4. Evaluation of impacts

4.1. Overview

At the landscape scale, the major ecological impacts from increasing road networks are associated with loss of habitat, disruption of landscape processes through fragmentation, barriers to wildlife movement and the loss of biodiversity, both for flora and fauna (Forman & Alexander 1998). The project would increase the current road network in the north coast region and therefore would increase road density over remaining habitat in the region with the potential to increase fragmentation, loss of threatened species habitat and create a barrier to the movement of fauna.

The severity of the impact is minimised to a degree by the fact that major portions of the project are an upgrade or duplication of the existing Pacific Highway and that the overall route was developed with consideration for the protection of biodiversity. A biodiversity offset strategy has been developed which includes offsetting the cumulative impacts associated with the project. It is anticipated that the biodiversity offset strategy would contribute to the long-term conservation of biodiversity in the bioregion.

4.2. Avoidance measures

4.2.1. Key considerations to avoid and minimise biodiversity impacts

The key principle of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA 2011a) with regard to managing biodiversity for road development and associated impacts on biodiversity is that the planning and construction of roads should, in order of consideration, endeavour to:

- Avoid and minimise impacts first
- Mitigate impacts where avoidance is not possible
- Offset where residual impacts cannot be avoided.

The range of measures that were adopted for the project to avoid and minimise impacts on biodiversity are discussed in Section 4.2.2. This discussion is followed by the identification of any residual impacts that may remain. Measures to mitigate impacts during construction and operation of the project are presented in Chapter 5.

4.2.2. Route selection

The previous development project ecological assessments (RTA, 2005-2011) identified significant ecological values in order to inform planning decision around avoiding and minimising impacts to biodiversity. This involved a preliminary examination of a number of possible route options and their potential impacts on the environment and other factors (for example, economic and social considerations). Those potential routes that best fit the environmental, social and economic criteria were then short-listed.

Minimising impacts involved reducing the loss of habitat or potential impacts on threatened species, populations and communities were considered as far as practicable in minimising impacts. Short-listed routes were generally loosely defined within a broad corridor. The detailed surveys within the project boundary sought to refine the alignment and width of the footprint to further minimise the loss of important vegetation communities and habitats and avoid significant plant species or fauna habitat features. The engineering constraints and RMS road design and safety standards were also considered when locating the project alignment and footprint.

The selection of the preferred route was partially influenced by the ecological investigations. The data informed both the route selection processes and the preliminary design of the preferred route corridor. The route selection process considered total potential vegetation and habitat loss in addition to habitat condition and the presence of species and ecological communities of conservation significance.

In calculating the potential vegetation clearing for each route option, consideration was given to minimising impacts on existing vegetation by selecting a route that largely impacts on disturbed and cleared land.

Any issues raised and recommendations from each of the investigations with respect to further avoiding and minimising impacts on biodiversity were considered at the concept design and the ecological assessment stage.

4.2.3. Avoidance during detailed design

While disturbance and clearing of vegetation as a result of the project would be unavoidable, there are further opportunities to avoid and minimise the loss of native vegetation and fauna habitat during the detailed design. The following principles would be prioritised during all aspects of the detailed design:

- Avoiding and minimising vegetation removal wherever possible
- Sensitive selection of ancillary facilities. The ancillary facilities identified present a selection of available sites, however during detailed design an evaluation should be conducted to select the minimum number of sites required with a priority to avoid native vegetation clearing if possible. A site inspection is required prior to construction to survey and map hollow-bearing trees and check for large nests for species such as raptors, including Osprey and also Black-necked Stork at these sites

- Construction compounds and stockpile sites are to be sited in cleared or sparsely treed portions of the ancillary facility sites where feasible and reasonable, to avoid unnecessary clearing of vegetation and threatened flora species
- Water quality basins are to be placed in the optimal location for treating surface runoff. During detailed design, the location of water quality treatment measures are to consider the competing environmental requirement of minimising vegetation removal, particularly where there is the potential for threatened plant species, threatened fauna habitat or in identified regional wildlife corridors.

4.2.4. Ancillary facilities

Eighty one potential ancillary facilities have been identified along the project. These facilities are temporary sites to be used during construction and comprise of uses such as construction compounds and / or stockpile sites. Of the 81 sites identified, 26 are located wholly within the project boundary and the loss of vegetation and habitat has therefore been included in the project impact calculations in Table 4-1. The estimate of vegetation and habitat loss on the remaining 55 sites has been based on desktop data and general field data for surrounding areas. These sites have been selected predominantly in cleared land.

Desktop data and knowledge of flora and fauna within the project boundary was considered in a review of potential locations for ancillary facilities as documented in the EIS. Potential sites were identified taking into consideration a number of factors including the sensitivity of the flora and fauna at the location. This includes identification of areas with minimal tree cover and outside of a key habitat or regional corridor zones. Of the land identified for potential ancillary facilities outside of the project boundary (about 233 hectares) a maximum of around 25 hectares of native vegetation may be cleared should these sites be used for the project. The CRAFTII / BioMetric broad-scale vegetation mapping identifies this vegetation to consist of the following vegetation types:

- Dry Heathy Blackbutt-Bloodwood and Cleared
- Dry Grassy Blackbutt - Tallowwood, Swamp Oak and Cleared
- Northern Open Grassy Blackbutt (inland), Dry Blackbutt (inland) and Cleared
- Heathy Scribbly Gum
- Sherwood Needlebark Stringybark, Needlebark Stringybark, Lowland Red Gum winter flowering and Forest Red Gum - Grey Gum/Grey Ironbark – Rough-barked Apple
- Sandstone Spotted Gum-Blackbutt, Spotted Gum - Blackbutt and Clarence Lowlands Spotted Gum.

Further targeted field investigations for ancillary facilities would be conducted and reported during the EIS submissions phase and any ecological constraints and values identified as a means of refining the selection of ancillary sites. During this process sites with identified high value habitat for threatened species or threatened ecological communities would not be considered further as ancillary sites.

4.3. Potential impacts

In general, the types of impacts to biodiversity that are likely to occur during construction and operation of the project are summarised below and in the following sections. These include:

- Loss of native vegetation (including threatened flora and threatened ecological communities and their habitats)
- Loss of terrestrial, riparian and aquatic habitat for protected and threatened fauna (including food resources, shelter and refuge areas during non-breeding and breeding life-cycle events)
- Direct mortality of protected and threatened fauna
- Loss of connectivity for protected and threatened flora and fauna species and populations with the degradation of wildlife and habitat corridors (including links to national parks and state forests)
- Fragmentation of terrestrial, arboreal and aquatic habitat and edge effects from road noise, light and wind turbulence
- Drainage, clearing and degradation of ground water dependant ecosystems and wetlands (including SEPP 14 and nationally important wetlands)
- Changes to water quality as a result of works in or adjacent to aquatic habitats and alterations to natural hydrological flows
- Invasion and spread of terrestrial and aquatic weeds and pest fauna species
- Potential spread of disease pathogens
- Introduction or increased exposure to key threatening processes that may affect terrestrial and aquatic species, populations, ecological communities and their habitat (including threatened biota)
- Regional cumulative impacts affecting long term viability and survival of common and threatened species, populations and ecological communities and their habitats.

4.3.1. Loss of native vegetation

Native vegetation clearing

Clearing of native vegetation is a key threatening process listed under the TSC Act and the EPBC Act (refer to Section 4.4).The project would clear about 948 hectares of native remnant vegetation, affecting a number of vegetation types as described in Table 4-1. These clearing estimates have been calculated based on the construction footprint (the road construction footprint including water quality and sediment basins plus an additional 10 metre allowance for construction). This does not include clearing that may be required for potential ancillary facilities beyond this construction footprint. The loss of vegetation associated with potential ancillary facilities would equate to an additional 25 hectares (this is discussed separately below).

The construction footprint extends over about 870 hectares of cleared land and small areas of modified vegetation that is not associated with natural vegetation communities.

Table 4-1: Summary of vegetation loss for the project by BioMetric vegetation community and area

BioMetric vegetation association*	Direct loss (hectares)	Potential edge effects (hectares)
Black Bean - Weeping Lilly Pilly Riparian Rainforest of the North Coast	1.4	0.5
Blackbutt - Bloodwood Dry Heathy Open Forest on Sandstones of the Northern North Coast	79.7	28.9
Blackbutt Grassy Open Forest of the Lower Clarence Valley of the North Coast	46.2	11.3
Coast Cypress Pine Shrubby Open Forest of the North Coast Bioregion	27.4	5
Coastal Floodplain Sedgelands, Rushlands, and Forblands	3.0	0.8
Coastal Heath on Sands of the North Coast	0.2	2
Flooded Gum - Tallowwood - Brush Box Moist Open Forest of the Coastal Ranges of the North Coast	2.0	1.6
Forest Red Gum - Swamp Box of the Clarence Valley Lowlands of the North Coast	73.9	29.4
Grey Gum - Grey Ironbark Open Forest of the Clarence Lowlands of the North Coast	48.2	7.1
Hoop Pine - Yellow Tulipwood Dry Rainforest of the North Coast	0.5	0.3
Mangrove - Grey Mangrove Low Closed Forest of the NSW Coastal Bioregions	1.5	0.4
Narrow-Leaved Red Gum Woodlands of the Lowlands of the North Coast	34.7	30.6
Needlebark Stringybark - Red Bloodwood Heathy Woodland on Sandstones of the Lower Clarence of the North Coast	58.2	15.4
Orange Gum (*Eucalyptus bancroftii*) Open Forest of the North Coast	11.5	6
Paperbark Swamp Forest of the Coastal Lowlands of the North Coast	49.5	17.1
Red Mahogany Open Forest of the Coastal Lowlands of the North Coast	46.2	16.7
Scribbly Gum - Needlebark Stringybark Heathy Open Forest of Coastal Lowlands of the Northern North Coast	71.9	35.5
Spotted Gum - Grey Box - Grey Ironbark Dry Open Forest of the Clarence Valley Lowlands of the North Coast	2.1	10.3
Spotted Gum - Grey Ironbark - Pink Bloodwood Open Forest of the Clarence Valley Lowlands of the North Coast	144.8	124.2
Swamp Box Swamp Forest of the Coastal Lowlands of the North Coast	28.5	0
Swamp Mahogany Swamp Forest of the Coastal Lowlands of the North Coast	44.2	18.4
Swamp Oak Swamp Forest of the Coastal Lowlands of the North Coast	56.2	21.5
Tallowwood Dry Grassy Forest of the Far Northern Ranges of the North Coast	53.0	23

BioMetric vegetation association*	Direct loss (hectares)	Potential edge effects (hectares)
Turpentine Moist Open Forest of the Coastal Hills and Ranges of the North Coast	44.5	17.6
Wet Heathland and Shrubland of Coastal Lowlands of the North Coast	10.0	3.7
White Booyong - Fig Subtropical Rainforest of the North Coast	8.6	4.3
Cleared and Modified	870.1	
Total approximate vegetation direct and indirect impacts (excluding cleared and modified habitats)	**948**	**431.6**

**Vegetation classification system based on the OEH vegetation types database (Office of Environment and Heritage 2012a) used in BioMetric 2.0 (Gibbons et al. 2008).*

Threatened ecological communities

Of the about 948 hectares of vegetation to be cleared, about 337.7 hectares (35 per cent) consists of threatened ecological communities listed under the TSC Act, one of which is also listed as critically endangered under the EPBC Act. The community type and impact are presented in Table 4-2 and additional to these impacts, there would be indirect impacts from edge effects and these are addressed in Section 4.3.5. This table also presents the estimated loss of each vegetation type from its former known historical distribution as identified in the Over Cleared Vegetation Types Database (DECCW 2010a).

Of particular importance is the loss of 10.3 hectares of Lowland Rainforest in NSW North Coast and Sydney Basin Bioregions given the very small areas of remaining rainforest across its former distribution and the high degree of fragmentation of remaining remnants. The loss of Swamp Sclerophyll Forest and Swamp Oak Forest accounts for a further 150 hectares. The former widespread distribution of these communities has also been heavily reduced.

Table 4-2 Summary of impact on threatened ecological communities

Threatened ecological community (listed status)	Direct impact (hectares)	Potential edge effects (hectares)	Estimated cleared from former historical distribution
Subtropical Coastal Floodplain Forest of the NSW North Coast Bioregion (Endangered TSC Act)	137.1	60	40-70%
Swamp Sclerophyll Forest On Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions (Endangered TSC Act)	93.7	35.5	75%
Swamp Oak Floodplain Forest Of The NSW North Coast, Sydney Basin And South East Corner Bioregions (Endangered TSC Act)	56.2	21.5	75%

Threatened ecological community (listed status)	Direct impact (hectares)	Potential edge effects (hectares)	Estimated cleared from former historical distribution
Coastal Cypress Pine Forest In The NSW North Coast Bioregion (Endangered TSC Act)	27.4	5	40%
Freshwater Wetlands On Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions (Endangered TSC Act)	13.0	0.8	40-80%
Lowland Rainforest in NSW North Coast and Sydney Basin Bioregions (Endangered, TSC Act) *Lowland Rainforest in Sub-tropical Australia (Critically Endangered, EPBC Act)	10.3 (5.8*)	5.1	No data, estimates of up to 97% (Floyd 1990)
Total	337.7	197.9	

Lowland Rainforest in Subtropical Australia – Critically Endangered, EPBC Act

Impacts to areas of Lowland Rainforest include 5.8 hectares identified within condition thresholds for the federally listed critically endangered ecological community based on the patch size, canopy cover, species richness and level of weed invasion. The distribution of the federally listed community is limited to an area in Section 10 to the north and south of Coolgardie Road and is displayed in Figure 3-30. Other smaller rainforest patches identified to the south of this area and highly modified patches in Section 10 are not included under the federal listing due to these patches not being within the defined condition thresholds.

The project would impact on six patches of this critically endangered ecological community and these are detailed in Table 4-3. Only one patch will be dissected by the proposal comprising patch number 5 (refer to Table 4-3) with approximately 0.3 hectares remaining on the eastern side of the project footprint and 2.9 hecatres remaining on the western side of the project footprint.

Table 4-3 Patches of the critically endangered (EPBC Act) Lowland Rainforest of Subtropical Australia potentially impacted by the project

Patch number /	Total patch	Area	Area remaining	Proportion of

(approximate station)	area (ha)	impacted (ha)	following impact (ha)	patch remaining
1 (155.5 to 156.0)	2.27	0.37	1.90	84%
2 (155.0 to 157.0)	30.38	0.47	29.91	98%
3 (156.5 to 157.5)	5.95	0.68	5.27	89%
4 (157.0 to 158.0)	4.93	0.54	4.39	89%
5 (157.5 to 158.0)	5.49	2.21	3.28	60%
6 (158.0 to 159.0)	3.38	1.53	1.84	55%
TOTAL	**52.4**	**5.8**	**46.6**	89%

Of the six patches potentially impacted, four of these will be reduced in extent by 2 to16%, and the remaining two will be reduced in extent by 40 to 45%. The overall reduction in extent for the ecological community is 11%, with 89% of the ecological community remaining in surrounding areas.

