, soil mound is proposed along the southern edge of the bypass corridor. A 2.5metre wide shared pathway would be provided along the north side of North Street, connecting east and west into the existing network of township footpaths.

Figure 36: Berry Bypass infrastructure.

5.6 Urban design strategy

The proposed construction of the highway-scale Berry Bypass infrastructure would bring changes for the township of Berry. Some of these changes would be positive including:

- Completion of this important section of the Princes Highway would provide a quicker and safer route for locals travelling regionally and along the NSW coast, tourists visiting South Coast destinations and day-trippers visiting the popular heritage and festival destination of Berry travelling to/from Sydney; boosting tourist accommodation, cafe/restaurant and retail business opportunities and employment in the township.
- The upgrade to a highway standard roadway would reduce fatalities and accidents along this currently difficult stretch of highway.
- The volume of truck and through traffic on the Queen Street retail 'Main Street' would be considerably reduced. There would be an opportunity to refocus 'Main Street' as a pedestrian friendly zone with increased and safer crossings, more opportunities for outdoor cafe-style seating, street tree planting and urban furniture.

The highway corridor and interchanges are large physical structures and the urban strategy has been to investigate means by which these structures could be integrated into the northern edge of the township and into the surrounding attractive rural floodplain landscape - minimising the urban, landscape and visual impacts on the environment.

The strategy incorporates a series of urban and landscape design initiatives to reinforce the attractive rural character of the North Street Precinct, including:

- Reducing the visual impact of the road corridor through adjustments to the highway's vertical and horizontal alignment – moving the alignment and Northern Interchange further north of the township.
- Introducing generous open space buffers between Berry Bypass and the north and northwest edges of the township.
- Wherever possible re-establishing rural land uses on RMS residual, non-operational, property – Riding School, pastures for agistment, re-establishing land suitable for dairy farming, re-establishing the riparian vegetation and habitat along creek lines.
- Reducing the noise impacts through incorporation of landscaped noise barriers along the edges of the alignment to EPA requirements.
- Screening the roadway from the township with innovative landscaped 'Ha Ha' sloped landform.
- Retaining as much as possible existing landscape defines the rural character of the region and which screens from view the new roadway, bridge and interchange structures.
- Establishing a landscape strategy that reinforces the small scale, rural, 'country lane' character of North Street.

The Urban Design Strategy diagram illustrates the key initiatives that are proposed to integrate Berry Bypass within this uniquely picturesque setting.

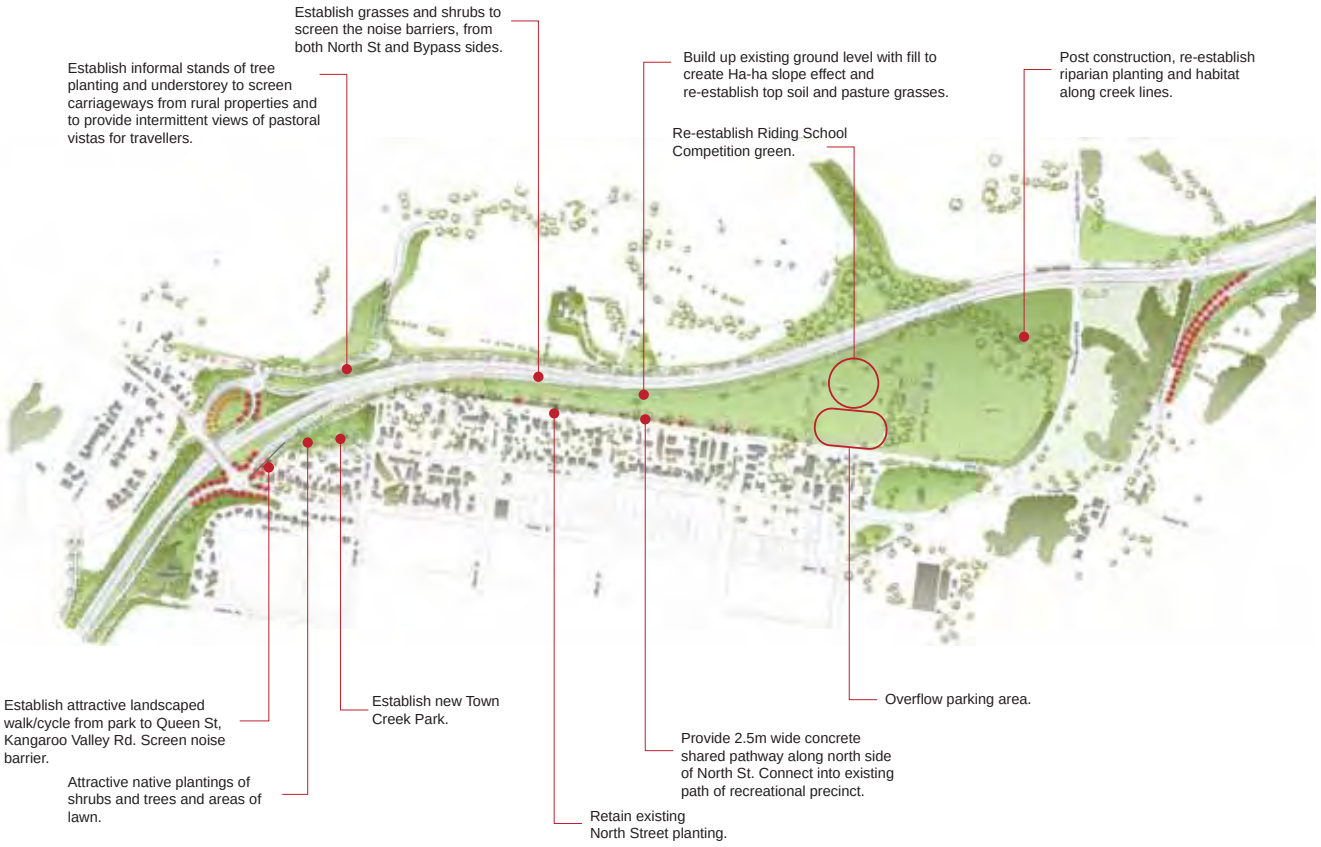

Figure 37: Urban design strategy.

5.7 Precinct plan

The Precinct Plan illustrates the proposed urban and landscape concept design for the North Street Precinct.

Figure 38: Precinct Plan - North Street.

5.8 Cross section and vantage point study

At the end of 2011 and beginning of 2012 a series of cross sectional studies were undertaken that aim to minimise the potential acoustic and visual impacts of the proposed Berry Bypass. It was during this period that the 'Ha Ha' concept was developed. A 'Ha Ha' is basically an artificially created, gently sloping, usually grass covered landform, that screens from view a distant structure, such as a security fence, or in this case, traffic passing along a highway.

The slope would be so gentle that the progressively increasing height would not be noticed. When viewed from North Street the grassed 'Ha Ha' slope would provide a foreground of pastureland, whilst allowing occasional views of the taller tree canopies to the north of the Bypass and importantly to the dramatic backdrop of the Cambewarra Escarpment. The 'Ha Ha' slope and landscaped noise mound would screen views of traffic along the highway, whilst achieving the required acoustic barrier height of 4.0metres above the Bypass carriageway.

A series of photomontage images, generated by accurate 3D computer modelling, were prepared at four key locations along North Street. The existing view is provided on top, whilst for direct comparison purposes, the same view with the noise barrier mound and proposed screen landscaping in place, is illustrated below.

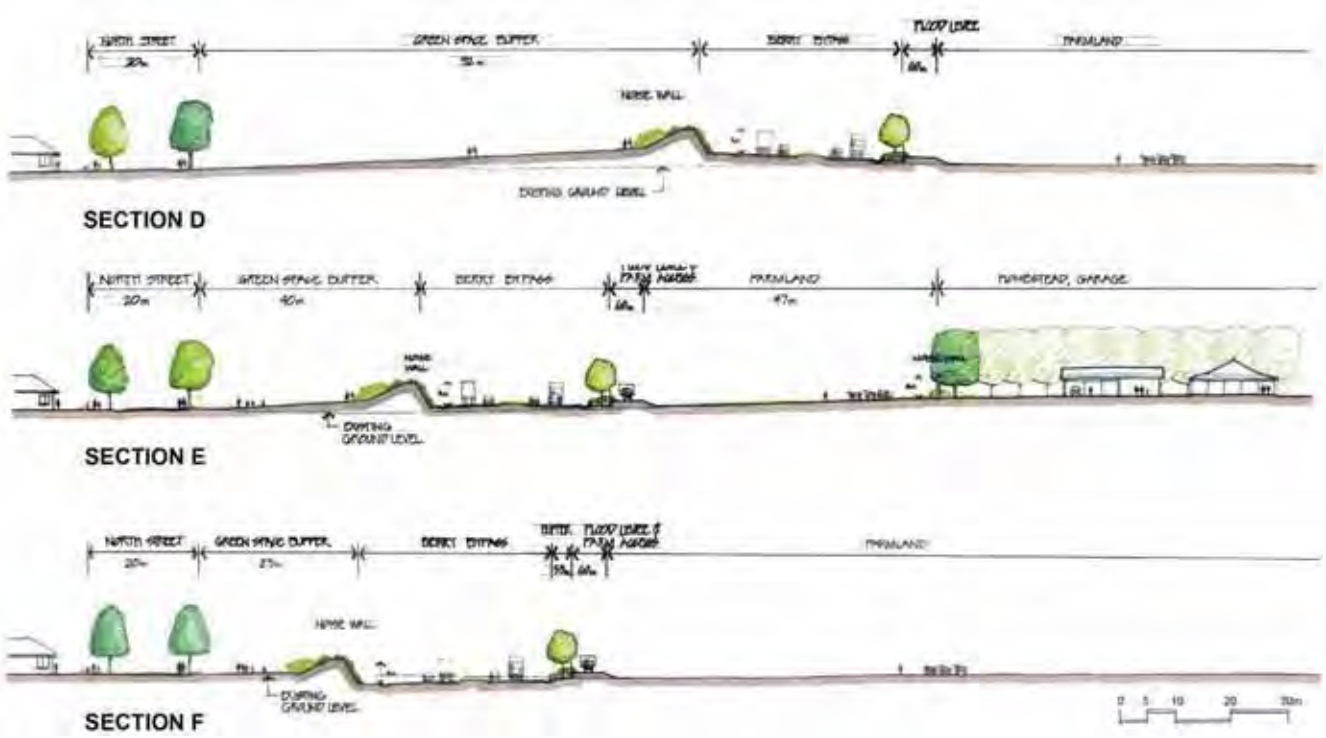

Figure 39: North Street cross section study.