Threatened flora

Larger populations of threatened flora recorded in the study area are discussed in detail below. These generally include numerous individuals occurring as separate populations throughout the study area. A discussion of impacts to smaller populations of threatened flora species recorded at single location in the study area is summarised in Table 4-11. Assessments of significance have been undertaken for each of these species, and these are provided in Appendix E.

Sandstone Rough-barked Apple (*Angophora robur*) - Vulnerable, TSC Act and EPBC Act

The regional extent of the population consists of three large clusters or sub-populations, all located within 30 kilometres of Grafton. Specimens were sent to the National Herbarium of NSW for identification and these were confirmed as being *Angophora robur*. A description and estimated size of the different sub-populations is detailed in Table 4-4 and the distribution of the species is graphically displayed in Figure 3-73 to Figure 3-75. This table includes the estimated direct and indirect impacts on the species based on the construction footprint and an additional 10 metre buffer. All of the population clusters impacted by the project (refer to Table 4-4) will be dissected by the proposal with individuals remaining on both sides of the project footprint.

The targeted surveys assessed all properties within the project boundary where this species was predicted to occur and then looked beyond the project boundary out to 500 metres east and west of the project to identify the full extent of the local population. Additional sites throughout the region were then surveyed to determine the extent of the regional population

and this included those locations described in Table 4-4 for the northwest and southwest populations.

Table 4-4: *Angophora robur* regional population and comparison with subject population (Section 3)

Subpopulation location	Area of habitat occupied (hectares)	Population number	Number of individuals in project boundary	Area of occupied habitat in project boundary (proportion)
Eastern Population (Pillar Valley, Tucabia, Tyndale including Pine Brush SF and Newfoundland SF)				
Population Cluster 1 – Pillar Valley	*451.5*	*37928*	*1516*	*18 hectares (4%)*
Population Cluster 2 – Firth Heinz Rd	*14.7*	*1237*	*148*	*1.8 hectares (11.9%)*
Population Cluster 3 – Bostock Road	*15.8*	*1328*	*293*	*3.5 hectares (22.1%)*
Population Cluster 4 – Sommervale Road to Tallowwood Lane	*189*	*15876*	*1294*	*15.4 hectares (8.1%)*
Population Cluster 5 – Tucabia Road	*14.1*	*1183*	*142*	*1.7 hectares (12%)*
Population Cluster 6 – Tyndale	*684.2*	*57476*	*3500*	*41.7 hectares (6.1%)*
Eastern Population (total)	Known: 1,471.4	Known: 123,601	Known: 6893	82.1 hectares (5.6% of known local population)
Northwest Population*(*Copmanhurst, Coaldale including Fortis Creek NP))	Known: 457 Predicted 7,368	Known: 38,388 Predicted 619,912	0	0
Southwest Population *(*Glenreagh, Kangaroo Creek, Chambigne NR)	Unknown	500 known from records	0	0
Total (including known and predicted and records from southwest population)	9,296 hectares	782,401	6893	82 hectares from total 9,296 hectares (0.9% of known regional population)

Eastern Population (Pillar Valley, Tucabia, Tyndale including Pine Brush SF and Newfoundland SF)

The population within and surrounding the project boundary represents the known eastern distribution of the species. Eleven subpopulations within the larger eastern subpopulation have been mapped within and surrounding the project boundary occurring over 1471

hectares with individual clusters ranging from 1.3 to 684 hectares in area. All clusters within 500 metres of each other have been regarded as being part of the same subpopulation based on the likely dispersal distance of pollinators between subpopulations.

The 11 subpopulations also include four smaller outlying populations to the north in Woodford Island State Forest and to the south in Newfoundland State Forest, however these clusters include a high abundance of *Angophora woodsiana* and a low abundance of *Angophora robur* as well as intergrades between the two species. There is also a low abundance of *Angophora robur* (around 1 individual per hectare) occurring with *Angophora woodsiana* over an additional 445 hectares on the more skeletal ridges and upper slopes.

There were 7734 individuals directly counted within or directly adjacent to the project boundary at 841 point locations over around 100 hectares. Due to property access constraints several areas could not be assessed, therefore the average density was extrapolated across these areas where habitat appeared suitable.

In the project boundary there is estimated to be around 6893 individuals over 105 hectares based on detail surveys comprising direct counts of individuals within the corridor and detail mapping of the distribution. Based on calculations from the field surveys, the average number of individuals per hectare is 84. This average was extrapolated across the known and predicted regional distribution for this species to make the calculations of the regional population consistent with calculations for the project boundary. The eastern subpopulation is estimated to comprise 123,601 individuals occurring over an area of 1471 hectares, based on the known extant and average density of the species (84 individuals per hectare). The individuals in the project boundary represent around 5.6 per cent of the known local population and around 7.1 per cent of the known occupied habitat of the local population.

There would also potentially be indirect impacts from edge effects and habitat fragmentation these are addressed in Section 4.3.5. *Angophora robur* was recorded in currently edge affected habitats in the study area including open paddocks. Therefore *Angophora robur* is likely to be somewhat tolerant of edge effects and indirect impacts are not expected to significantly impact the life cycle attributes of *Angophora robur*, particularly with appropriate mitigation to reduce these edge effects such as weed treatment, water quality controls and native landscaping.

The age structure and density of the populations varied substantially depending on the disturbance history of the area, with densities varying from 16 to 920 individuals per hectare based on transect and plot data. Some areas supported a very high density of juveniles and medium trees whilst other areas supported a low density of larger mature trees. The edges of the population clusters generally supported a lower abundance of the species with numerous outliers from the main population recorded.

The known regional distribution including the eastern and northwest subpopulations is estimated to comprise 161,952 individuals over 1928 hectares and the predicted distribution is estimated to consist of an additional 618,912 individuals over 7368 hectares. In total the known and predicted population potentially comprises an estimated total of 780,864 individuals occurring over 9296 hectares.

There may be larger populations in surrounding state forests and national parks (ie Yuraygir, Woodford Island, Newfoundland state forests) as these areas have not been extensively surveyed and are relatively remote. During the field surveys the species was

recorded in Corymbia, Yuraygir and Wombat Creek state conservation areas and Fortis Creek National Park. It is also reserved in Banyabba and Sherwood nature reserves and Waihou Flora Reserve (Johnson & Hill, 1990; Sheringham & Westaway, 1995).

Hairy-joint Grass (*Arthraxon hispidus*) - Vulnerable, TSC Act and EPBC Act

Several large populations of this species were recorded in Section 10 between Lumleys Lane and Coolgardie Road. Details of the population clusters of *Arthraxon hispidus* are detailed in Table 4-5. The species was recorded in four locations within and around the project all within Section 10 as shown in Figure 3-79. These are referred to below as sub-populations 1-4 and cover a total area of 20.8 hectares. Forty-seven per cent of this area (9.8 hectares) occurs within the project boundary.

Four distinct subpopulations have been identified based on their spatial distribution with all occupied habitats within 150 metres of each other regarded as being part of the same subpopulation. Pollen from wind pollinated grass species have been observed to travel up to 150 metres in favourable conditions (Wang et al 2003).

Table 4-5: *Arthraxon hispidus* population clusters

Subpopulation location	Population bisected by project boundary	Distance from nearest subpopulation (metres)	Area of occupied habitat (hectares)	Area of occupied habitat (hectares) in project boundary	Proportion of occupied habitat in project boundary
Subpopulation 1 – Lumley's Lane	No	995	4.2	2.9	70%
Subpopulation 2 - Central	Yes	450	4.8	3.4	71%
Subpopulation 3 – Pacific Highway 1	Yes	450	2.9	1.9	68%
Subpopulation 4 – Pacific Highway 2	No	200	8.9	1.5	17%
Total	**-**	**-**	**20.8 hectares**	**9.8 hectares**	**47%**

A relatively significant proportion of occupied habitat would be potentially impacted from the project, particularly for subpopulations 1, 2 and 3 with up to 68 to 71 per cent of these subpopulations being impacted. Only 17 per cent of the largest population would be potentially impacted by the project.

There is potential for indirect impacts to alter the existing habitat attributes such as hydrology regimes and weed invasion which may increase the overall proportion of occupied habitat impacted.

Cyperus aquatilis - Endangered, TSC Act

Species is only known from a small number of records north of Grafton in NSW, mainly between the Pacific Highway in the east and Summerland Way to the west (OEH 2012c), including records in the project boundary. This species has been observed at numerous locations throughout the project between 2006 and 2010 as shown in Figure 3-76 and Figure 3-77.

Survey and assessment of this species has the following complications:

- The highly ephemeral nature of this species makes it difficult to predict the optimal survey period
- Suitable habitat occurs as small patches which are relatively widespread and cannot be readily identified from vegetation mapping data and aerial photos, generally comprising areas of disturbed soil where standing water is present such as muddy trails and grazed paddocks
- Habitat quality is highly dependent on recent disturbance, and therefore areas of suitable habitat identified in previous or current surveys may not be suitable now or in the future
- The small habit and presence of similar species can make detection and identification difficult.

The species was recorded at six locations in Sections 6 and 7 (Ecos Environmental 2007) in low to moderate abundance. During further surveys (January 2012), it could only be located in Mororo State Forest, where a relatively large population (around 80 plants) was previously recorded. Similarly, locations of this species recorded in winter 2005 where found not to support the species during summer 2006, suggesting the distribution and abundance of the species is highly variable and dependant on numerous factors such as habitat disturbance, flooding events, seed dispersal and climatic conditions.

Other records in the study include a grazed paddock area south of Jacky Bulbin Road (around 18 plants), a disturbed drainage line north of Glencoe Road (nine plants) and several locations where only 1-3 individuals were recorded including at Tabbimoble Floodway No. 2. Most of the occurrences recorded during summer 2006 were associated with boggy access tracks that had recently been disturbed by tractors or other vehicles (Ecos Environmental 2007). Recent field surveys found there was little evidence of disturbance in the locations previously surveyed by Ecos Environmental (2007), and growth of other *Cyperus* spp. and grasses may have limited the germination of the species in these areas.

Table 4-6: *Cyperus aquatilis* population clusters

Location	Approximate area of suitable habitat (sq metres)*	When recorded and population size
Mororo State Forest, on western side of highway in a grassed easement along property boundary (Section 6)	1683	Summer 2006 – 80 individuals Summer 2012 – 10 individuals
South of Jacky Bulbin Road on the eastside of the highway in a grazed paddock (Section 6)	2279	Summer 2006 – 18 individuals Summer 2012 - None
Tabbimoble Floodway No. 2 on the westside of the highway (Section 7)	78	Winter 2005 – 3 senescent individuals Summer 2006 – None Summer 2012 – None
Adjacent to Tabbimoble State Forest on the eastside of the highway (Section 7)	5231	Winter 2005 – 3 senescent individuals Summer 2006 - None Summer 2012 – None
South of Serendipity Road on the eastside of Road (Section 7)	1042	Summer 2006 – 1 individual Summer 2012 – None
North of Glencoe Road on both sides of the highway on disturbed trails (Section 7)	1019	Summer 2006 – 9 individuals (2 on westside of highway and 7 on eastern side) Summer 2012 - None
Trustums Hill there is a roadside drain which potentially provides suitable habitat with other *Cyperus* spp. present (Section 7)	400	None recorded in this area to date, but suitable habitat observed along edge of existing highway in roadside drain.

*based on 2012 observations

The population of *Cyperus aquatilis* in the study area appears to be part of a larger population extending northeast into Tabbimoble Swamp Nature Reserve and Bundjalung National Park (Geolyse 2005). Impacts to this species are potentially significant given the relatively widespread occurrence of potential habitat and the numerous records of the species within the project boundary.

There is potential for indirect impacts to alter the existing habitat attributes such as hydrology regimes and weed invasion which may limit the germination and growth of this species in remaining habitats. *Cyperus aquatilis* was recorded in the study area in currently edge affected habitats in the study area including open paddocks, muddy trails and roadside environments. Therefore *Cyperus aquatilis* is likely to be somewhat tolerant of edge effects and indirect impacts. As the existing populations are currently fragmented by the existing highway, the project would result in further fragmentation of individuals, with individuals being retained on either side of the project.

Square-fruited Ironbark (*Eucalyptus tetrapleura)* - Vulnerable, TSC Act and EPBC Act

The major populations for *Eucalyptus tetrapleura* were recorded in the Glenugie area (Section 2) which has been partially impacted by the Glenugie upgrade as shown in Figure 3-72. Large populations are predicted to be present to the east of Glenugie State Forest on private property adjoining Yuraygir State Conservation Area and Glenugie Peak Flora Reserve. *Eucalyptus tetrapleura* was recorded along areas of Rockview Road at Chambigne during the surveys and was observed to extend into areas of private property surrounding this road, and although no population assessments were carried out in this area, *Eucalyptus tetrapleura* is expected to be relatively abundant in this area.

The local abundance of the species varied considerably within each of the different populations and so separate densities were calculated for each population. The density of trees was often dependant on the degree of recruitment, with some areas supporting a large number of juvenile trees and smaller saplings, whilst other areas supported more mature trees with fewer juveniles. The abundance of juveniles is dependent on several factors including fire history, understory structure and other disturbances such as logging activities. Many of the state forest areas supported a large number of juveniles possibly due to past disturbance from logging activities providing bare soil for germination. However, certain fire regimes are likely to favour germination particularly during a fire event in the major fruiting period.

Population estimates were established for several locations surrounding the project with several other locations including state forests and national parks also assessed. The population estimates for each of the areas assessed is detailed in Table 4-7.