Figure 40: Cross section and photomontage viewpoint location plan.

Figure 41: Viewpoint 1 (near Edward Street) - existing view.

Figure 42: Viewpoint 1 (near Edward Street) - with noise barrier and landscaping.

Figure 43: Viewpoint 2 (at Albany Street) - existing view.

Figure 44: Viewpoint 2 (at Albany Street) - with noise barrier and landscaping.

Figure 45: Viewpoint 3 (at Alexandra Street) - existing view.

Figure 46: Viewpoint 3 (at Alexandra Street - with noise barrier and landscaping.

Figure 46: Viewpoint 4 (at Prince Alfred Street) - existing view.

Figure 48: Viewpoint 4 (at Prince Alfred Street) - with noise barrier and landscaping.

5.9 Urban design elements

The North Street Precinct section of the Berry Bypass would incorporate a number of urban design elements. These include an approximately 800metre long and 4.0metre high noise barrier, a shared path and associated footpath connections, street and local park furniture and precinct lighting. All these elements have been considered as contributing to an overall coordinated design outcome.

5.9.1 Noise barrier options study

Three noise barrier design options were investigated, presented to the North Street Precinct working group, then published in local news media and exhibited at the RMS project office in Berry,; to provide an opportunity for broader community comment. The three options are:

1. Precast concrete wall

A precast concrete retaining wall, at a 10 degree slope from vertical. Angling the wall reduces the sense of being walled in, and reduces the incidence of reflected vehicular noise. A 2.0metre wide landscaped planter bed would be raised up 815millimetres above the carriageways on the bypass side, and planted with shrubs and grasses – this breaks down the apparent overall barrier height and introduces some contrasting green vegetation into the bypass corridor. On the North Street side there would be a 2H:1V sloped earth batter. The wall extends 1.2m above the top of the batter to provide a balustrade for pedestrian safety. The batter would be planted with native grasses, shrubs and small trees to screen the top of the wall from view. All visible surfaces of the noise wall are finished in a charcoal-dark green colour to visually recede in the overall pastoral landscape.

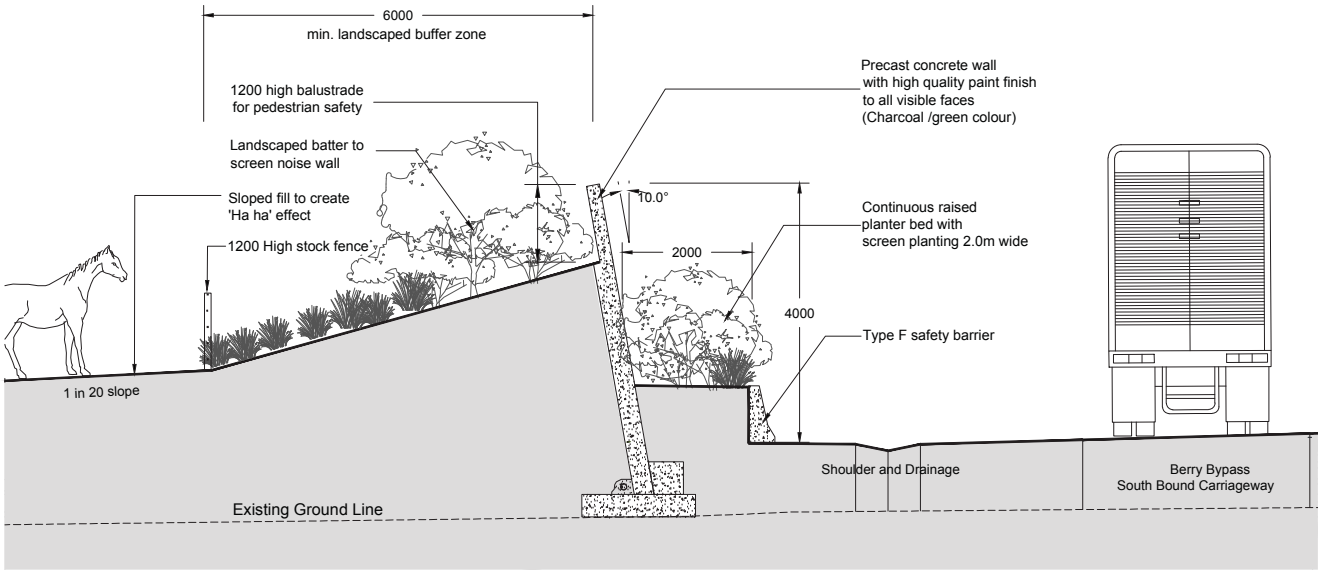

Figure 49: Noise barrier option 1 - precast concrete wall typical cross section.

Figure 50: Noise barrier option 1 - precast concrete wall photomontage.

2. Planted soil reinforced mound

This barrier type was suggested by Berry Alliance/BOB. The noise barrier consists of a 4.0m high reinforced soil mound, with a thirty degree slope face, from vertical, on the bypass carriageway side. This would be hydroseeded with pasture grasses, whilst on the North Street side there would be a 2H:1V sloped earth batter, planted with native grasses, shrubs and small trees to screen the mound from view. RMS Maintenance has advised that this type of planted soil retaining structure has been used on a number of RMS projects in NSW and if carried out in accordance with the relevant technical specifications, would be acceptable to the RMS. Photos and diagrams of proprietary reinforced soil systems are illustrated in Figure 53. This option would be the preferred barrier type to proceed to the next stage of development.

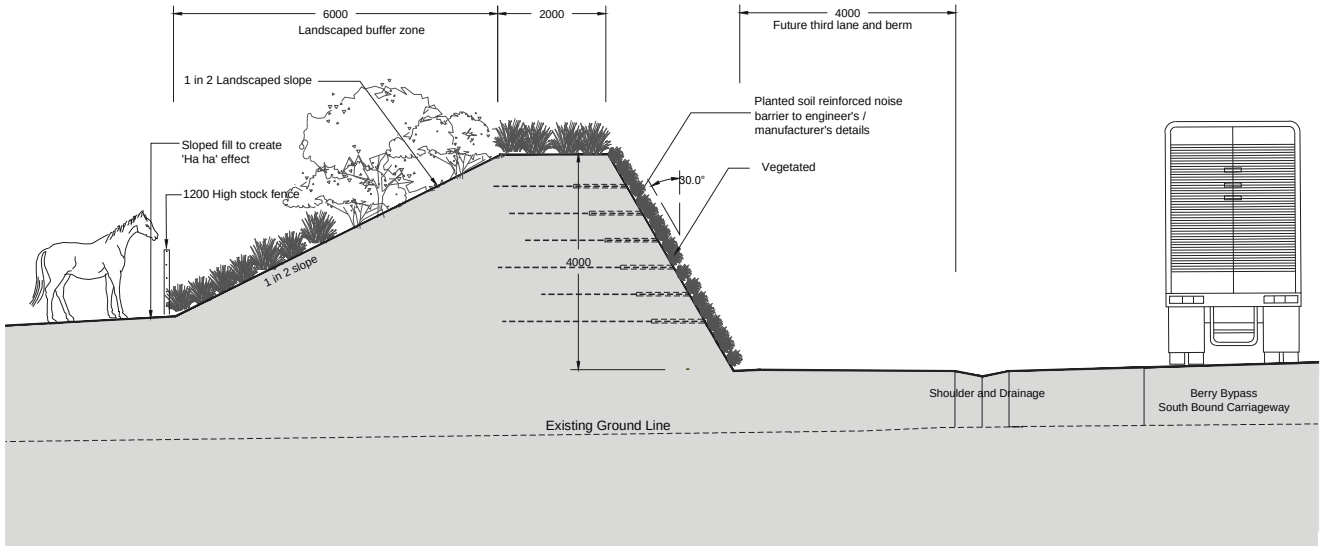

Figure 51: Noise barrier option 2 - Planted soil reinforced mound typical cross section.

Figure 52: Noise barrier option 2 - Planted soil reinforced mound photomontage.

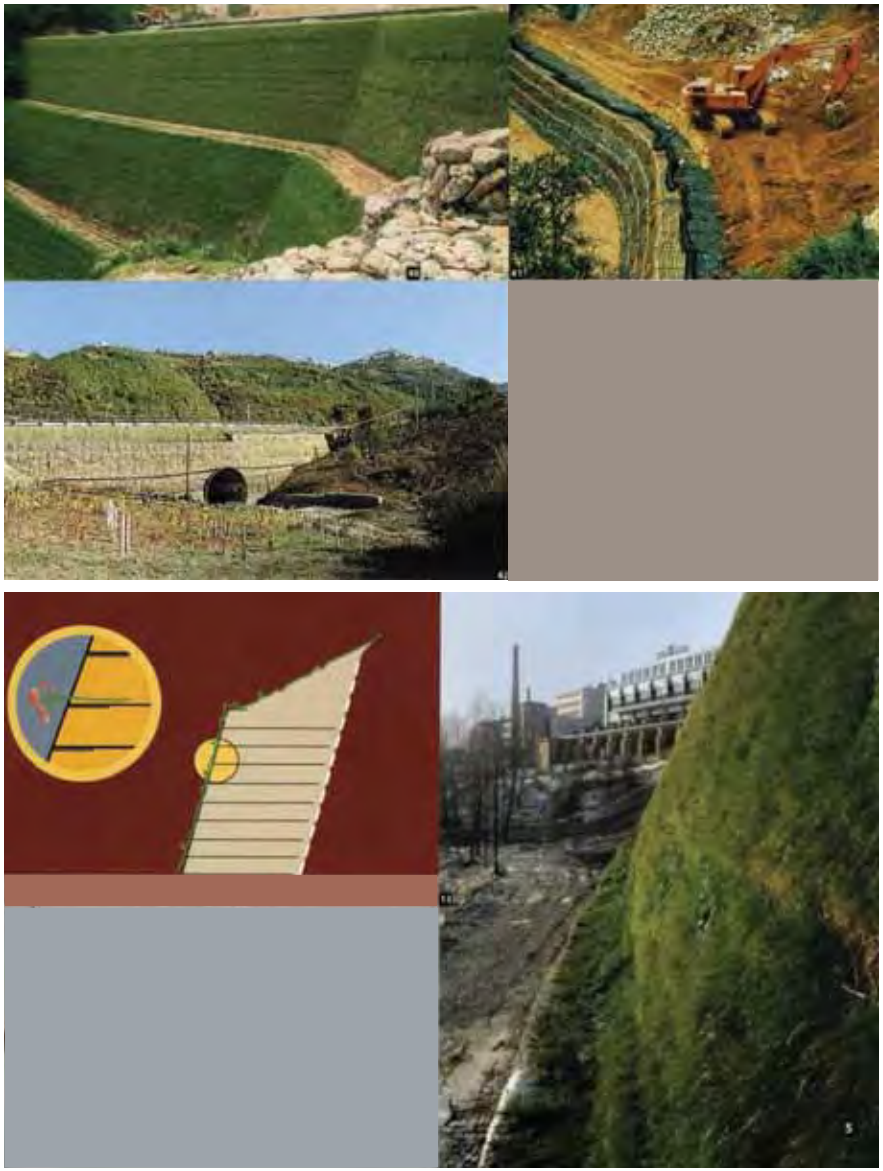

Figure 53 : Noise barrier option 2 - Planted soil reinforced mound examples of proprietary systems.

3. Combined stone wall and timber fence

This hybrid noise barrier option, is part local stone retaining wall, part timber noise wall, part landscaped mound – reducing the apparent scale of the barrier by breaking it into a series of steps and terraces. A palisade fence would be required at the top of the stone retaining wall for OH&S reasons. An advantage of this barrier configuration is that the landscape can be maintained from the North Street side without the need, on occasions, to close off the bypass road shoulder.

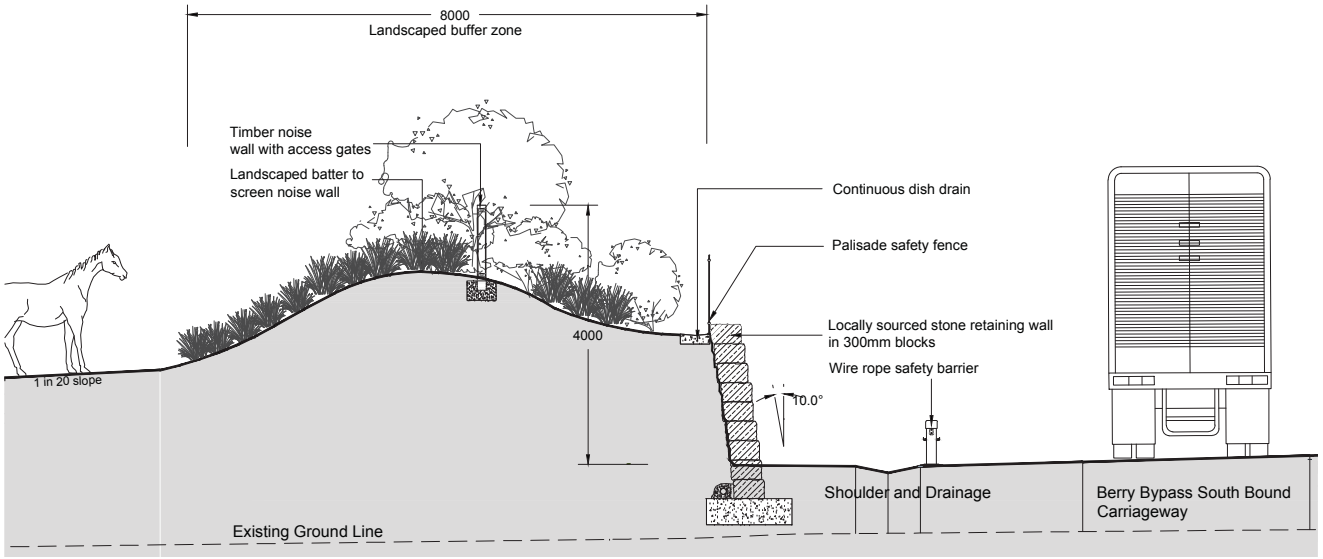

Figure 54: Noise barrier option 3 - combined stone wall and timber fence typical cross section.

Figure 55: Noise barrier option 3 - combined stone wall and timber fence photomontage.

5.9.2 Shared path

A shared pathway is a generous width concrete pathway that can accommodate both pedestrians and cyclists. Shared paths often incorporate line markings and signage identifying their intended use. A strict speed limit allows cyclists and pedestrians to share the same pathway safely. Shared paths cater for recreational cyclists, prams, motorised mobility scooters, children on bikes, joggers and walkers, and often become a focus for community interaction and socialising.

5.9.3 Street and park furniture

The proposed Town Creek Park and North Street shared pathway would incorporate comfortable bench seating at intervals along its length, to provide opportunities to rest and to enhance the enjoyment and amenity of these local green spaces.

5.9.4 Lighting

North Street currently has overhead power supply and street lights on about every second power pole along the south side of the street. Additional pole mounted street lights may need to be installed on the existing poles without lights, to adequately illuminate the shared pathway on the north side of the street.

The proposed Town Creek Park and landscaped pedestrian link from North Street through to Queen Street, would require pedestrian scaled lighting to supplement adjoining street lighting and to provide a safe passage in the evening. The proposed type of pole top light is illustrated below.

Pathways - a catalyst for community.

Proposed park seating.

Proposed park lighting.

Murase Plaza Memorial Park, Wilsonville, OR, USA Source: Louis Poulsen Projects & Products 2011-1012.

Example of recreational pathway.

5.10 Landscape design strategy

The landscaping would complement and unify the proposed cross section, to blend seamlessly with the surrounding context. An informal rural landscape character is proposed, with groupings of endemic native trees and shrubs planted in grasslands to create a 'parkway'.

Road embankments, either in cuttings or raised, would be planted with low groundcovers or native grasses, endemic shrubs and trees. Mowable embankments with slopes less than 1:3, would be planted with pasture grasses and copses of trees. Sound barrier mounds, where required, are softened by endemic trees and shrubs.

The use of native species would strengthen the local ecology and provide potential wildlife and habitat corridors for local fauna. Refer to Figures 56.

5.10.1 Bypass verges and noise barrier

View from Bypass Road side

Embankment batters to be planted with native grasses and groundcovers.

Proposed species:
Lomandra longifolia

View from Bypass road side:
Informal copses of Eucalypts, tall shrubs, occasional groundcovers and pasture grasses.

View from property:
Informal copses of Eucalypts and tall shrubs in grassland.

Proposed species :
Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)
Eucalyptus amplfoia (Cabbage Gum)
Hakea dactyloides
Melaleuca linarifolia
Groundcover:
Pasture grasses

Refer to Figures 57 and 58.