Table 4-7 *Eucalyptus tetrapleura* population clusters

Location	Survey status	Area of population (hectares)	Estimated population (no.)	Area of pop in project boundary (hectares)	Estimated number in project boundary
Glenugie State Forest	Surveyed	638.8	103,826	4.14	612
Pine Brush State Forest	Surveyed	139.31	10,336	0	0
Newfoundland State Forest	Surveyed	53.51	5510	0	0
Subtotal - State Forests		**831.62**	**119,672**	**4.14**	**612**
Chambigne Nature Reserve	Surveyed	13.28	1010	0	0
Yuraygir State Conservation Area	Surveyed	18.7	1023	0	0
Wells Crossing Flora Reserve	Surveyed	86.62	4218	10.36	495
Subtotal - Conservation Reserves		**118.6**	**6251**	**10.36**	**495**
Private property - Glenugie	Surveyed	40.73	6540	0.06	12
Private property - Rockview	Confirmed Records	28.18	1409	0	0
Private property – Glenugie Offset	Surveyed	354.83	22,960	0	0
Private property – Dirty Creek	Surveyed	1.52	94	1.52	94

Location	Survey status	Area of population (hectares)	Estimated population (no.)	Area of pop in project boundary (hectares)	Estimated number in project boundary
Private property - Predicted	Predicted	168.54	19,664	0	0
Subtotal – Private Property		**593.8**	**50,667**	**1.58**	**106**
Shannon Creek Dam (Crown Land)	Atlas Records	170	3173	0	0
Total (with impacts from Glenugie Upgrade project subtracted)		**1,714.02**	**179,763**	**16.08**	**1,213**
Total area local population impacted by the project (occurrences within 500 metres of each other)	Surveyed	**1,289.24**	**159,629**	**16.08**	**1,213**
Glenugie Upgrade	Surveyed	**34.52**	**6,061**	**0**	**0**

Table 4-7 describes population estimates for 12 sites. However the total population number is estimated to be significantly larger than indicated as many additional NSW Atlas records occur on private lands to the west of Glenugie State Forest (ie at least around 30 records) that have not been assessed in detail. Additionally the species is also known to occur in the following state forest and national park estates:

- Whipore State Forest
- Gibberagee State Forest
- Candole State Forest
- Southgate State Forest
- Camira State Forest
- Fullers State Forest
- Mt Neville Nature Reserve
- Sherwood Nature Reserve
- Ramorning National Park.

The total regional population based on recorded locations to date is therefore considered to comprise in the order of 50 different sub-groups with a conservative estimate of between 170,000 to 250,000 individuals.

The local population within the project boundary comprises all occurrences within 500

metres radius of each other considering the high mobility of some pollinator species such as insects, birds and bats, as well as wind dispersal of pollen. This local population is estimated to consist of around 159,629 individuals including occurrences in Glenugie State Forest, Wells Crossing Flora Reserve, private property including the Glenugie offset property and Yuraygir State Conservation Area. The potential impact from the project and the Glenugie upgrade represents around 0.76 per cent of the local population and around 1.25 per cent of the area of occupancy (1,289.24 hectares). This project would have impacts to the local distribution of the species, removing part of the local gene pool and 16.08 hectares of known habitat for *Eucalyptus tetrapleura*.

When considering cumulative impacts from the Glenugie upgrade and the current project, the combined impacts to the local population comprise around 7,274 individuals occurring over 50.6 hectares of habitat representing 4.6 per cent of the local population and up to 3.9 per cent of the occupied habitat. The project would result in the removal of habitat for pollinator species, however sufficient habitat for large populations of potential pollinator species would remain in surrounding areas. The cumulative impacts of the project and the Glenugie upgrade, while reducing the local gene pool, however it is considered that there would be significant genetic diversity in the remaining 95 per cent of the population and sufficient habitat for pollinator species to avoid inbreeding depressions or impacts from stochastic events.

The project would result in a larger fire break to fire approaching from the west of the highway, potentially resulting in the frequency of fire to be reduced in populations to the east. However state forest areas are likely to be fire-managed with control burns implemented in areas during cooler months. Although there is potential for fire regimes to change following the project it is considered unlikely to significantly impact the life cycle of populations of *Eucalyptus tetrapleura*.

Vegetation clearing would potentially contribute to further invasion of *Lantana camara* and other exotic species particularly along the edges of the project boundary where there would be increased sunlight. Other indirect impacts from vegetation clearing would include stormwater run-off potentially increasing water and nutrient loads entering adjacent bushland areas, leading to the increased growth and spread of exotic species. To offset the ecological impacts from the project an offset strategy is proposed to provide greater protection of *Eucalyptus tetrapleura* and habitat for other threatened flora and fauna.

The population is currently fragmented by the existing highway and the project would widen the disturbance width further fragmenting habitats on the western side of the existing highway from populations to the east.

Four-tailed Grevillea (*Grevillea quadricauda)* - Vulnerable, TSC Act and EPBC Act

Grevillea quadricauda was recorded in the project boundary at two different locations in Section 3. It occurs in moderate abundance in the project boundary comprising two subpopulations around 1.4 kilometres apart. One of these subpopulations is very small occurring in partially cleared disturbed habitats consisting of eight individuals and a larger population consisting of at least 200 individuals extending to the east of the project boundary. This species occurs in dry sclerophyll forest on sandy soils adjacent to creek lines and surrounding slopes, with the majority of the population occuring on dryer slope environments up slope of the project footprint. The population number and area of occupancy of these subpopulations are summarised in Table 4-8.

Table 4-8 *Grevillea quadricauda* populations and potential impacts

Subpopulation name/location	Area of habitat occupied (ha)	Total population number	Number of individuals in project boundary	Area of occupied habitat in project boundary
Northern population	0.013	8	5	0.012
Southern population	0.632	200	3	0.008
Total	**0.646**	**208**	**8**	**0.02**

The potential impacts of the project would result in the removal of a high proportion of individuals (62.5 per cent) from the northern population with only three individuals occurring outside of the project boundary. The viability of the northern population is likely to currently be low considering a total population number of eight individuals, and the population is currently threatened from clearing and agricultural activities. It is unlikely that cross-pollination would occur between the two known populations, however there is potential for other occurrences of this species in habitats adjacent to the study area which would improve the potential viability of this population. In the absence of any additional occurrences of *Grevillea quadricauda* within 500 metres of the northern population the project is likely to significantly reduce the viability of this population.

The southern population represents a relatively large abundance of individuals occurring in intact habitats on sandy slopes surrounding the project boundary. The occurrence of this population in the footprint is on the edge of an existing trail near a major creek line, evidence of selective logging was observed in areas of this population. This population is largely avoided by the project and impacts would be limited to three individuals representing around 1.5 per cent of the known population in this area. The removal of three individuals from this population is considered unlikely to significantly reduce the genetic diversity within this population. However there is potential for indirect impacts to alter the habitat of the remaining individuals and mitigation measures are required to minimise indirect impacts.

As the majority of the population occurs to the east of the project boundary areas of known habitat would not be fragmented from the project. However habitat connectivity would be affected including potential habitat for *Grevillea quadricauda* and pollinator species.

Slender Screw Fern (*Lindsaea incisa*) - Endangered, TSC Act

Population recorded in or directly adjacent to the project boundary in sections 1 to 3 and Section 6. Populations were found along the edges of drainage swales with sandy soils. The four locations are detailed in Table 4-9 and these are described below, comprising:

- Population 1: A large population extending into the corridor on the western side of the highway opposite Lemon Tree Road in Section 1. This population occurs in dense shrubs and sedges along the edges of drainage line in a disturbed area of swamp forest
- Population 2: A small patch 12 metres upstream to the east of the project boundary on an elevated area in the centre of Halfway Creek, Section 2
- Population 3: A large population 20 metres downstream to the west of the project boundary near Tucabia in Section 3. This population occurs amongst dense shrubs and sedges on the edges of a broad drainage swale through partially disturbed swamp forest habitats
- Population 4: A large population extending into the project boundary in Mororo State Forest in Section 6. This population occurs in pockets along the edges of a broad drainage swale in sclerophyll forest grading into swamp forest, extending into disturbed habitats within the road reserve. This population is the largest population occurring over around 2 hectares of habitat.

Table 4-9 *Lindsaea incisa* population clusters

Subpopulation name/location	When recorded	Area of habitat occupied (ha)	Area of occupied habitat in project boundary (ha)	Proportion of occupied habitat in project corridor
Population 1 – Section 1 (western side of the highway opposite Lemon Tree Road)	First recorded in December 2011	0.04	0.02	53.3%
Population 2 – Section 2 (Halfway Creek)	First recorded in December 2011	0.01	0	0%
Population 3 – Section 3 (Tucabia)	First recorded in August 2007 and resurveyed in December 2011	0.64	0	0%
Population 4 – Section 6 (Mororo State Forest)	First recorded in May-June 2005 and resurveyed in January 2012	1.974	0.355	18%
Total		**2.666**	**0.379**	**14.2%**

Two of the four populations would potentially be impacted from the project, comprising Population 1 and Population 4 (refer to Table 4-9). The population number could not be accurately estimated during field surveys considering fronds grow from a spreading rhizome and the high abundance of fronds growing within dense understorey vegetation. The area of

occupancy, therefore, was mapped and is used as the basis for the impact assessment.

Around 53 per cent of Population 1 would potentially be impacted, representing a significant proportion of the available gene pool and occupied habitat. There are potentially other locations of this species in adjacent areas of habitat not surveyed which would reduce the proportion of the population being impacted. The project boundary is relatively broad in this area (up to 215 metres wide) and should be reduced to avoid significantly impacting this population.

Around 18 per cent of Population 4 would potentially be impacted representing a relatively significant proportion of the available gene pool, however it is likely that there are other locations of *Lindsaea incisa* in adjacent areas of habitat not surveyed which would reduce the proportion of the population being impacted. The project boundary in this area includes several large water quality ponds which increases the impact on *Lindsaea incisa*. These sediment basins should be relocated to avoid impacts to *Lindsaea incisa*.

Impacts to Population 1 and Population 4 would not result in the dissection of any population clusters with impacts being limited to one side of the known extant of the population. However potential habitat for the species would be further fragmented by the project removal of known and potential habitat.

Maundia triglochinoides - Vulnerable, TSC Act

Maundia triglochinoides grows in swamps, creeks or shallow freshwater 30 to 60 centimetres deep on heavy clay with low nutrients. In the study area, it was observed growing in major creeks and rivers or lagoons associated with these such as Halfway Creek, Wells Crossing, Coldstream River and Chaffin Creek. It was also associated with smaller drainage lines and areas of swamp forest at several locations. Several of the locations appeared to have sandy soils rather than heavy clay.

Maundia triglochinoides has been recorded at 15 locations during field surveys in 2011 and 2012, of which 12 are within the project boundary. The 12 population clusters are detailed below in Table 4-10, including the approximate area occupied by the population and the density of plant clumps within each clump.

Table 4-10: *Maundia triglochinoides* population clusters

Location	Population dissected by project	Population density	Known area occupied (metres^2)	Known area within project (metres^2)	Proportion of population within project
Population 1 - Halfway Creek (Section 2)	No	Very high	10,322	250	2%
Population 2 - Wells Crossing (Section 2)	Yes	Very high	1324	288	22%
Population 3 - Coldstream River (Section 3)	Potentially	Very high	1183	0	0%
Population 4 - Chaffin Creek (Section 3)	No	Very high	3818	0	20%
Population 5 - Un-named creek south of Bostock Road (Section 3)	No	Moderate	175	0	0%
Population 6 - Several lagoons associated with un-named drainage lines east of Tallowwood Lane (Section 3)	Yes	Low to very high	6828	497	7%
Population 7 - Un-named creek east of Tucabia Road (Section 3)	No	Low	155 m^2	0	0%
Population 8 - Swamp Forest south of Tabbimoble Floodway No.2 (Section 7)	No	Low	106 m^2	106 m^2	100%
Population 9 - Tabbimoble Floodway No.2 (Section 7)	No	Very high	419 m^2	34 m^2	8%
Population 10 - Tabbimoble Floodway No.1 (Section 7)	No	High	314 m^2	154 m^2	49%
Population 11 - Un-named creek 1 north of New Italy (Section 7)	No	Moderate	594 m^2	28 m^2	6%
Population 12 - Un-named creek 2 north of New Italy (Section 7)	No	Moderate	49 m^2	49 m^2	100%
TOTAL			**29,628 m^2**	**2,183 m^2**	**7%**

The project would potentially result in the total removal of the entire area of two populations (Population 8 and 12), a large proportion (10 to 50 per cent) of three populations (Population 2, 4 and 10), moderate impacts (five to 10 per cent) to three populations (Population 6, 9 and 11) and low level impacts (two per cent) to Population 1. Additional to these direct impacts there would potentially be large scale indirect impacts to populations downstream of the project boundary from altered hydrology, sedimentation and erosion.

The project boundary at Population 4 and 12 includes large sediment basins which increases the impact on *Maundia triglochinoides*. These sediment basins should be relocated to avoid impacts to *Maundia triglochinoides.*

Weeping Paperbark *(Melaleuca irbyana)* - Endangered, TSC Act

The only population known to occur in the project boundary is at New Italy and is currently bisected by the existing Pacific Highway with individuals occurring on both sides of the highway. Habitat for *Melaleuca irbyana* is in a higher condition on the western side of the highway comprising mature Spotted Gum-Ironbark forest with little weed invasion. This area contains mature individuals of *Melaleuca irbyana*, some of which are large specimens. It is one of the few locations *Melaleuca irbyana* occurs in mature forest (Ecos Environmental 2007). On the eastern side of the highway, *Melaleuca irbyana* habitat is bisected by driveways, fence lines, firebreaks and a powerline easement, and the majority of forest has been disturbed by clearing. However the powerline and road easements appear to provide suitable habitat for the species with maintenance activities encouraging suckering of *Melaleuca irbyana* resulting in dense clusters of this species adjacent to the eastern side of the existing highway. The population extends into private property to the west of the project boundary occurring in modified habitats including semi-mature forest and unmaintained areas supporting dense tall grass with occasional saplings including *Melaleuca irbyana*.

The New Italy population contains around 800 individuals comprising 250 trees (greater than three metres high) and 550 saplings and suckers, spread over around 1.5 hectares with around 400 individuals and 0.75 hectares of habitat on both the eastern and western sides of the highway (Ecos Environmental 2007).

Field surveys aimed at establishing a population estimate for individuals within the project boundary. Considering the suckering nature of *Melaleuca irbyana,* it can be difficult delineate between individuals and to count individuals occurring as dense clusters. Therefore, estimates have been made for individuals occurring on the eastern side of the highway where a large number of suckering plants are present in powerline easement and within the existing highway reserve.

It is estimated that around 514 individuals are present within the project boundary comprising 207 individuals within mature forest areas on the western side and 307 individuals on the eastern side of the highway occurring as dense clusters in the power easement and road reserve.

Other populations between Glenugie Upgrade and Tyndale occur outside of the project boundary comprising small localised clusters of plants in regenerating forest.