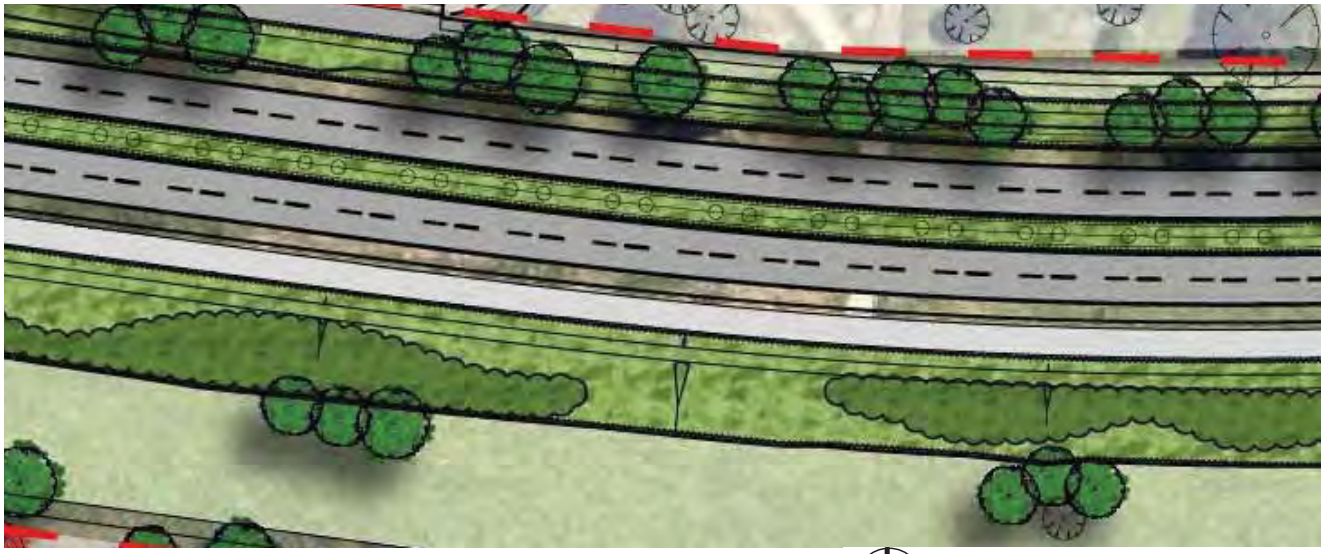

Figure 56: Bypass verges and noise barrier typical landscape plan.

Figure 57: Species selection.

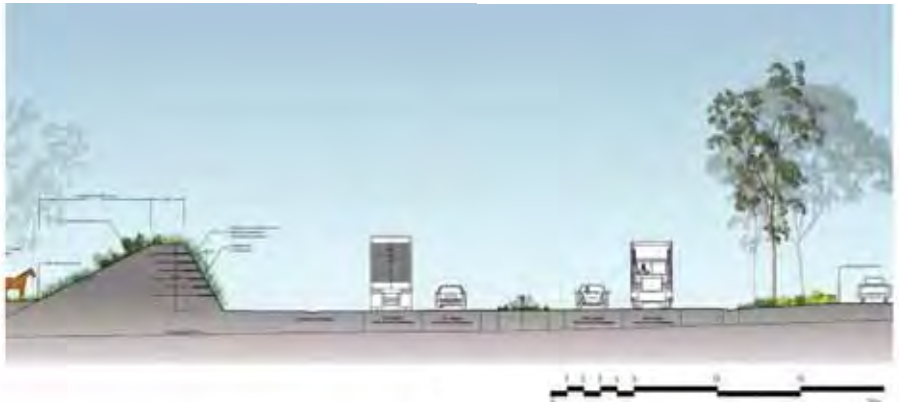

Figure 58: Typical cross section.

5.10.2 North Street

Road side character:
Informal country lane character overlooking open fields, fringed by groups of indigenous Eucalypt trees. Occasional exotic trees to add colour and to complement existing character. Refer to Figure 59.

Proposed species:
Eucalypt trees to reinforce existing trees, which would be retained, as shown in Figure 60.

Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)

Possible exotic highlight trees:
Jacaranda mimosifolia (Jacaranda)
Fraxinus oxycarpa aurea (Claret Ash)

View from North Street
Backdrop of informal groupings of Eucalypts trees and shrubs planted on the bypass noise mound, providing partial screening to the new bypass.

Proposed species :
Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)
Hakea dactyloides
Melaleuca linarifolia
Groundcover:
Pasture grasses

Refer to Figure 61.

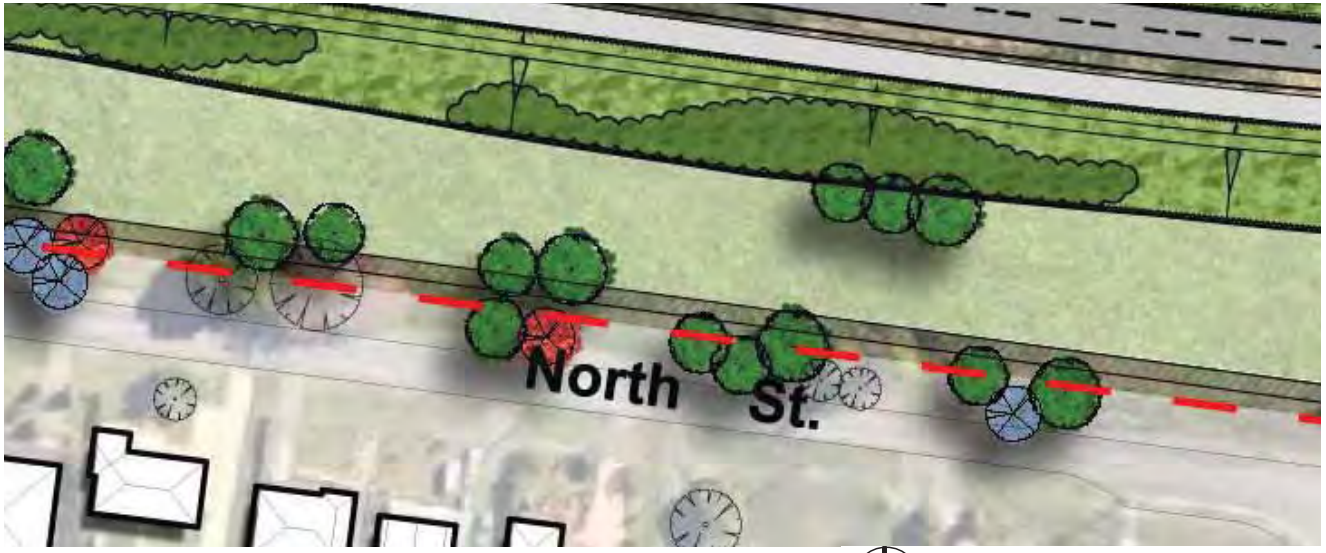

Figure 59: North Street typical landscape plan.

Figure 60: Species selection.

Figure 61: Typical cross section.

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5.10.3 Town Creek Park and Queen Street link

A new open space incorporating the upper reaches of the former Town Creek, and shared path link to Queen Street.

Character:
Informal parkland with central open grass area, native trees defining the perimeter and new road embankment. A new gateway into park to be created at the corner of George Street and Albert Street. Clear sightlines into the park are maintained for safety and security. Refer to Figure 62.

Activities:
Passive recreation, seating areas. Running and jogging trail. Shared path from the Berry sports precinct to Mark Radium Park traverses the precinct.

Proposed tree species:
Indigenous Eucalypts such as
Euc.microcorys (Tallowood)
Euc.botyroides (Bangalay)
Euc.pilularis (Blackbutt)
Eucalyptus robusta (Swamp Mahogany) highlighted with
Ficus coronata (Sandpaper Fig)
Melaleuca quinquinervia (Wide Leaved Paperbark)

Refer to Figure 63.

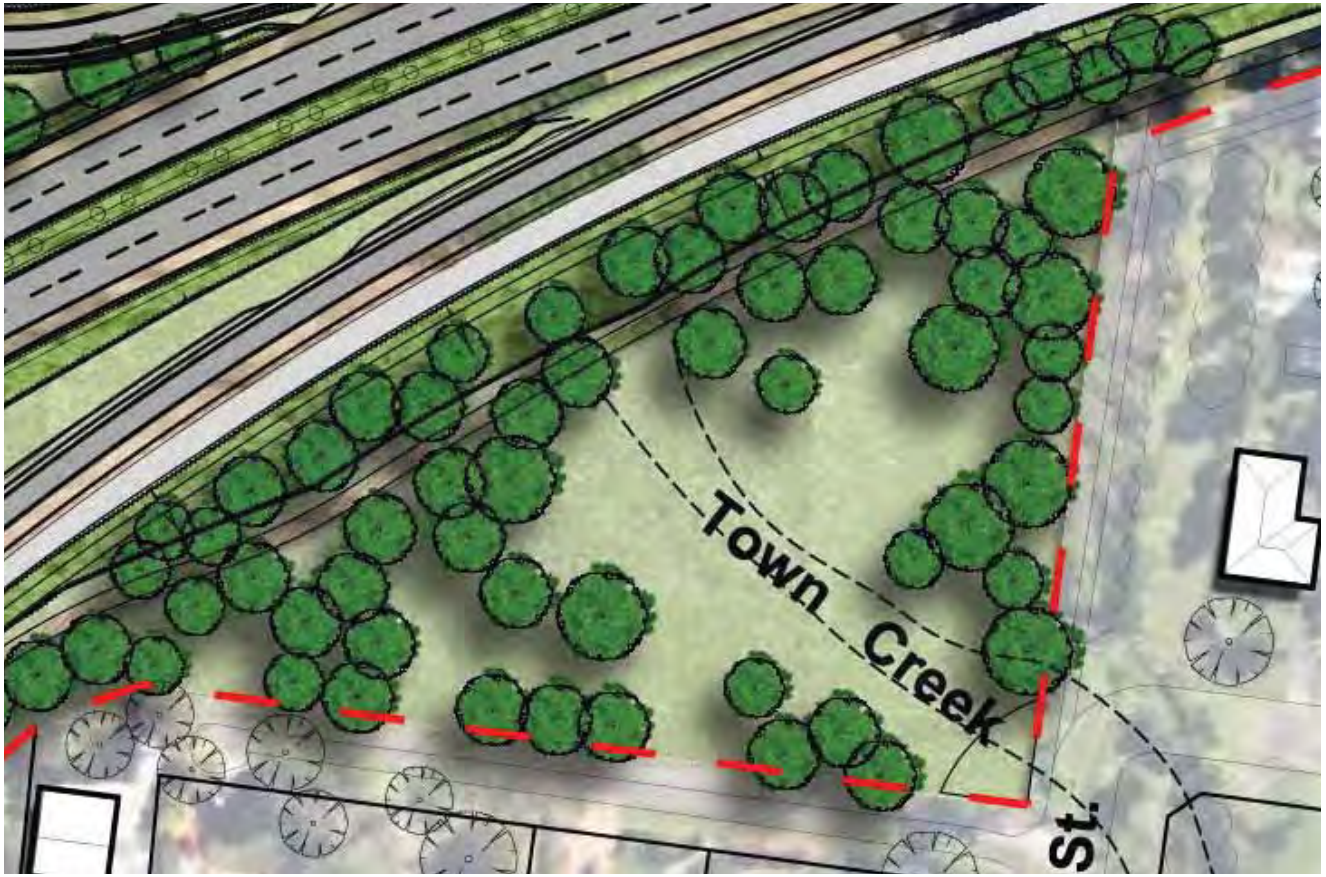


Figure 62: Town Creek Park and Queen Street link typical landscape plan.

Euc. microcorys *Euc. botryoides* *Euc. pilularis* *Euc. robusta* *Ficus coronata* *Melaleuca quinquenervia*

Figure 63: Species selection.

Figure 64: Attractive Queen Street vista south, to proposed Kangaroo Valley Road Interchange.

Figure 65: Queen Street and Kangaroo Valley Road intersection.

Figure 66: Climbing up the ridge to Queen Street.

Figure 67: Existing southern Princes Highway approach to Berry.

6.0 Kangaroo Valley Road Interchange and Victoria Street Precinct

The precinct is located at the western edge of the township of Berry, and extends in a broad arc, commencing in the southwest at the current Princes Highway southern approach to Berry, sweeping to the northeast, intersecting with Kangaroo Valley Road and the west end of Queen Street (the township's Main Street). The northeast extent of the precinct, and the northern extent of township development, would be defined by North Street.

The precinct includes the western end of Victoria Street and Queen Street, a proposed new connection from Hitchcock's Lane to Huntingdale Park Road, the eastern end of Kangaroo Valley Road, the western end of North Street and the entry to Huntingdale Park estate (currently in development). In the overlap between this precinct and the North Street Precinct there would be a triangular parcel of vacant land defined by George Street (to the east) and a private access driveway (to the south).

6.1 Setting and urban character

The township of Berry and urban development to the west along Kangaroo Valley Road is elevated above the surrounding floodplains, by a northwest-to-southeast ridgeline. In the southwest, between Hitchcock's Lane and Victoria Street lies an open grassed valley including a small creek, wetlands and scattered stands of trees, following the watercourses and property boundaries.

To the east of the Princes Highway two retirement villages are established – The Grange at Berry and The Arbour. These recent developments consist of clusters of one and two storey residences that have incorporated open space improvements to creek and drainage lines, feature estate entry landscaping, new footpaths and have improved Victoria Street with new street tree planting.

Mark Radium Park is located at the corner of the Princes Highway and Victoria Street and features a large stand of tall mature Eucalypt trees. The popular picnic spot incorporates a small pond, picnic tables, playground, public toilets, walking paths, vehicular loop and parking area.

To the west of the Princes Highway is the Huntingdale Park residential estate that is in its early development phase. The main entry to the estate is established on Kangaroo Valley Road, featuring sandstone estate signage and tree planting. Huntingdale Park Road, the main access for the estate, is elevated above the Princes Highway atop a retaining wall approximately 200metres long and reaches up to 5metres in height.

The western end of Queen Street and the eastern end of Kangaroo Valley Road are characterised by residential properties, set back from the street frontage with mostly informal street tree planting; supplemented by mature trees and shrub plantings, within well kept residential front gardens.

Private front gardens along Queen Street are generally open and defined by low scale fences, whilst on the south side, near the intersection with Kangaroo Valley Road and continuing down to Mark Radium Park, timber paling back fences face the street. A row of large Eucalypt trees is a feature of this corner. The verges have grass nature strips, standard municipal kerb and gutter, and concrete footpaths on both sides.

Currently the main traffic thoroughfare of Berry, Queen Street is an attractive undulating streetscape, with a vista west to the ranges framed by attractive street trees.

Kangaroo Valley Road is an intimate local scale residential street, with significant street tree planting supplementing front gardens. Generally verges are unformed with grass swales providing drainage and generally no footpaths are provided.

Refer to Figures 64 to 75.

Figure 68: Princes Highway and Victoria Street intersection.

Figure 69: The attractive mature stands of Eucalypts in Mark Radium Park.

Figure 70: Victoria Street vista west to Princes Highway.

Figure 71: Victoria Street view east, entry to The Arbour retirement village on right.

Figure 72: Kangaroo Valley Road vista northwest.

Figure 73: Scenic panorama north from the centre of proposed interchange.

Figure 74: Huntingdale Park residential estate entry off Kangaroo Valley Road.

Figure 75: Large retaining wall supports east side of Huntingdale Park Road.

6.2 Design philosophy

The guiding philosophy for the urban design of the Kangaroo Valley Road Interchange and Victoria Street Precinct, has been to:

- Integrate the new interchange within the existing topography and landscape.
- Integrate the new interchange infrastructure within the existing Main Street and the hierarchy of township local access streets.
- Provide a fitting Berry arrival and departure experience.
- Improve pedestrian and cyclist access and amenity and provide a safe pedestrian and cyclist environment for parks and walkways through adopting CPTED principles.
- Integrate noise mitigation structures within the urban landscape.
- Provide an attractive journey and outlook for drivers on the Berry Bypass.
- Develop an urban and landscape design that is low maintenance, durable and deters graffiti.
- Develop a materials and finishes palette that wherever practical incorporates elements of locally sourced stone and timber and colour finishes, that complement the natural colours of the environment.
- Generally utilise native plantings that are endemic to the region, whilst also incorporating cultural exotic plantings, when warranted, as highlight or feature plantings.

6.3 Urban design principles

The following urban design principles have guided the precinct urban and landscape design (refer to Figure 76):

1. Establish a continuity of streetscape from Queen Street to Kangaroo Valley Road.
2. Provide an attractive vista west along Queen Street.
3. Provide a footpath connection from Queen Street to Mark Radium Park.
4. And from Mark Radium Park to the adjoining Windsor Drive residential area.
5. Provide a recreational pathway from Kangaroo Valley Road to North Street.
6. Develop an arc of interconnected green spaces following the southern edge of the bypass corridor.
7. Incorporate the upper reaches of Town Creek as a feature within green spaces.
8. Capture attractive valley and escarpment views as part of the Bypass travelling experience.
9. Establish an attractive Berry township arrival experience
10. Incorporate signature existing eucalypts into township arrival experience.

Figure 76: Urban design principles.

6.4 Berry Bypass infrastructure

The Berry Bypass corridor is generally 34.0metres wide, widening to accommodate the on and off ramps of the Kangaroo Valley Road Interchange. The Kangaroo Valley Road Interchange consists of an overbridge and associated roundabouts to the east and west providing legible local road access. A full northbound and southbound Bypass interchange would be provided with on and off slip roads. Different to the standard 'diamond' interchange configuration the northbound off ramp would continue beneath the overpass bridge to loop around and connect into the proposed interchange roundabout on Kangaroo Valley Road. This configuration would simplify the access arrangements to the entry of the Huntingdale Park estate, and would potentially reduce the visual impacts of the noise barrier on Huntingdale Park residents. North Street (west) would be connected to Rawlings Lane to maintain vehicular access to the two farm properties located to the north of the bypass.

A noise barrier would be proposed along the southern edge of the bypass corridor, extending to Queen Street.

A 2.5metre wide shared pathway would be provided connecting North Street with Queen Street, and on both sides of the interchange overbridge linking Queen Street to Kangaroo Valley Road.

Access to Mark Radium Park and to The Arbour retirement village would be maintained at the western end of Victoria Street, however it is proposed that there would be no access to the upgraded Bypass from Victoria Street. Access would be maintained to the Hitchcock's Lane rural properties with a new road link to Huntingdale Park Road.

Figure 77: Berry Bypass infrastructure.

6.5 Urban design strategy

The proposed construction of the highway-scale Berry Bypass infrastructure would bring changes for the township of Berry. Some of these changes would be positive including:

- Completion of this important section of the Princes Highway would provide a quicker and safer route for locals travelling regionally and along the NSW coast, tourists visiting South Coast destinations and day-trippers visiting the popular heritage and festival destination of Berry travelling to/from Sydney; boosting tourist accommodation, cafe/restaurant and retail business opportunities and employment in the township.
- The upgrade to a highway standard roadway would reduce fatalities and accidents along this currently difficult stretch of highway.
- The volume of truck and through traffic on the Queen Street retail 'Main Street' would be considerably reduced. There would be an opportunity to refocus 'Main Street' as a pedestrian friendly zone with increased and safer crossings, more opportunities for outdoor cafe-style seating, street tree planting and urban furniture.

The highway formation and interchanges are large physical structures and the urban strategy has been to investigate means by which these structures could be integrated at the edge of the township and into the surrounding attractive rural landscape - minimising the urban, landscape and visual impacts on the environment.

The strategy incorporates a series of urban and landscape design initiatives, including:

- Reducing the visual impact of the road formation through adjustments to the highway's vertical and horizontal alignment.
- Introducing generous open space buffers between the Berry Bypass and urban development to the west and east.
- Wherever possible, re-establishing the riparian vegetation and habitat along creek lines.
- Reducing noise impacts through incorporation of landscaped noise barriers along the edges of the alignment.
- Retaining as much as possible existing landscape, that defines the region and screens from view the new roadway and interchange structures.