To mitigate the loss of individuals within the project boundary and prevent significant losses to the local gene pool, it is proposed that seed collection and propagation program be implemented for *Melaleuca irbyana* near the project boundary. There is up to three hectares of disturbed areas of potential *Melaleuca irbyana* habitat adjacent to the western side of the project boundary which could be rehabilitated for translocation of *Melaleuca irbyana* from the project boundary as well as direct seeding and planting of tubestock.

As the existing population is currently fragmented by the existing highway, the project would result in further fragmentation of individuals, however individuals would only be retained on the western side of the project boundary.

Other threatened flora species

The potential impacts from the project on smaller populations of threatened flora subject species not covered in the above text which would potentially be impacted by the project are provided in Table 4-11. There is potential to minimise the likely impacts discussed through appropriate and targeted mitigation and management actions during construction and operation and this is discussed in Chapter 5. Assessments of significance have been undertaken for each of these species, and these are provided in Appendix E, where further information regarding the impacts and mitigation to each of these species is provided.

Table 4-11 Potential impacts to threatened flora species

Species	Status	Distribution and abundance in study area	Potential direct impacts	Dissected by the project
Archidendron hendersonii White Laceflower	Vulnerable (TSC Act)	11 individuals in subtropical rainforest around Coolgardie Road in Section 10.	6 individuals	
Cryptocarya foetida Stinking Cryptocarya	Vulnerable (TSC Act and EPBC Act)	A total of 17 individuals were recorded in and surrounding the project boundary in Section 10 around Coolgardie Road.	13 individuals	Yes
Endiandra hayesii Rusty Rose Walnut	Vulnerable (TSC Act and EPBC Act)	Recorded in a patch of subtropical rainforest near Coolgardie Road in Section 10 comprising a total 8 individuals consisting of 5 larger individuals and 3 juveniles.	5 individuals	No
Endiandra muelleri subsp. bracteata Green-leaved Rose Walnut	Endangered (TSC Act)	Recorded in a patch of subtropical rainforest near Coolgardie Road in Section 10 comprising a total 8 individuals consisting of 5 larger individuals and 3 juveniles.	6 individuals	Yes
Macadamia tetraphylla Rough-shelled Bush Nut	Vulnerable (TSC Act and EPBC Act)	68 individuals recorded near Coolgardie Road in Section 10 including juveniles and mature trees.	37 individuals	No
Oberonia titania Red-flowered King of the Fairies	Vulnerable (TSC Act)	Recorded outside the project boundary in Section 10 during 2010 and in Section 7 during 2005 but these could not be relocated during surveys in 2012.	0 individuals	No
Olax angulata Square-stemmed Olax	Vulnerable (TSC Act and EPBC Act)	One individual has been recorded in the project boundary north of Halfway Creek at Section 2.	1 individual	No
Prostanthera cineolifera Singleton Mint Bush	Vulnerable (TSC Act and EPBC Act)	Occurs at a single location on Tabbimoble Creek south of Tullymorgan Road. The population number is conservatively estimated to comprise 5,000-8,000 individuals occurring over 2.22 hectares	250 individuals	Project would contribute to existing fragmentation
Syzygium hodgkinsoniae Red Lilly Pilly	Vulnerable (TSC Act and EPBC Act)	A single individual recorded in a patch of subtropical rainforest north of Coolgardie Road.	1 individual	No

Species	Status	Distribution and abundance in study area	Potential direct impacts	Dissected by the project

4.3.2. Loss of habitat for fauna

As discussed the project would result in the clearing of about 948 hectares of native vegetation, thereby affecting extensive areas of habitat for fauna. The loss of fauna habitat according to habitat type is presented in Table 4-12. These habitat types also support several microhabitat types such as bush rocks, leaf litter, dead wood and dead trees in all sections.

These clearing estimates have been calculated based on the construction footprint. This does not include clearing that may be required for potential ancillary facilities outside the construction footprint as discussed previously due to the fact that these habitats have not been ground-truthed. The construction footprint extends over about 870 hectares of cleared land and small areas of modified vegetation that would not be associated with natural vegetation communities. These areas would however provide habitat for species that have adapted to modified habitats, including mammals, birds, reptiles and amphibians.

Table 4-12 Summary of clearing for broad fauna habitat types

Fauna habitat	Direct loss (hectares)
Dry sclerophyll forests on sandy and clay soils	443.7
Wet / moist sclerophyll forests on floodplains and riparian areas	329.1
Lowland rainforest on floodplains	10.3
Swamp forests	149.9
Wet and dry heath and freshwater wetlands	13.3
Estuarine wetlands	1.5
Cleared and modified lands	870.1
Total fauna habitat cleared (excluding cleared and modified)	**948**

Loss of hollow-bearing trees

The loss of hollow-bearing trees is listed as a key threatening process under the TSC Act. Hollow bearing trees are a critical habitat feature for a number of threatened species (Gibbons & Lindenmayer 2002), providing breeding and/or sheltering habitat. Gibbons and Lindenmayer (2002) found that hollow bearing trees were more common in older stands, gullies, vegetation not logged and on flat terrain. Habitats with high productivity were also noted to support a higher number of hollow bearing trees.

Hollow-bearing trees are present in habitats to be cleared by the project in all habitat types and project sections. The number and location of hollow-bearing trees was not quantified for the biodiversity assessment. Reliance is on the habitat assessment (refer to Chapter 3) to identify the relative densities of hollow-bearing trees for each habitat type. The highest density of hollow-bearing trees recorded in the dry sclerophyll forests on clay soils followed by the floodplain eucalypt forests and dry forest on sandy soils. These three habitats account for a combined loss of 772.8 hectares (81.5 per cent of the total habitat loss). The mean number of hollow-bearing trees per habitat type was recorded over 1 hectare (calculated from 0.1 hectare survey plots). Assuming that habitat condition is homogeneous across the project this impact would equate to a loss of 18 (±8.36) hollow bearing trees per hectare for the dry sclerophyll forest on clay soils, 14.29 (±11.34) hollow-bearing trees per hectare for the floodplain eucalypt forests and 12.31 (±11.66) hollow-bearing trees per hectare for the dry forests on sandy soils.

Hollow bearing trees occur in all project sections. Loss of these is likely to be greatest where the project would deviate from the existing Pacific Highway alignment in Section 3 and in sections 9 and 10. However, the presence of hollow-bearing trees may also be high in habitats adjoining the highway, where they would be impacted by the duplicated highway.

In NSW, terrestrial vertebrate species that are reliant on tree hollows for shelter and nests include at least 46 mammals, 81 birds, 31 reptiles and 16 frogs (Gibbons and Lindenmayer 1997, Gibbons and Lindenmayer 2002). Of these, 22 are listed as threatened species (TSC Act or EPBC Act) and have either been identified in the study area or are considered likely to occur in the three dominant habitat types discussed (Table 4-13).

Table 4-13 Threatened species in study area impacted by loss of hollow-bearing trees

Common name	Scientific name	TSC Act	EPBC Act
Glossy Black-cockatoo	*Calyptorhynchus lathami*	V	
Brown Treecreeper (eastern subsp.)	*Climacteris picumnus picumnus*	V	
Double-eyed Fig-parrot	*Cyclopsitta diophthalma coxeni*	E	
Little Lorikeet	Glossopsitta pusilla	V	
Powerful Owl	*Ninox strenua*	V	
Masked Owl	*Tyto novaehollandiae*	V	
Sooty Owl	*Tyto tenebricosa*	V	
Eastern Pygmy-possum	*Cercartetus nanus*	V	
Hoary Wattled Bat	*Chalinolobus nigrogriseus*	V	
Little Pied Bat	*Chalinolobus picatus*	V	
Spotted-tailed Quoll	*Dasyurus maculatus*	V	E
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	V	
Beccari's Freetail-bat	*Mormopterus beccarii*	V	
Eastern Freetail-bat	*Mormopterus norfolkensis*	V	
Southern Myotis	*Myotis macropus*	V	
Eastern Long-eared Bat	*Nyctophilus bifax*	V	
Yellow-bellied Glider	*Petaurus australis*	V	
Squirrel Glider	*Petaurus norfolcensis*	V	
Brush-tailed Phascogale	*Phascogale tapoatafa*	V	
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	V	
Greater Broad-nosed Bat	*Scoteanax rueppellii*	V	
Pale-headed Snake	*Hoplocephalus bitorquatus*	V	

Common name	Scientific name	TSC Act	EPBC Act
Stephen's' Banded Snake	*Hoplocephalus stephensii*	V	

Loss of foraging resources

There are a number of potential impacts associated with the loss of foraging resources. These relate to the direct loss of vegetation biomass available to herbivores and frugivores, and the extent to which remaining resources could potentially be exploited. The latter type of impact is likely to decline with increasing risk of disturbance associated with road operation, edge effects and fragmentation and weed infestation.

The direct loss of foraging resources in the form of foliage, nectar and sap exudates equates coarsely to the clearing impacts described in Table 4-12. The indirect impacts of this clearing relate to loss of habitat for prey species, in particular insects. However, this may over estimate the impact by assuming that all habitats being lost have equal value as foraging habitat and equal accessibility and does not consider competition for resources and forage quality and quantity per habitat type.

The potential consequence of these losses on the size of fauna populations cannot be quantified using the field survey data at this scale. For example, other factors to consider are the adaptations of species associated with accessing fragmented resources in the landscape, such as nectarivorous bats and birds, as opposed to sedentary species that require a habitat patch size threshold to maintain viable populations. As such not all fauna species are affected by loss of foraging resources equally.

Foliage and nectar foraging resources are present in multiple strata including the upper canopy, mid to lower and ground level strata. Threatened species potentially impacted at the patch scale are forest dependent species such as Squirrel Glider, Yellow-bellied Glider, Eastern Pygmy Possum and Brush-tailed Phascogale, Koala, Rufous Bettong and small insectivorous bats. Species expected to be impacted at the landscape level include Swift Parrot, Regent Honeyeater, Little Lorikeet, and Grey-headed Flying-fox. The latter are responsible for cross-pollination and genetic diversity in many plant species.

A number of threatened species require winter flowering foraging resources to supply food year-round, or to coincide with migratory movements. As such, the presence of annually reliable winter-flowering species is considered a limiting factor in the distribution of a number of threatened species, including Squirrel Glider, Yellow-bellied Glider, Regent Honeyeater, Swift Parrot, Little Lorikeet and Grey-headed Flying-fox. Other species, such as the Yellow-bellied Glider and Squirrel Glider, rely on a tree species composition providing year-round continuity of nectar and pollen. Of the habitats impacted by the project, at least four of those are dominated by winter-flowering species (refer Table 4-1 including Swamp Mahogany (*Eucalyptus robusta*), Forest Red Gum (*E. tereticornis*), Grey Ironbark (*E.siderophloia)* and Broad-leaved Paperbark (*Melaleuca quinquenervia*).l).The loss of these habitats equates to around 321 hectares (33.9 per cent) of the total loss of native vegetation.

Table 4-14 lists the flowering periods for dominant trees and shrubs within the vegetation types identified near the project boundary. This information illustrates the availability of

nectar and pollen across all habitats and seasons outside of the project boundary within retained habitats.

Table 4-14 Flowering period of dominant trees and shrubs within the project boundary

Scientific name	Common name	Flowering period
Acacia concurrens	A wattle	Winter
A. disparrima	Hickory Wattle	mid-summer to autumn
Angophora woodsiana	Smudgy Apple	Summer
Banksia integrifolia	Coastal Banksia	Autumn to spring
B.oblongifolia	Swamp Banksia	Autumn to early winter
B.spinulosa ssp.*collina*	Hairpin Banksia	Winter
Corymbia gummifera	Red Bloodwood	Summer
C.henryi	Large-leaf Spotted Gum	Summer
C.intermedia	Pink Bloodwood	Summer
Eucalyptus carnea	Broad-leaved White Mahogany	Spring
E.microcorys	Tallowwood	Spring
E.pilularis	Blackbutt	Spring
E.planchoniana	Needlebark Stringybark	Summer
E.propinqua	Small-fruited Grey Gum	Summer to early autumn
E.signata	Scribbly Gum	Summer
E.resinfera	Red Mahogany	Summer
E.robusta	Swamp Mahogany	Winter
E.seeana	Narrow-leaved Red Gum	Summer
E.siderophloia	Northern Grey Ironbark	Winter to spring
E.tereticornis	Forest Red Gum	Winter to spring
E.tindaliae	Grafton Stringybark	Winter
E.umbra	White Mahogany	Early spring
Leptospermum polygalifolium ssp. *cismontanum*	Teatree	Spring to summer
Melaleuca alternifolia	Teatree	Spring
Melaleuca quinquenervia	Broad-leaved Paperbark	Autumn-Winter
M.nodosa	Ball Honeymyrtle	Spring
M.sieberi	White Paperbark	Summer
Syncarpia glomulifera	Turpentine	Spring to summer

Other foraging resources available within the study area include plant exudates (Acacia and Eucalyptus sap), foraging substrates such as tree trunks and fallen logs, creek lines (insect prey source) and Koala feed tree species (including Forest Red Gum (*E. tereticornis*), Swamp Mahogany (*E. robusta*) and Tallowwood (*E.microcorys*). Koalas are also known to browse on Broad-leaved paperbark (*Melaleuca quinquenervia*).

Important koala populations in the study area have been identified from Ashby, Iluka and Woombah (Clarence Valley Council 2010) to the east of the project boundary, also the western regions of the Clarence Valley LGA (Clarence Valley Council 2010), northern regions of the Coffs Harbour LGA (Coffs Harbour City Council 1999) and the west of Woodburn in the larger state forests of the Richmond LGA (AKF 2008).

The koala inhabits a range of eucalypt forest and woodland communities where favoured food trees are present (Phillips 2000b) which may also include isolated paddock trees (White 1999). The quality of the habitat for koalas is influenced by a range of factors (Reed et al. 1990), 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.

Primary food trees exhibit a level of use that is significantly higher than that of other Eucalyptus spp. while also demonstrating use by koalas that is independent of density. Secondary and/or supplementary food trees invariably exhibit (on average) a significantly lower level of use than a primary food tree (Phillips 2000). Table 4-15 lists known primary, secondary and supplementary koala food tree species in the NSW North Coast as identified in DECC (2008). The area of habitat to be removed comprising primary koala food tree species is around 548.4 hectares. An additional 297.4 hectares containing secondary and supplementary koala food tree species would also be removed. The total area impacting on koala food tree species is around 845.8 hectares.