The Urban Design Strategy diagram illustrates the key initiatives that are proposed to integrate Berry Bypass within this uniquely urban setting.

An aerial view is provided in Figure 79.

Figure 78: Urban design strategy.

Figure 79: Aerial view looking northeast.

6.6 Precinct plan

The Precinct Plan illustrates the proposed urban and landscape concept design for the Kangaroo Valley Road Interchange and Victoria Street Precinct.

Figure 80: Precinct Plan - Kangaroo Valley Road Interchange and Victoria Street Precinct.

6.7 Cross section studies

Four cross sectional studies were prepared at the Kangaroo Valley Interchange (Refer to Figure 77). The existing ground level is shown as a dashed line. At Kangaroo Valley Road the Bypass is in a cutting, with sloped batters that are landscaped with native grasses and informal tree planting. The predominant landscape plantings are of natives, primarily Eucalypts, with some feature tree plantings of Birch and Ash to highlight arrival and departure.

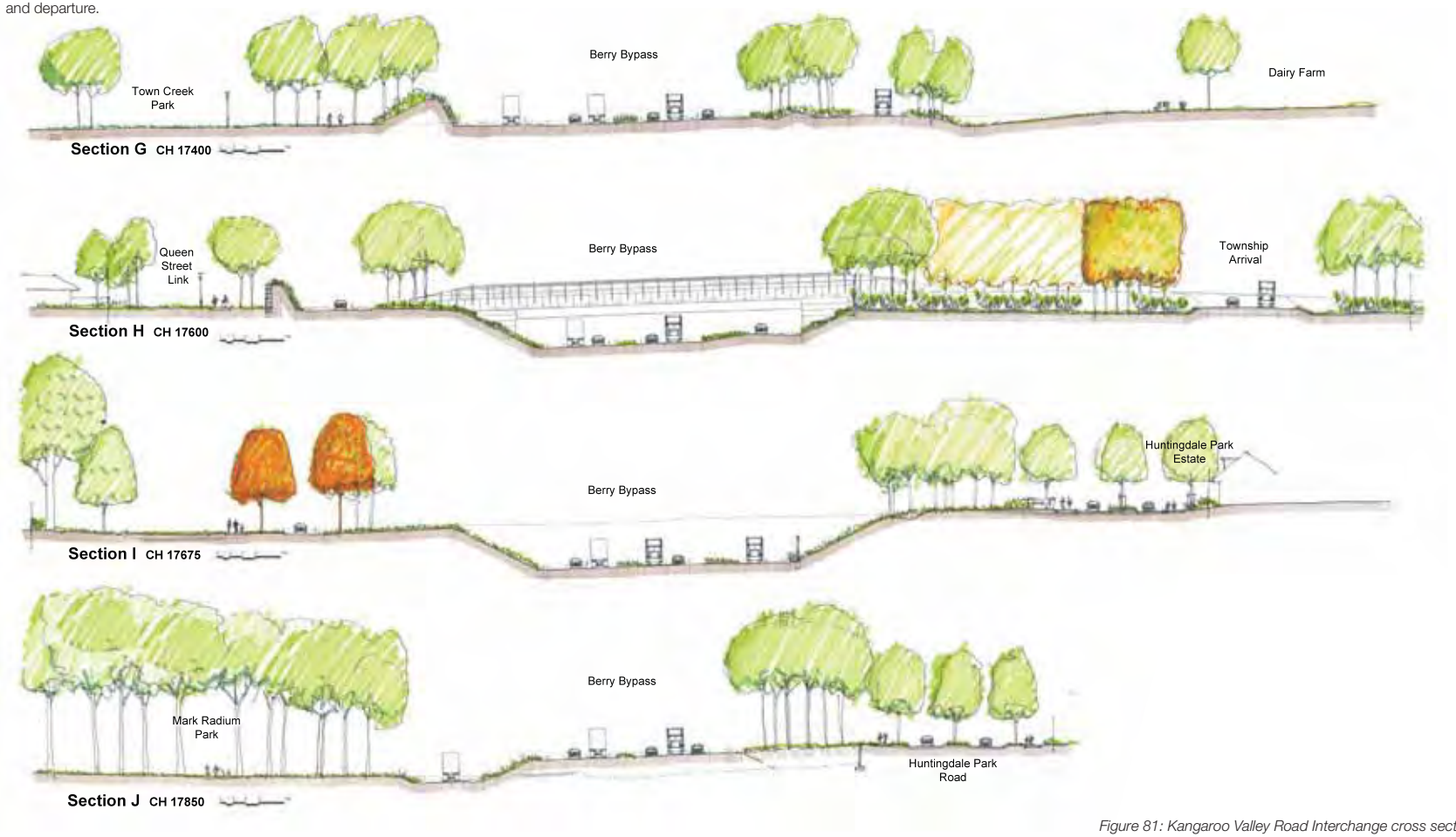


Figure 81: Kangaroo Valley Road Interchange cross sectional studies.

6.8 Urban design elements

The Kangaroo Valley Road Interchange and Victoria Street Precinct of the Berry Bypass would comprise urban design elements ranging from large scale, such as the interchange overbridge, on-off ramps, roundabouts and local access connections, to the smaller scale, including footpaths, street and park lighting, street furniture and signage. Integrated with the urban design would be the landscape design of the interchange, adjoining streets and associated local green spaces. All urban and landscape design elements have been considered as contributing to the overall coordinated design outcome.

6.8.1 Kangaroo Valley Road Interchange

The Kangaroo Valley Road Interchange requires road, ramp, overbridge and noise barrier infrastructure of significant scale. Considerable care would be necessary to fully integrate the interchange within the sensitive residential neighbourhoods situated to the east and west, the open rural pastureland to the north and the valley, creekline and green spaces to the south.

The 100 kilometre/hour highway design standard necessitates a broad sweeping road alignment for the main bypass carriageways. This dramatic curve would be reiterated by 2H:1V sloped cut batters along each side of the roadway as it passes through the local ridgeline. A counterpoint to this dramatic sweeping alignment would be the overbridge that connects Queen Street with Kangaroo Valley Road. The continuity of the curved road alignment, associated landforms and noise barriers should be emphasised, with views beneath the bridge remaining as open as possible to maximise the vistas along the curved corridor to adjoining picturesque rural pastures, local ranges and to the distant escarpment.

As a counterpoint to the curved road alignment the architecture of the bridge should emphasize its inherent horizontal qualities, with streamlined superstructure, abutments, parapet and throw screens.

Two roundabouts are proposed at either end of the bridge. The east roundabout provides an opportunity to complete the Queen Street visual axis. In addition to retaining the row of large Eucalypt trees on the south side to mark the location, colourful feature trees planting and a central planter would be proposed, to provide a fitting arrival/point of departure for travellers. The west roundabout would complete the Huntingdale Park estate entry; a central feature planter, combining with the existing sandstone estate signage, feature posts and street trees.

Distinctive feature planting would be proposed as part of the arrival approach to Berry, from the south. The Bypass off-ramp continues beneath the overbridge and then curves upwards in a broad sweep to arrive at the west roundabout. The large open space at the centre of the curved ramp would accommodate a large stand of feature Birch trees, with their seasonal foliage colour and distinctive trunks creating a memorable landmark.

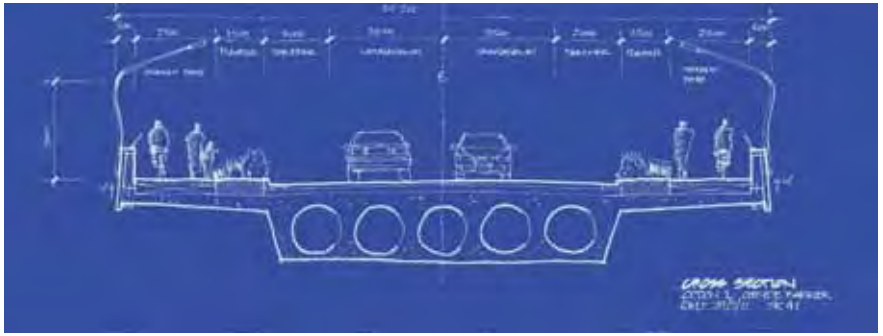
Figure 82: Kangaroo Valley Road Interchange design concept.

6.8.2 Interchange overbridge design options

Two options were explored for the design of the cross section of the interchange overpass bridge. Option 1 located the vehicular safety barrier on the outside edge of the bridge deck, provided a more or less standard local street cross section of kerb and gutter and landscaped verge, and explored the possibility of introducing a sculptural profile to the throw screen. This offers a sense of protection from the inherent exposed nature of such elevated bridges, and introduce a sense of delight and lightness for those crossing the bridge. Two landscaped strips approximately 1.5metres were proposed to soften the otherwise hard paved surfaces and to introduce some attractive landscaping along the shared use pathway. This was the preferred design option at the Community Working Group (CWG) meeting held in Berry on the 29th March 2012.