The Interim Koala Referral Advice for Proponents (DSEWPaC 2012b) lists critical habitat for koalas as:

- primary koala food tree species comprise at least 30 per cent 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,
- primary food tree species are absent but secondary food tree species alone comprise at least 50 per cent of the overstorey trees

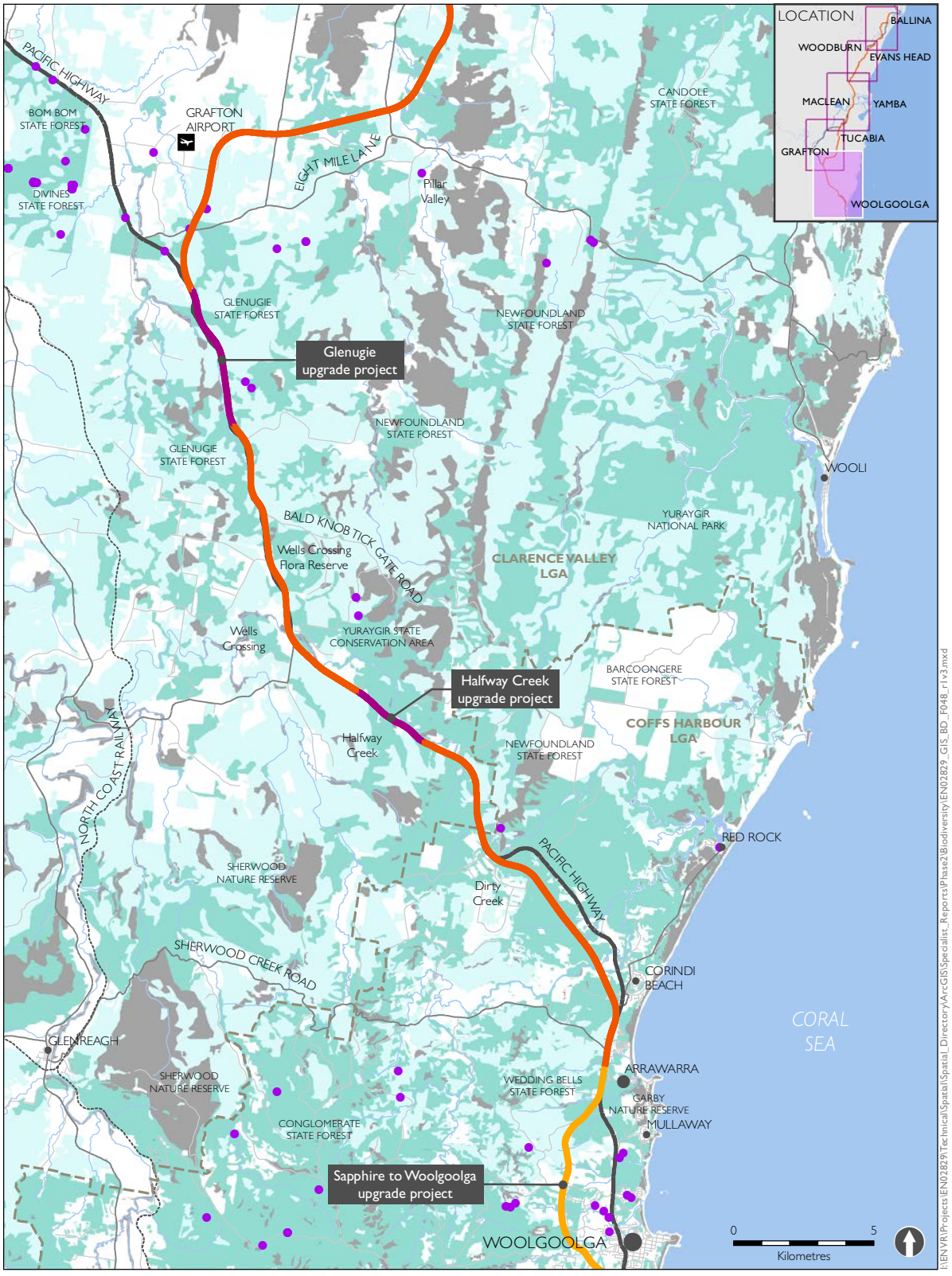
The proportion of each primary and secondary tree species in the overall canopy for each biometric vegetation type was not assessed for this study. Therefore as a precautionary measure, it is assumed that the total impact of 845.8 hectares is critical habitat for the species.

Table 4-15 Critical habitat containing Koala food tree species to be cleared

BioMetric vegetation type containing food trees as dominant or sub-dominant	Koala food tree species			Area to be cleared (hectares)
	Primary	Secondary	Supplementary	
Blackbutt - bloodwood dry heathy open forest on sandstones of the northern North Coast	Tallowwood (*E. microcorys*)			79.7
Blackbutt grassy open forest of the lower Clarence Valley of the North Coast	Tallowwood (*E. microcorys*)		White stringybark (*E. globoidea*)	46.2
Flooded Gum - Tallowwood - Brush Box moist open forest of the coastal ranges of the North Coast	Tallowwood (*E. microcorys*)	Small-fruited grey gum (*E. propinqua*)		2.0
Forest Red Gum - Swamp Box of the Clarence Valley lowlands of the North Coast	Forest red gum (*E. tereticornis*)	Small-fruited grey gum (*E. propinqua*) Grey box (*E. moluccana*)		73.9
Narrow-leaved Red Gum woodlands of the lowlands of the North Coast	Tallowwood (*E. microcorys*) Forest red gum (*E. tereticornis*) Orange gum (*E. bancroftii*)	Narrow-leaved red gum (*E. seeana*) Red mahogany (*E. resinifera*) Small-fruited grey gum (*E. propinqua*)		34.7
Orange Gum (Eucalyptus bancroftii) open forest of the North Coast	Orange gum (*E. bancroftii*)			11.5
Scribbly Gum - Needlebark Stringybark heathy open forest of coastal lowlands of the northern North Coast	Orange gum (*E. bancroftii*)			71.9
Spotted Gum - Grey Box - Grey Ironbark dry open forest of the Clarence Valley lowlands of the North Coast	Forest red gum (*E. tereticornis*) Orange gum (*E. bancroftii*)	Grey box (*E. moluccana*) Small-fruited grey gum (*E. propinqua*)	Thin-leaved stringybark (*E. eugenioides*)	2.1
Swamp Box swamp forest of the coastal lowlands of the North Coast	Swamp mahogany (*E. robusta*)			28.5
Swamp Mahogany swamp forest of the coastal lowlands of the North Coast	Swamp mahogany (*E. robusta*) Forest red gum (*E. tereticornis*)	Red mahogany (*E. resinifera*)		44.2
Swamp Oak swamp forest of the coastal lowlands of the North Coast	Forest red gum (*E. tereticornis*)			56.2
Tallowwood dry grassy forest of the far northern ranges of the North Coast	Forest red gum (*E. tereticornis*	Small-fruited grey gum (*E. propinqua*)		53.0

BioMetric vegetation type containing food trees as dominant or sub-dominant	Koala food tree species			Area to be cleared (hectares)
	Primary	Secondary	Supplementary	
Turpentine moist open forest of the coastal hills and ranges of the North Coast	Tallowwood (*E.microcorys*)	Red mahogany (*E. resinifera*) Small-fruited grey gum (*E. propinqua*)		44.5
Total habitat containing primary koala food trees				**548.4**
Grey Gum - Grey Ironbark open forest of the Clarence lowlands of the North Coast		Small-fruited grey gum (*E. propinqua*)		48.2
Needlebark Stringybark - Red Bloodwood heathy woodland on sandstones of the lower Clarence of the North Coast		Red mahogany (*E. resinifera*)	Stringybark (*E. tindaliae*)	58.2
Red Mahogany open forest of the coastal lowlands of the North Coast		Red mahogany (*E. resinifera*)		46.2
Spotted Gum - Grey Ironbark - Pink Bloodwood open forest of the Clarence Valley lowlands of the North Coast		Small-fruited grey gum (*E. propinqua*) Grey box (*E. moluccana*)	Stringybark (*E. tindaliae*)	144.8
Total area containing secondary and supplementary koala food trees				**297.4**

Figure 4-1 Koala records and presence of primary, secondary and supplementary food trees



The project
Upgrade completed to dual carriageway
Upgrade under construction
Existing Pacific Highway
Koala record (Atlas data)
Habitat containing primary koala food trees
Habitat containing secondary and supplementary koala food trees
Habitat containing no known koala food trees

Figure 4-2 Koala records and presence of primary, secondary and supplementary food trees

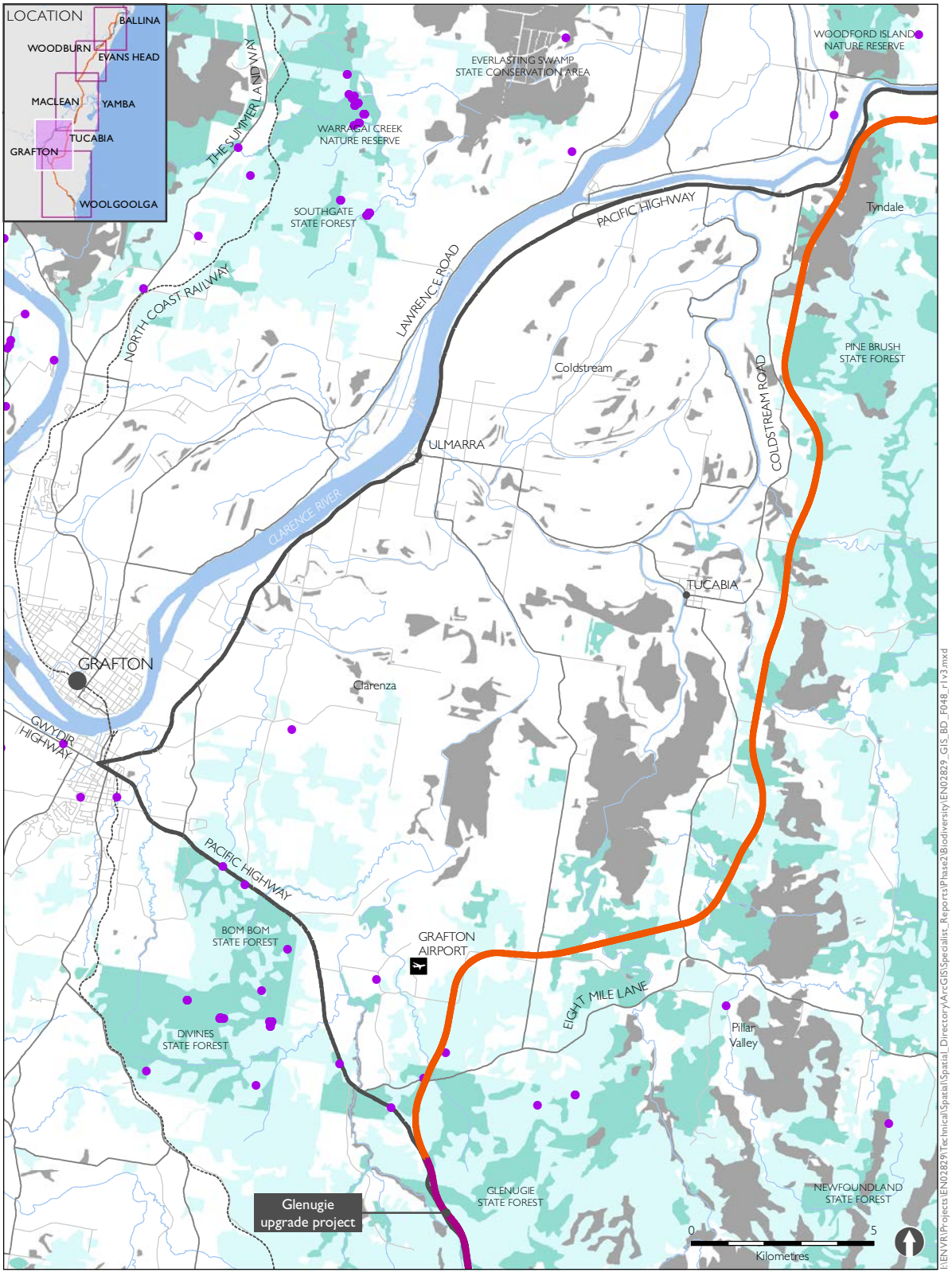


Figure 4-3 Koala records and presence of primary, secondary and supplementary food trees

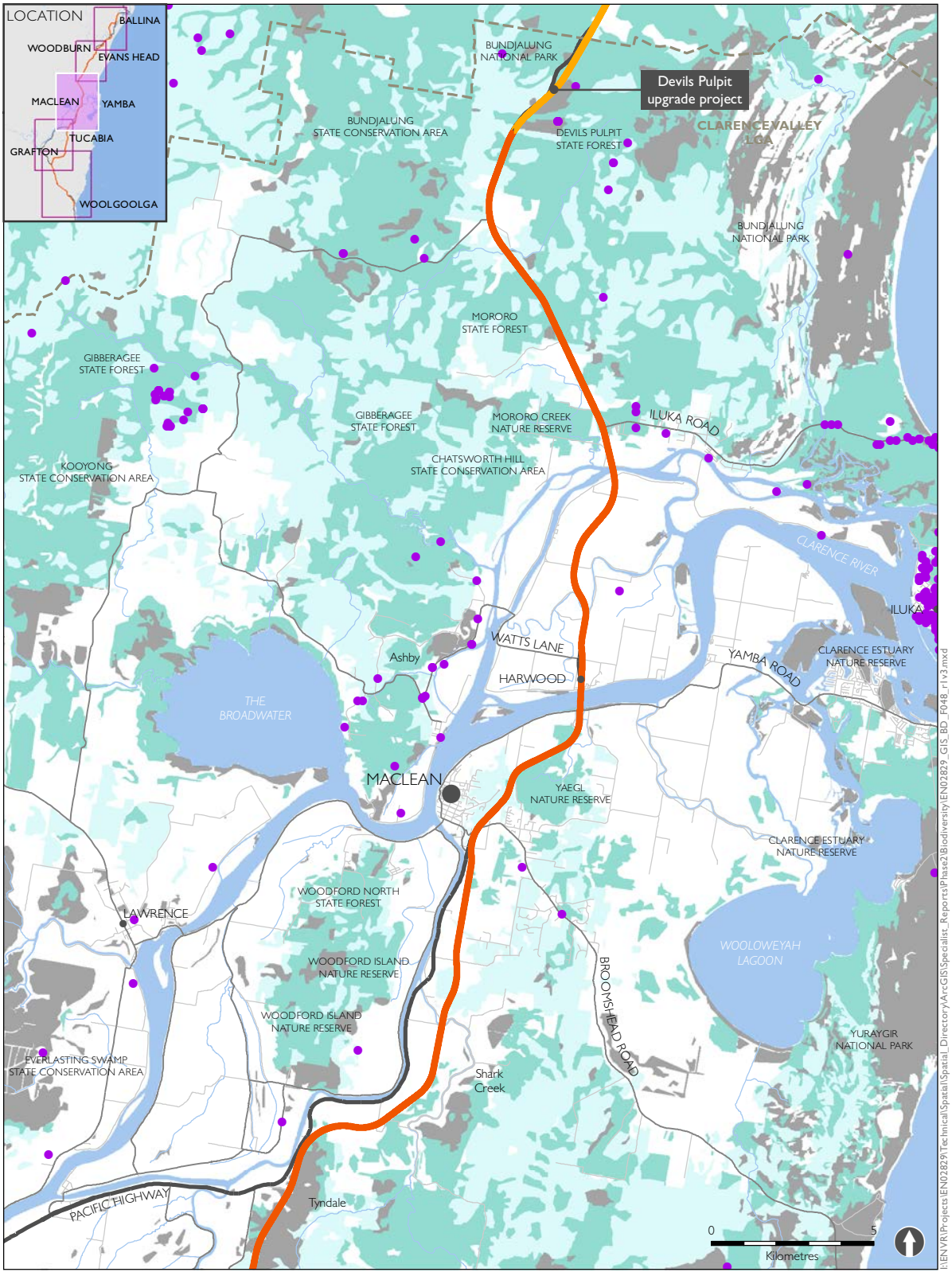


Figure 4-4 Koala records and presence of primary, secondary and supplementary food trees

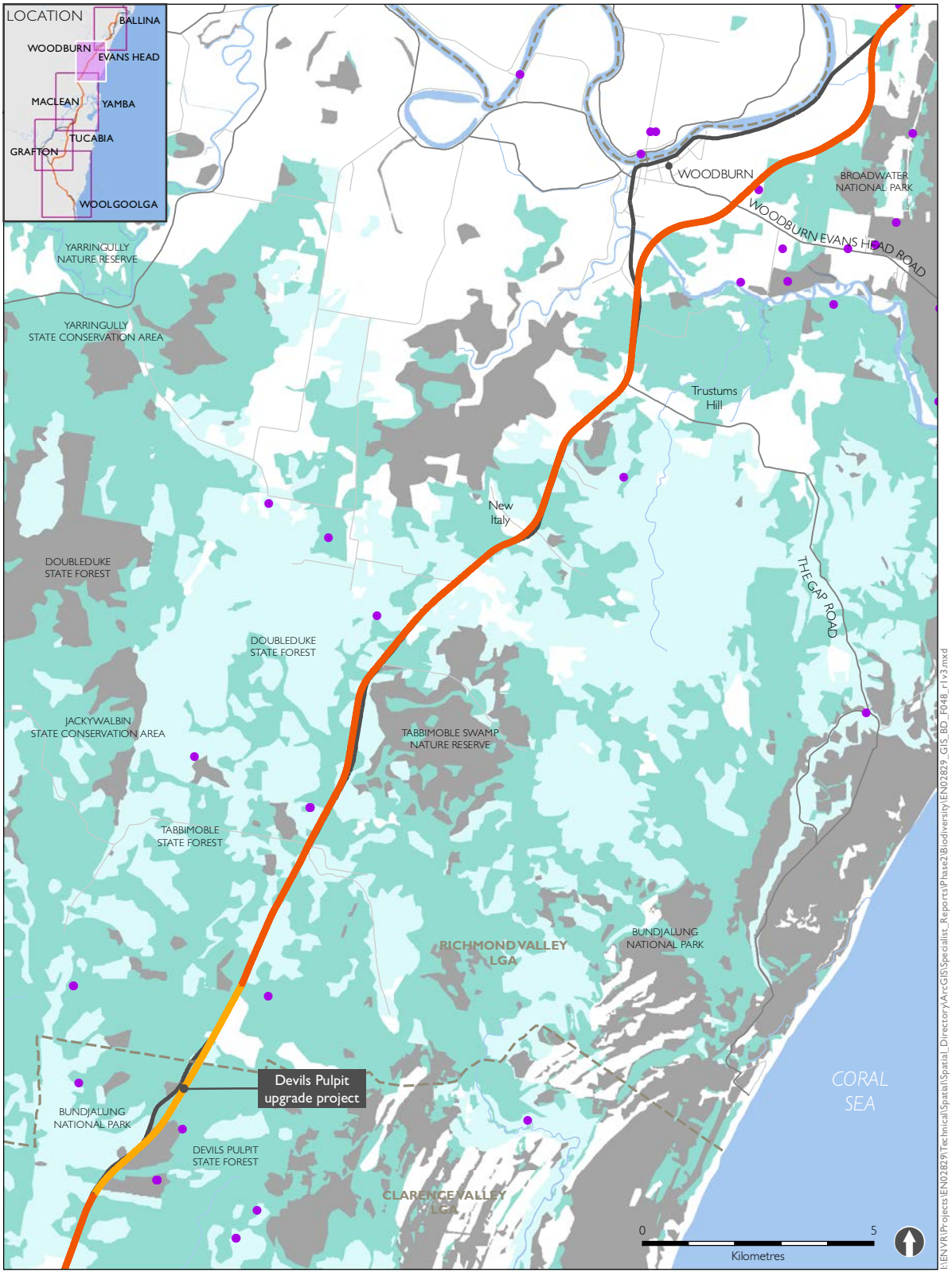
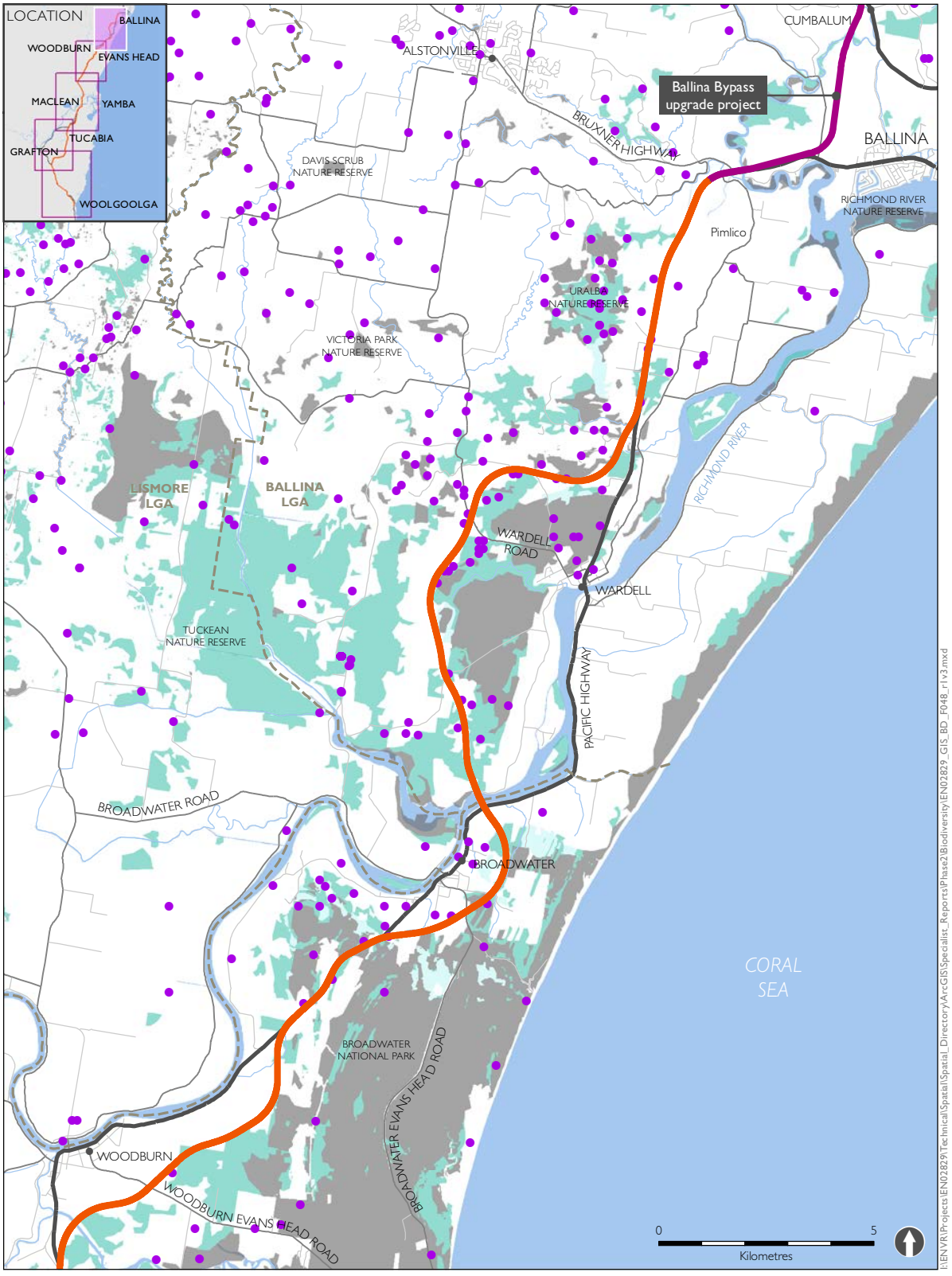


Figure 4-5 Koala records and presence of primary, secondary and supplementary food trees



Threatened fauna populations

The results of the background data analysis and fauna field surveys identify two types of threatened fauna records, i) records consisting of a low density and scattered locations of single species where it is difficult to define the population distribution, and ii) multiple records of the same species over a defined location or habitat type, for example Emu, Rufous Bettong, Koala or Oxleyan Pygmy Perch. The strategy defines the latter as key listed fauna populations.

The following discusses the impacts on key listed fauna population firstly followed by a discussion on impacts to threatened fauna in general, including widespread species and potential subject species, follows in Table 4-16. Assessments of significance have been undertaken for each of these species, and these are provided in Appendix E.

The project would impact populations of several key listed fauna populations. This was determined through ecological surveys undertaken 2006 to 2012, review of NSW Atlas data identifying broad population hotspots and consultation with OEH. The following species are not restricted to the project and occur over a wide distribution; however portions of their distribution include the project boundary. Populations include:

- Endangered population of the Coastal Emu in the lower Clarence Valley and Yuraygir area and intersected by the project boundary from Pillar Valley to lower Shark Creek (Section 3 and 4)
- Important populations of Rufous Bettong, and Brush-tailed Phascogale from Woolgoolga, Halfway Creek, Wells Crossing, Glenugie and Pillar Valley (Sections 1-3)
- Populations of Yellow-bellied Glider and Squirrel Glider from Woolgoolga to Wells Crossing (Sections 1, 2), Tabbimoble (Section 6 and 7) and Broadwater National Park (Section 9)
- A relatively higher density of records of Spotted-tailed Quoll from Woolgoolga and Halfway Creek north to Wells Crossing (Sections 1-2) and Devils Pulpit to Broadwater (Sections 7-9) suggesting the likely presence of quoll populations in these areas
- Scattered areas of primary and supplementary Koala habitat identified on both sides of the project boundary between Tabbimoble and Woodburn (Section 7) as well as high densities of koala records between Woodburn and Wardell (Section 9 and 10) including Broadwater National Park. The majority of these records occur to the west of the project boundary but in some locations these cross the project around the Richmond River
- Population of Long-nosed Potoroo in Wardell Heath (Section 10)
- Giant Barred Frog identified in Section 1 (Wedding Bells State Forest) and also identified in Yuraygir State Conservation Area near Section 2 and Section 9 Broadwater National Park. Green-thighed Frog potential populations were identified either side of the highway in Section 2 Halfway Creek to Wells Crossing Flora Reserve and Devils Pulpit to Tabbimoble Swamp Nature Reserve (Section 7). Wallum Froglet was identified in Tabbimoble Swamp Nature Reserve (Section 7) and in Section 9 Broadwater National Park.

Coastal Emu (Endangered population: TSC Act)

Knowledge on emu groups and their range are based on interpretation and discussion of the annual survey results from NPWS land managers (Gina Hart NPWS and Matt Clarke formerly NPWS *pers comm.*) and interviews with property owners in the Pillar Valley to Tyndale area. The data suggests that the population is divided by a number of social groups that show fidelity to particular areas and habitat that support important pre and post-breeding life cycle events. The degree of relatedness and interaction between the groups is not known.

The majority of the population is centred on Yuraygir National Park including Station Creek to Red Rock, Wooli, Diggers Camp, Minnie Waters, Sandon, Sandon River, Brooms Head, Wooloweyah, James Creek and Taloumbi. These groups range at a considerable distance from the project boundary with the exception of an additional two separate groups to these, which are predicted to be impacted by the project between Glenugie Upgrade and Maclean (Sections 3 and 4). The groups include:

1. One ranging within the area south of Tucabia from the Coldstream River wetlands in the west to Pillar Valley and Yuraygir National Park in the east (Section 3)

2. A second that is largely found on the agricultural land and woodland between Pine Brush and Candole State Forest in the south, Tyndale Swamp and north to Shark Creek and Green Hill and cane farms around Byrons Lane and McIntyres Lane at Tyndale (Section 3 and 4).

These two groups are typically active around the floodplain wetlands and creeks such as Chaffin Swamp and Pillar Valley Creek. They frequent agricultural land during pre- and post-breeding activities in spring and summer with the cane fields frequently occupied by adult males raising young. There is some evidence to suggest that nesting occurs well above the floodline further east of the project boundary, for example Chaffin Hill and may extend to the eastern foothills of the Sommervale Range. However, there has been no reported nesting within the project boundary.

Congregations of emus reportedly occur in mid-autumn to winter prior to nesting and at this time flocks of birds are often observed. The occurrence of such groupings indicates that the birds may travel reasonable distances, as most emu sightings are usually of solitary adults, or of birds in small family groups (Plates 1-2).

Plate 1. Congregation of Emus in grazing/cropping land

Plate 2. Juvenile emus grazing around sugar cane paddocks

Breeding

Breeding is assumed to occur in four broad areas:

1. Station Creek to Red Rock River (south)
2. Wooli - Diggers Camp - Minnie Water - Sandon River (central)
3. Brooms Head - Sandon River - Candole State Forest - Wallaby Lane (north)
4. Pillar Valley around Chaffin Hill and Whites Hill in the western edge of their range.

The first three of these areas are in the eastern part of their range within 10 kilometres of the coast.

Breeding is evidenced by the presence of young chicks in winter and anecdotal evidence of nest sites in these locations. The full extent of areas used for breeding is not known, as breeding localities have only been identified based on family groups with striped chicks in July-September. These observations may be also skewed as they correlate to coastal villages, public lands and roads where there are more opportunities for viewing emus and their behaviour. Based on this current knowledge, there are no breeding sites west of the project, all breeding sites occur to the east of the project.