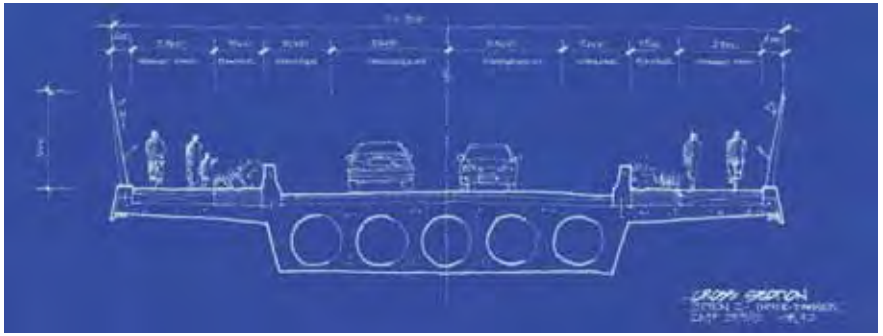
Option 2 looked at locating the vehicle safety barrier at the street kerb. This allowed the throw screen to be full height, providing a more open crossing experience. The CWG preferred Option 1 as it was seen to provide a better sense of protection from the elements when crossing the bridge (this was seen as particularly important for children).

Figure 83: Option 1 - Outside barrier photomontage.



Option 1 - Outside barrier indicative cross section.

Figure 84: Option 2 - Inside barrier photomontage.



Option 2 - Inside barrier indicative cross section.

6.8.3 Preferred interchange overbridge design

The preferred overbridge design would be a concrete structure of a post tensioned, cast in situ, voided slab construction that would achieve a single, clear span of approximately 47.8metres. The abutments would consist of reinforced soil walls incorporating precast concrete facing panels with emphasized horizontal joints in a 2.0metre wide by 1.0metre high grid. Alternate bridge structural types that utilise spill-through abutments would also be assessed to see whether the view corridor beneath the bridge can be opened up further.

The bridge deck would be approximately 20.0metres wide and 2.3metres deep, and accommodates at two way carriageway with paved shoulders. The bridge cross section would be kept as close as possible in appearance to a regular local street: with generous width, pathways, and a standard kerb and gutter and 'nature strip'.

Shared use paths of 2.5metres width would be provided on both sides of the bridge. Between the shared use path and the carriageways would be a landscaped strip of 1.5metres width. To prevent seepage into the bridge structure below, completely separate planter boxes, constructed of glass reinforced concrete (GRC) sit atop the deck and house the minimum 450millimetres depth to accommodate the necessary mulch, soil and drainage course. Hardy plants would be selected, such as Lomandra and the like to ensure a long term low maintenance landscape. Irrigation would be necessary during the initial plant establishment period.

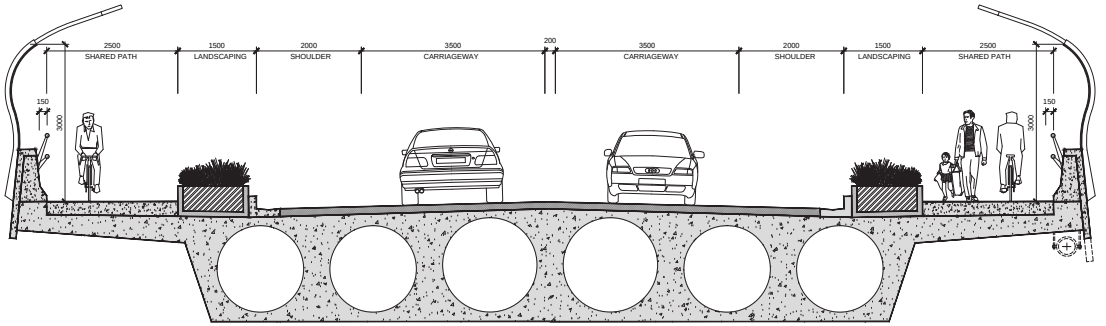
Figure 85: Kangaroo Valley Road Interchange preferred design.

The bridge parapet top and outside face would consist of high quality precast concrete units (visible from the main carriageways) and would be integrated in design with the throw screen structure above. Additional precast concrete 'skirt' length would be provided to screen any services that are required to be hung from beneath the bridge.

The shared use pathways would be lit at night for pedestrian safety (it is recommended that the faces of pedestrians using the paths be illuminated), with efficient long life light fittings integrated within the throw screen structure. A bicycle rail and pedestrian height handrail would be provided along the outside edge of the shared use path.

The bridge has a 4.0% slope from the west to the east. It is envisaged that this slope would facilitate drainage of the deck along its length, avoiding the need for scuppers or drain pipes to be fixed to the underside of the bridge.

Utility services would be accommodated in conduits cast in the concrete shared use path slab and in the Type F edge safety barrier.



CROSS SECTION

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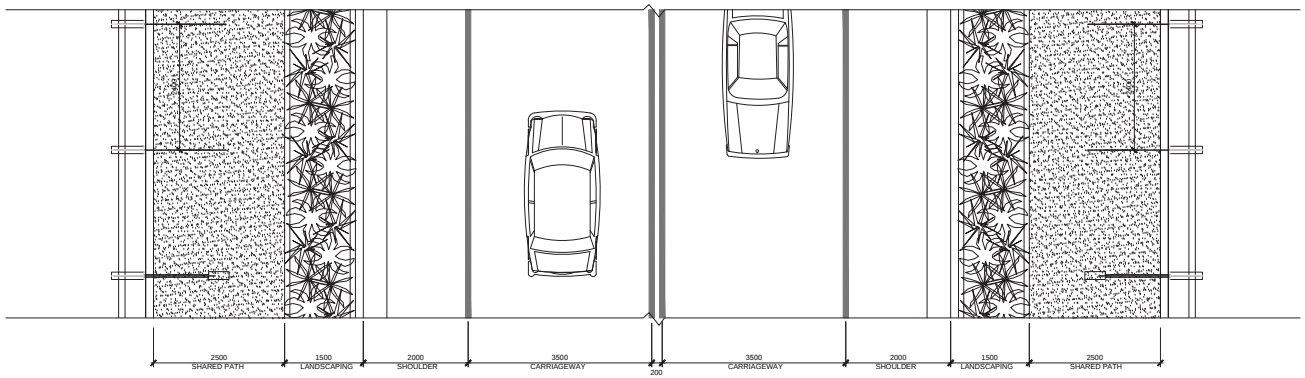

PLAN

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KANGAROO VALLEY ROAD INTERCHANGE
BRIDGE CROSS SECTION - OPTION 1- PREFERRED DESIGN
Dwg No 12001-SK-057
Issued 16 July 2012

KANGAROO VALLEY ROAD INTERCHANGE

VIEW FROM NORTH BOUND LANES

Dwg No 12001-SK-059
Issued 13 July 2012

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Architecture + Interior + Heritage + Urban Design + Masterplanning
52-58 William Street East Sydney NSW 2011 Australia
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KANGAROO VALLEY ROAD INTERCHANGE

VIEW FROM SOUTH BOUND LANES

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KANGAROO VALLEY ROAD INTERCHANGE

PEDESTRIAN VIEW LOOKING NORTH WEST FROM KANGAROO VALLEY ROAD BRIDGE

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KANGAROO VALLEY ROAD INTERCHANGE

PEDESTRIAN VIEW LOOKING SOUTH EAST FROM KANGAROO VALLEY ROAD BRIDGE

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6.8.4 Noise barrier

Noise modelling studies undertaken by Aecom have established that two 4.0metre high noise barriers would be required in the vicinity of the interchange. The first noise barrier would be required along the outer edge of the southbound off-ramp. This barrier would be a continuation of the planted reinforced soil 'green wall' that runs along the south edge of the corridor in the North Street precinct. To realise the expression of an uninterrupted, streamlined barrier when seen from the Bypass corridor, it is envisaged that the 'green wall' face would continue up to Queen Street following the grade of the off-ramp.

The width available to the south of the noise barrier is limited in the North Street to Queen Street link. This would necessitate a vertical face to the rear of the barrier through this section. A galvanised steel mesh gabion wall structure is envisaged that would be filled with local stone sourced from project excavation.

A second noise barrier would be required along the northbound off-ramp leading up to the overbridge. It is approximately 140metres long and 4.0metres high (above the level of the main carriageways).

Refer to Figures 86 and 87.

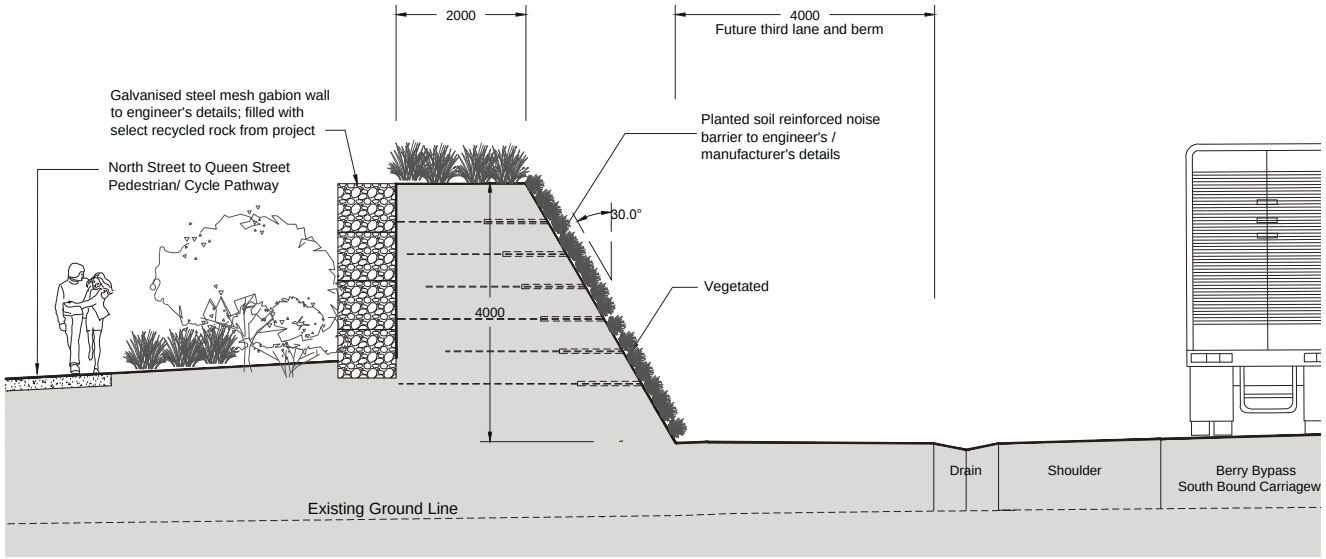

Figure 86: Noise barrier - planted soil reinforced typical cross section.