Habitat use

To support the life-cycle activities of feeding and drinking, breeding and nesting, the emus appear to depend on a mosaic of vegetation types including both natural and modified habitats. This includes open forest, heath, woodland, agricultural land (grazing and cropping land), grasslands and wetland fringes.

Diet and water requirements

Studies on the species in open plain habitats in Western Australia indicate that at all times the birds are semi-nomadic, keeping in touch with variation in availability of food (Davies 1978; 1984). Emus are omnivorous relying on insects, seeds, fruits and succulent vegetation (Dawson *et al* 1983) which may include both native and exotic plant species in coastal areas (McGrath and Bass 1999). In any locality in a particular time of year emus exhibit clear food preferences (Davies 1976) a factor which is associated with the typical sporadic and seasonal occurrences of fruits and seeds and this may partly explain their semi-nomadic behaviour and need to travel long distances to access available food sources. In their study of emus in arid landscapes Dawson *et al* (1983) recorded regular daily movements of 10-12 kilometres in autumn and 18 to 25 kilometres in summer reflecting the availability of food. The daily movements and length of travel of the coastal emus is not known however genetic data taken from across the species distribution indicates that there is considerable mixing in the population (Appendix K)

The emu's ability to transport many large seeds over long distances could prove an important link between fragments of remnant vegetation by helping to maintain the genetic mix in plant communities (McGrath and Bass 1999). Information obtained from landholder surveys in the Pillar Valley, Tucabia and Tyndale area indicate that the birds feed on crops, in particular soy beans and lablab beans as well as young growth on burnt grass or soft wetland plants. Fruits include Bangalow Palm, Native figs and Inkweed and seeds include

sedges and graminoids (*Gahnia* and *Lomandra* spp.).

The water requirements of adult emus do not appear high but intake may be limited by the size of the simple gut, resulting in a relatively high frequency of drinking, once per day and occasionally twice per day during hot summer conditions (Dawson *et al* 1983). Drinking rarely occurs during incubation. These data may support the hypothesis that the floodplain wetlands are critical to emu movements due to the regular supply of water, and the fact that they would be important year round, but particularly in the warmer months.

Evidence in western populations suggests that emus show a high fidelity to particular watering sites which may include artificial dams (Dawson *et al* 1983).

Regular movements

Emus are semi-nomadic moving in response to the availability of food and water resources. However, seasonal access to frequented habitats may be via regular but broad movement pathways across the landscape. There has been no study on the movements of the emu population in the Clarence Valley and data on movements is based on observations, landowner interviews and the genetic pilot study (Appendix K) as discussed. Several main emu movement areas are assumed based on regular sightings at the same locations and include:

- Pillar Valley across Wooli Road at Whites Bridge (Pillar Valley Creek) and also south towards Coldstream Wetlands (Section 3)
- Sommervale Flats and Tyndale Swamp north to Shark Creek and Byrons Lane area (Sections 3 and 4)
- Brooms Head to Green Hill and McIntyres Lane (Section 4).

The incidence of broad movement pathways suggests that any crossing structures targeting this species need to be closely spaced with multiple structures needing to cover a broad distance. Emus are often observed moving along vehicle tracks and frequent lightly wooded areas and clearings through forest and woodland particularly where they provide access through dense forest and heath, such areas may provide suitable locations for crossing structures. Further discussion on the proposed crossing structures for emus is discussed in the Biodiversity Connectivity Strategy (Appendix A).

Potential impacts

The population consists of small numbers of emus that occupy a broad landscape mosaic of both natural and modified habitats. Being predominantly nomadic, non-breeding birds move from place to place without regard to season or direction and depend on resources that occur rarely at the same site. A continuity of resources can be ensured only if birds are able to locate successive favourable areas that are often spatially separated (Davies 2007). In areas where environmental conditions are regular, the movements of emus can appear regular but the birds are still influenced by the same suite of behaviour patterns as are birds in environments that are less consistent (Davies 2007).

Based on the distribution of emu records for the Pillar Valley to Shark Creek group, the evidence suggests that the relatively stable environmental conditions associated with the floodplain wetlands and swamps of the Coldstream River, Chaffin Swamp, Champions Creek, Pillar Valley Creek, Tyndale Swamp and Shark Creek including the associated agricultural land, support reliable food and water resources, both spatially and temporally. These habitats account for observed movements in the pre and post breeding life-cycle periods of birds. The wetlands are currently contiguous with the forest and heath communities to the east of the floodplain via relatively natural and modified habitats, albeit for a network of smaller roads, such as the Tyndale-Tucabia Road, continuing to the coastal lands of Yuraygir National Park and surrounds.

The project in the eastern extent of the lower Clarence floodplain would effectively skirt around the Coldstream wetlands, eventually crossing Pillar Valley Creek, Chaffin Creek, Champions Creek and Shark Creek and therefore potentially introduce a physical barrier for emus accessing the wetlands from the east.

Therefore, the impact to the population from the project would include the direct removal, fragmentation and isolation of important habitat. This factor combined with the increased risk of vehicle strike associated with the project, adding to the existing mortality from vehicle strike on local roads, has potential to have significant long-term impacts associated with a cumulative reduction in the population leading to loss of viability. The project would have the greatest impact on the group ranging the Pillar Valley to Tyndale. The degree of relatedness and interaction of this group to the other identified groups extending to the coast is not known.

The impacts of the barrier effect and fragmentation have been addressed though a specific focus on this species in the Biodiversity Connectivity Strategy in Appendix A and the mitigation and management measures specified in Chapter 5.

Rufous Bettong and Brush-tailed Phascogale

The species distribution in the NSW North Coast Bioregion largely extends on the eastern slopes and ranges of the Great Dividing Range from Port Macquarie to the Queensland border and coming to the coast between Coffs Harbour and Woodburn. Records are generally widespread however there are known hotspots in the area from Halfway Creek (Section 2) to Eight Mile Lane including Glenugie State Forest, Nine Mile Creek and Pillar Valley to Tucabia (Section 3). This population is associated with dry sclerophyll forest on sandy and clay soils and includes the lower undulating lands and slopes of the Sommervale Range.

Rufous Bettong inhabit a variety of forests from tall, moist eucalypt forest to open woodland, with a tussock grass understorey. A dense cover of tall native grasses is the preferred shelter. The species also frequents cleared agricultural land near forest edges and is tolerant of fragmentation of habitat. Major threats are roadkill and predation by foxes, cats and dogs.

The Brush-tailed Phascogale is largely arboreal and occupies intact and fragmented dry

open sclerophyll forests and woodlands with an open ground layer and moderate density of trees and shrubs in the mid-stratum. The species is dependent on tree hollows for shelter and breeding, using many different hollows within its range over a short time span (Trail and Coates 1993). Individuals forage preferentially in rough-barked trees of 25 centimetres or greater.

There are three broad locations where known populations of both species are affected by the project:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Section 1-2)
- Pillar Valley to Harwood (Section 3 and 4) in the foot slopes of the Summervale Range extending to intact and fragmented habitats on lower undulating lands near Bostock Road, Sommervale Road to Tyndale and Gulmarrad and upper Shark Creek
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).

Potential impacts

Potential impacts are associated with loss of habitat, in particular those containing hollow-bearing trees in the case of the Brush-tailed Phascogale, and the barrier effect of the highway as well as potential for increased predation associated with fragmentation and degradation of habitat adjoining the project. The severity of the impact on a regional scale is low, as both species are widespread over a large portion of the bioregion,

The lower Clarence Valley to Yuraygir area including Gleungie State Forest appears to be a stronghold for the coastal parts of the bioregion for the Rufous Bettong and localised impacts in these areas may be more moderate. The impacts of the barrier effect and fragmentation have been addressed via a focus on these species in the Biodiversity Connectivity Strategy in Appendix A and the mitigation and management measures specified in Chapter 5. Both species are tolerant of modified and fragmented habitats as evidenced by the size of the populations and habitats used in Glenugie State Forest and adjacent grazed and slashed habitats in the Pillar Valley to Tyndale area.

Yellow-bellied Glider and Squirrel Glider

The distribution of the Yellow-bellied Glider in the North Coast Bioregion is widespread across slopes, ranges and coastal areas being largely restricted to the large key habitats and corridors. It is generally absent from the heavily fragmented alluvial floodplains, wetlands and north of the Richmond River in the coastal heath and floodplains.

There are two main locations of Yellow-bellied Glider population intersected by the project:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Sections 1 and 2)
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).

These populations are largely associated with the taller, mature dry and moist sclerophyll

forests on nutrient rich soils. They rely primarily on plant and insect exudates, including nectar, sap, honeydew and manna with pollen and insects providing protein and are dependent of tree hollows for shelter and breeding.

The species is very mobile and occupy large home ranges between 20 to 85 hectares to encompass dispersed and seasonally variable food resources (Goldingay and Kavanagh 1991).

The distribution of the Squirrel Glider throughout the North Coast Bioregion is widespread within a range of habitats, dominated by coastal sclerophyll forests and swamp forests, but extends into drier forests and woodlands of the tablelands in the northern regions. They frequent habitats with an abundant and varied supply of nectar and arthropods (Kavanagh 1984).

There are three broad locations of Squirrel Glider population intersected by the project:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Sections 1 and 2)
- The slopes of the Summervale Range from Pillar Valley to Pine Brush State Forest and Gulmarrad (Section 3)
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).

These populations are largely associated with the mature dry and moist sclerophyll forests on both sandy and clay soils. They rely primarily on a diversity of eucalypt species in the canopy and in some locations, Banksia and Melaleuca to supply the nectar supply. They are also dependent on tree hollows for shelter and breeding which limits their distribution to older growth remnants. However, Squirrel Gliders have also been recorded denning in isolated paddock trees, so they are capable of traversing partially cleared land.

Potential impacts

Potential impacts for both species are associated with the loss of habitat including potential den sites, fragmentation and the barrier effect of the high leading to increased isolation of family groups and reduced genetic diversity. The severity of the impact on a regional scale is moderate, as the species are widespread over a large portion of the bioregion. However impacts on local populations are high. The impacts of the barrier effect and fragmentation have been addressed via a focus on this species in the Biodiversity Connectivity Strategy in Appendix A and the mitigation and management measures specified in Chapter 5. Large areas of habitat would remain in state forests and reserved habitats for the longer-terms viability of these species.

Spotted-tailed Quoll

The species is very widespread throughout all areas and habitats of the North Coast Bioregion. There are no records of particular clusters near the project that would suggest an important population exists. However based on the habitats present, in particular the larger state forests and conservation reserves, two main areas exist which may represent important habitat for regional populations. These are the areas from Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (sections1 and 2) and Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (sections 6 and 7). These habitats are largely associated with the mature dry and moist sclerophyll forests on both sandy and clay soils.

Potential impacts

Potential impacts for the species are associated with the loss of habitat including potential den sites, fragmentation and the barrier effect of the highway potentially leading to increased genetic isolation. The species is known to frequent roadsides feeding on roadkill and where would be threatened by vehicle strike. The severity of the impact on a regional scale is low as the species is very widespread over a large portion of the bioregion, although localised impacts in areas discussed may be more moderate. The impacts of the barrier effect and fragmentation have been addressed via a focus on this species in the Biodiversity Connectivity Strategy in Appendix A and the mitigation and management measures specified in Chapter 5. Large areas of habitat would remain in state forests and reserved habitats for the longer-terms viability of this species.

Koala

There are over 11,000 recorded koala sightings in the NSW Atlas for the NSW North Coast Bioregion, spread over all local government areas in a wide range of topographies and habitats. This suggests that koalas could occur in all project sections in a range of habitats that would be impacted by the project. The two main centres of high density of koala records occur around Coffs Harbour, south of Woolgoolga (outside of the project), and in Richmond Valley LGA between Woodburn and Ballina (sections 9, 10 and 11).

Potential impacts

Impacts on koala were discussed previously in Section 4.3.2. These relate primarily to the clearing of around 580 hectares of habitat containing the primary koala feed tree species Forest Red Gum (*E. tereticornis*), Swamp Mahogany (*E. robusta*) and Tallowwood (*E.microcorys*). The species could also be negatively affected by fragmentation and the barrier effect of the highway and is regularly struck by cars where high-density populations occur in fragmented urban habitats. The impacts of the barrier effect and fragmentation have been addressed via a focus on this species in the Biodiversity Connectivity Strategy (Appendix A). Large areas of habitat would remain in the landscape including state forests and reserved habitats for the longer-term viability of this species.

Long-nosed Potoroo

An isolated population is known from Wardell Heath in Section 10 and associated with the wet and dry heath habitats on sandy soils. Wardell Heath is a name referring to a large area of land containing a mosaic of heath, forest and swamp habitats positioned adjacent on the western side of the Richmond River near Wardell. Section 10 of the project would traverse around this habitat on the western side and not directly involve a loss of habitat for the Long-nosed Potoroo. Potential indirect impacts may be associated with impacts on groundwater through construction potentially affecting the condition of the retained habitats and also the potential barrier effect on dispersal and movements of the species. There is limited connectivity to similar habitats for these species across the North Coast Bioregion, which explains its relative isolation. The Richmond River is a barrier to the east and the only movement opportunities are to the north across a network of existing roads. The impacts of the barrier effect and fragmentation have been addressed via a focus on this species in the Biodiversity Connectivity Strategy in Appendix A and the mitigation and management measures specified in Chapter 5. Large areas of habitat would remain in the landscape within Wardell Heath for the longer-term viability of this species.

Giant Barred Frog and Green-thighed Frog

Both species have a widespread distribution that includes coastal habitat to the eastern slopes of the range, occurring in wet forests and moist sclerophyll forests including swamp and riparian habitats adjoining drier open forest types. The two main locations intersected by the project are:

- Woolgoolga to Glenugie including Halfway Creek, Wells Crossing and Glenugie State Forest (Section1-2)
- Bundjalung National Park to Devils Pulpit, Tabbimoble State Forest and Doubleduke State Forest (Sections 6 and 7).

These populations are largely associated with the taller, mature moist sclerophyll forests and riparian habitats on nutrient rich soils.

Potential impacts

Impacts would include direct loss of habitat over small discrete areas through crossing drainage and creek habitats and the indirect edge effects on remaining areas adjacent to the road. There is potential for detrimental changes to drainage patterns in important habitats if present in small and local scale in addition to altered water quality associated with polluted water from runoff and overflow of sediment basins in drainage areas.