Example of gabion wall with select local stone.

Figure 87: Noise barrier - planted soil reinforced mound photomontage.

6.8.5 Overbridge throw screen

Throw screens are required on both sides of the overbridge, extending 6.0metres beyond the bridge abutments and extending to 3.0metres height above the finished level of the bridge deck. A sculptural 'S' shaped profile is proposed with galvanised steel mesh and integrated pedestrian safety lighting.

Shared use paths of 2.5metres clear width are proposed on both sides of the interchange overbridge. Refer to photomontages on pages 76 and 77.

6.8.6 Furniture

The proposed Town Creek Park shared pathway would incorporate comfortable bench seating at intervals along its length, to provide opportunities to rest and to enhance the enjoyment and amenity of these local green spaces.

6.8.7 Lighting

Queen Street, Kangaroo Valley Road and the Princes Highway currently have overhead power supply and street lights along the south side of the street.

With the construction of the new interchange, the electrical supply would need to be rationlised in the vicinity. A lighting design would be prepared at detail design stage to ensure appropriate lighting levels are achieved for driver and pedestrian safety.

The proposed Town Creek Park and landscaped pedestrian link from North Street through to Queen Street, would require pedestrian scaled lighting to supplement adjoining street lighting and to provide pedestrian safety at night.

The proposed pole top light is illustrated on page 55.

6.9 Landscape design strategy

The 'arrival' landscape into Berry would be designed to highlight the Kangaroo Valley Road Interchange and reinforce the rural Berry township character.

The landscape design would enhance the endemic tree canopy and habitat corridors, mitigate the visual impact of the road engineering and create a memorable, signature gateway to the Berry township.

6.9.1 Kangaroo Valley Road Interchange

Southern approach

The roadway from the south would be gradually lowered into a cut, densely planted on both sides with Eucalypts, on embankments seeded with native grasses and shrubs. The plantings are designed to create pleasant 'walls of green' along the roadway, and to screen out views of the freeway from the township and adjacent residential estates. As the road rises up to the Berry turn off, groves of Claret Ash (*Fraxinus oxycarpa aurea*) and Birches (*Betula pendula*) would provide colour and contrast against the backdrop of Eucalypt trees. The exotic trees are grouped in groves with generous gaps in between to retain views of the surrounding hills and rural landscape. The roundabouts would be planted with robust and colourful native and exotic groundcovers and incorporate opportunities for public art and signage. Refer to Figure 88.

Proposed native tree species:
Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)
Hakea dactyloides
Melaleuca linarifolia

Proposed exotic tree species:
Fraxinus oxycarpa aurea (Claret Ash)
Betula pendula (Silver Birch)

Proposed groundcover:
Native pasture grass

Refer to Figure 89.

Figure 88: Kangaroo Valley Road Interchange typical landscape plan.

Northern approach

The northern approach ramp into Berry would be defined by a generously planted median complementing the structure of the overhead bridge that connects Kangaroo Valley Road and Queen Street.

The left embankment would be a continuation of the southern acoustic mound, and would be densely planted with native grasses and tall Eucalypts as a backdrop.

An avenue of Claret Ash is proposed at the roundabout into Queen Street, reinforcing the species and colour proposed for the southern approach .

The groundcovers in this roundabout would include exotic shrubs to highlight the 19th and 20th century garden traditions of the heritage township.

Refer to Figure 88.

Similar robust and colourful groundcovers would also be planted on both sides of the overhead bridge, to create a welcoming and seamless entry statement into the Town's main street.

Proposed native tree species:
Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)
Melaleuca linarifolia

Proposed exotic tree species:
Fraxinus oxycarpa aurea (Claret Ash)

Proposed groundcover:
Lomandra longifolia (Spiny-Head Mat-Rush)
Native pasture grass

Refer to Figure 89.

Figure 89: Species selection.

6.9.2 Victoria Street

Victoria Street would be closed at its western end to create a cul de sac, adjacent to Mark Radium Park.

The former road would be turfed over and Eucalypts would be planted on the edges, visually extending the size of the park. Refer to Figure 90.

Proposed native tree species:
Eucalyptus punctata (Grey Gum)
Eucalyptus globoidea (White Stringybark)
Eucalyptus eugenoides (Thin Leaved Stringybark)
Hakea dactyloides
Melaleuca linarifolia

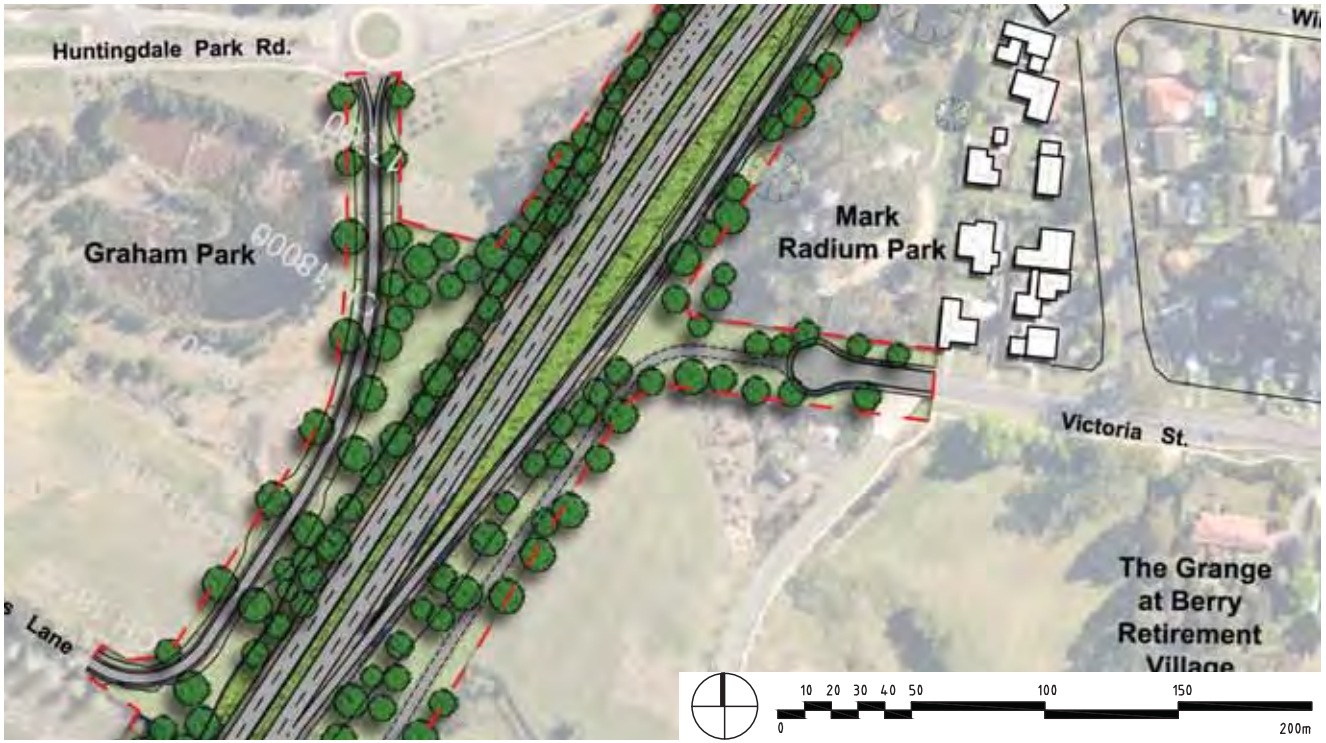

Figure 90: Victoria Street typical landscape plan.

7.0 Materials, finishes and colour strategy

7.1 Philosophy

The following urban design philosophy has guided the selection of the project materials and finishes palette:

- Taking a low-key approach.
- Complementing the natural environment.
- 'Natural' finishes preferred rather than applied.
- Utilising locally sourced stone and timber.
- Selecting finishes that weather and age well.
- Detailing that minimises staining and is self-cleaning.

7.2 Finishes selections

The adjoining sample photos (Refer to Figure 91) illustrate the proposed approach - including utilising local stone and timber when appropriate, and selecting materials and finishes that are generally low-key, robust and that weather well.

7.3 Graffiti strategy

The approach to deterring graffiti is to wherever possible 'design-out' situations where the potential for walls or surfaces that could be defaced are removed. Maximising the opportunity for passive surveillance through creating places that are attractive to people, are easily accessible and well lit at night would deter and minimise the occurrence of graffiti.

Local stone.

Destination signage.

Berry memorial.

Estate signage.

Local timber.

Stone faced retaining wall.

Complementing the natural contours of the region.

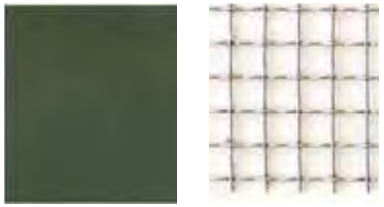

Figure 91: Materials, finishes and colour strategy.

NOTE: The images are for illustration purposes only.