Pink Underwing Moth

Small populations recorded in Section 10, would be restricted to lowland rainforest and moist floodplain forests comprising host plant species Carronia multisepalea. The host plant was identified in regrowth rainforest growing on rich soil derived from basalt. Carronia multisepalea was recorded over an area of 0.2 hectares, 35% of which falls within the project boundary. Potential impacts include the loss of habitat particular where the host plant occurs, there is scope to minimise the impact and target the use of this specie in revegetation works as part of the project. The Pink Underwing Moth is also likely to breed within the study area. Its host plant is prevalent from within the alignment to a little beyond the edge of the western buffer zone.

The project would clear up to 10 hectares of lowland rainforest including the removal of likely breeding habitat as determined by the presence of larvae and the host plant Carronia multisepalea. The project would likely have a significant impact on the burrowing / sheltering and breeding, and foraging life-cycle activities for the local population of this species. The records in the study area represent the first records for the region around Ballina and only the second record in NSW. There is no data on the size or distribution of the population; however as a precautionary measure this is likely to be restricted to a small number of fragmented floodplain rainforest remnants.

Atlas Rainforest Ground Beetle

The species was recorded at the northern end of project in section 10 with a rainforest remnant located within and adjacent to the project boundary. This observation comprised a single adult Atlas Rainforest Ground Beetle encountered in a burrow positioned under a large protruding root of a White Cedar (Melia azedarach) in soil derived from basalt. The potential habitat for this species includes lowland rainforest and is restricted to the northern end of the project (Section 10 and 11).

The project would clear up to 10 hectares of lowland rainforest and this would have a likely significant impact on the burrowing / sheltering and breeding, and foraging life-cycle activities for this species. The records in the study area represent the first records for the region around Ballina. There is only one previous record of the ground beetle between Alstonville and Coraki.

These species frequent rainforest and low elevation moist eucalypt forest. there is little known of the life-cycle requirements of associated habitat characteristics. The survival of this species is threatened by an extremely restricted distribution, clearing of rainforest remnants, removal of fallen timber and ground cover.

Other threatened fauna

The potential impacts from the project on other threatened fauna species is provided in Table 4-16. This includes species known from or predicted to occur in the study area that may potentially occur in the project boundary due to the presence of suitable habitats. However, these species have not been identified near the project boundary. Species in the table are discussed individually, however where a group of species shares similar habitat requirements and life-cycle strategies, these are discussed together, for example hollow-roosting microchiropteran bats, or wetland birds. Where there is insufficient information on the size and extent of the population to make an informed decision regarding the significance of the impact, the likely impact is based on the precautionary principle.

Table 4-16 Potential impacts on other threatened fauna known and likely to occur in the project boundary

Species	TSC Act	EPBC Act	Project section	Aspects of the species ecology of relevance to the project and potential impacts
Wetland birds				
Magpie Goose	V		2-6, 8-11	The similarity of these species lies in the broad range of habitats frequented from riverine, freshwater wetland and lake habitats to swamps and wetlands and farm dams, wet pastures and meadows to cane paddocks, and tea-tree plantations. All rely on the right complement of foraging, refuge and breeding habitats in their local landscape for population viability. May occur across all 11 project sections and Identified sections represent higher density of records and known breeding habitat for species such as Black-necked Stork. Potential impacts include relatively small loss of habitat for foraging and breeding. Potential longer-term changes to hydrology or water quality conditions affecting the density of prey species and foraging resources. This includes expected clearing or riparian zones and potential changes to local flood patterns. Black-necked Stork is known to nest in the study area associated with the Coldstream wetlands in the Pillar Valley to Tyndale area (Section 3) were nests are in disturbed wetland habitat situated on agricultural land (Clancy 2010). There are no known nest sites within the direct project boundary.
Black-necked stork	E		1-11	
Brolga	V		1-11	
Comb-Crested Jacana	V		3-9	
Black Bittern	V		1-3, 6-7, 9	
Australasian Bittern	E	E	1-4, 7-11	
Australian Painted Snipe	E	V	1-11	
Pale-vented Bush Hen	V		9-10	
Freckled duck	V		3-5	
Large forest owls				
Powerful Owl	V		1-11	The Powerful Owl and Masked Owl are widespread throughout the region being recorded in a range of habitats including the open forest and riparian habitats typical of the study area. The Barking Owl and Sooty Owl are less commonly reported. Nesting requirements are specialised being totally dependent on suitably large tree-hollows generally found in the trunks of tall and mature trees. Their dependence on this specific habitat feature restricts the local distribution of the species at least for breeding life-cycle requirements. Impacts would be associated with loss of habitat including current and potential nest sites and reduction in the area of habitat available for prey and for dispersal of young. Habitat clearing of regional scale not restricted the future distribution of the species.
Barking Owl	V		1-11	
Masked Owl	V		1-11	
Sooty Owl	V		1-2	

Species	TSC Act	EPBC Act	Project section	Aspects of the species ecology of relevance to the project and potential impacts
Frugivorous rainforest birds				
Wompoo fruit-Dove	V		1-2, 6-11	A low number of records are scattered throughout the study area. It is likely that occurrences of these species in the study area similarly sporadic due to nomadic movements as there is limited habitat available in the actual study area to support sedentary populations. Impacts associated with loss of potential food resources, mainly associated with the loss of lowland rainforest (10 ha) further limiting the area of available habitat. Impacts on the regional spatial distribution of resources for these potentially wide ranging species are not significant.
Rose-crowned Fruit Dove	V		1-2, 8-11	
Superb fruit-Dove	V		1-2, 8-11	
Barred Cuckoo-Shrike	V		1-2, 8-11	
Double-eyed Fig Parrot		E	10-11	
Cave-roosting microbats				
Little Bent-wing Bat	V		1-11	Potential impacts on the roosting life-cycle activities of these species are difficult to assess, as no known roost sites have been reported in the study area. Myotis and Miniopterus are known to roost under old bridges, both timber and concrete and inspections of the bridges to be removed by the project suggested they are currently not being used. Impacts would be associated with loss of foraging habitat and potentially short to medium term reduction in habitat for insect prey species.
Eastern Bent-wing Bat	V		1-11	
Southern Myotis	V		1-11	
Eastern Cave Bat	V		1-11	
Tree-roosting microbats				
Hoary Wattled Bat	V		1-11	Vegetation in the study area provides potential foraging and roosting habitat for the assessed species. These bat species frequent a variety of habitat types ranging from rainforest to wet and dry sclerophyll forest, woodland and open modified landscapes. Important life-cycle activities would be impacted by the project and include roosting and breeding and both are typically associated with tree hollows as well as foraging for insect prey which occurs in a variety of habitat types. The size of local populations is not known, although expected to be moderately large given the expanses of suitable habitat and tree hollow densities, particularly small hollows which are preferred by bats. Around 770 hectares of forest habitat containing hollow-bearing trees to be cleared.
Eastern False Pipistrelle	V		1-11	
Golden-tipped Bat	V		1-11	
Beccari's Freetail-Bat	V		1-11	
Eastern Freetail-Bat	V		1-11	
Eastern Long-Eared Bat	V		1-11	
Yellow-bellied Sheathtail-Bat	V		1-11	
Greater Broad-nosed Bat	V		1-11	
Arboreal snakes				
Pale-headed Snake	V		1-3, 6-8	Forest dwelling species dependent on mature dry and moist forests with tree hollows and

Species	TSC Act	EPBC Act	Project section	Aspects of the species ecology of relevance to the project and potential impacts
Stephens' banded snake	V		1-3, 6-8	dead trees for shelter. Feed predominantly on small mammals, mostly rodents and other reptiles (Fitzgerald et al 2003). Potential hunting and sheltering habitat is widespread and occurs across most sections with the exception of the fragmented floodplains. Impacts expected from the extensive loss of potential forest habitat, fragmentation of forests may also isolate areas of former habitat. Prey species are expected to be abundant pre- and post-construction.
Diurnal raptors				
Little Eagle	V		1-11	May occur across all sections in a broad range of habitats. Impacts generally associated with the loss of hunting habitat, up to about 770 hectares of forest habitat to be removed which would impact on habitat for prey species having potential local impacts for established nesting pairs.
Square-tailed Kite	V		1-11	
Red Goshawk	E		1-11	
Other fauna				
Glossy black-cockatoo	V		1-7	Glossy Black-cockatoos prefer she-oaks (mostly Allocasuarina) in forests, woodlands and along timbered watercourses. Sheoak was found to be moderately common in the drier forest types, particularly on sandy soils, however its distribution is patchy and not evenly distributed across all forest types such that it is difficult to quantify the impact in terms of loss of forest habitat. Nonetheless the project would impact on around 50% 443 hectares of dry open forest habitat comprising potential nest hollows and food resources for this species. The species distribution would be limited by the presence of these resources, such as local losses could have a significant long-term impact to the spatial distribution and breeding success of pairs.
Little Lorikeet	V		1-11	Little Lorikeets favour woodlands, forests, large trees in open country, timbered watercourses, shelterbelts and sometimes street trees as their habitat. Riparian habitats are particularly used, due to higher soil fertility and hence greater productivity. They nest in proximity to feeding areas if possible, most typically selecting hollows in the limb or trunk of smooth-barked Eucalypts. Impacts over a large scale including up to 770 hectares of forest habitat providing potential food and nesting resources. A wide ranging nomadic species adapted to fragmented landscapes and patchy resources, including using modified habitats. Impacts unlikely to be significant to local and regional populations.

Species	TSC Act	EPBC Act	Project section	Aspects of the species ecology of relevance to the project and potential impacts
Mangrove Honeyeater	V		4-5, 8-10	Recorded in section 10, the species occurs in mangroves swamp and estuarine wetlands which have only minor impacts from the project (1.5 hectares) relative to the extent of potential habitat in the estuaries of the lower Clarence and Richmond rivers.
Eastern Osprey	V		1-11	A widespread and relatively common species in the coastal regions of the NSW north coast, occurring in remnant intact and fragmented agricultural areas. Nesting may occur in swamps and dense open forests near rivers and creeks and commonly in cleared paddocks of forest fringes in disturbed areas. Impacts from clearing would extent into cleared and modified agricultural areas for these species in terms of removing potential nesting trees. No nest sites recorded in the project boundary at the time of the surveys, a known nest at Harwood is at least 500 m to the west of the project boundary.
Ground Parrot	V		8-10	Occupies dense wet and dry heath, potential and known habitat in Broadwater National Park and Wardell Heath would have minimal direct impacts. Not expected to significantly impact on the movements of the species and large areas of habitat would remain.
Eastern Grass Owl	V		1-11	Densely vegetated tall reed swamps, wet meadows including wetlands in cane farms and wet heaths. Hunts for small mammals, including introduced species such as Black Rat. Impacts on potential habitat for this species are relatively minor and large areas of suitable habitat remain in the region, in particularly north of the Richmond River, outside of the project boundary.
Coastal Petaltail	E		3-5	Rare species with very few records in the region probably linked to the short adult life-cycle. Could potentially occur in several of the large swamps in the Clarence and Coldstream and Shark Creek area. Low impact on potential habitat.
Common Blossom-Bat	V		8-11	Restricted habitat requirements associated with littoral rainforest for roosting in proximity to heathland habitats for foraging. Suitable habitat is widespread through the large coastal national parks in the region, and impacts on potential roosting habitat and foraging habitat are minimal.
Eastern Pygmy-Possum	V		1-11	Found in a broad range of habitats from rainforest through sclerophyll forest and woodland to heath, in north-eastern NSW they are most frequently encountered in rainforest. Feeds largely on nectar and pollen and shelters in tree hollows, rotten stumps, holes in the ground, abandoned bird-nests or thickets of vegetation. Very small home-range. Potential habitat is widespread and abundant particularly in large conserved coastal national parks. Impacts associated with loss of 770 hectares of forest habitat and fragmentation of forest patches.

Species	TSC Act	EPBC Act	Project section	Aspects of the species ecology of relevance to the project and potential impacts
Common Planigale	V		1-11	Found in a broad range of habitats from rainforest through sclerophyll forest and woodland. Very small home-range. Potential habitat is widespread and abundant particularly in large conserved coastal national parks. Impacts associated with loss of 770 hectares of forest habitat and fragmentation of forest patches.
Wallum Froglet	V		1-11	A relatively common and widespread species n the study area, occupying a diversity of habitats beyond those described as typical for the species, ie acid paperbark swamps. Also recorded in freshwater wetlands and swamps, and wet depression in open forest on sandy and clay soils. Potential impacts through loss of and degradation of habitat. Not significant due to the largely coastal distribution and widespread and abundant presence of suitable habitat.
Swift Parrot Regent Honeyeater		E E	1-11	Occasional visitors to the region during peak flowering events of the dominant trees, particularly the winter flowering Spotted Gum, Swamp Mahogany and Forest Red Gum. There are no resident populations known from the actual site or immediately surrounding lands and the habitat on site would constitute a small percentage of the available non-breeding habitat for transient populations. Records from the study area are relatively continuous extending over the last 30 years indicating that the region may constitute seasonally important foraging and refuge habitat for transient populations of these species, particularly during inland droughts. The current potential for these species to occur based on the presence of potential foraging habitat is expected to remain after completion of the project such that foraging, movement and other life-cycle attributes would not be impacted suggesting that the project would not lead to a long-term decrease in the size of populations of either species.
Large-eared Pied Bat		V	1-7	Potential impacts on the roosting life-cycle activities of these species are difficult to assess, as no known roost sites have been reported in the study area. Impacts would be associated with loss of foraging habitat and potentially short to medium term reduction in habitat for insect prey species.
Grey-headed Flying-Fox		V	1-11	Frequent diverse habitats from woodlands, forests, large trees in open country, timbered watercourses, parklands, suburban and urban landscapes. Roost in colonies also in a wide range of habitats, but generally close to water, No roosts sites identified in the project boundary from ecological surveys undertaken 2006 to 2012 and background review. Several known permanent and seasonal roosts in the region and many of the habitats to be removed would qualify as critical habitat according to the definitions of the species recovery plan (DECCW 2009). Impacts over a large scale including up to 770 hectares of forest habitat providing potential food resources. A wide-ranging nomadic species adapted to fragmented landscapes and patchy resources, including using modified habitats. Impacts unlikely to be significant to local or regional populations.

Species	TSC Act	EPBC Act	Project section	Aspects of the species ecology of relevance to the project and potential impacts
Olongburra Frog		V	9	Known distribution in the study area confined to Broadwater National Park in wet wallum heath habitat. Project would impact on around 17 hectares of the national park, however the area of habitat potentially suitable to this species is not known. Large areas of suitable quality habitat occur to the east and west of the project. Potential impacts from increasing the barrier effects of the existing highway
Brown Treecreeper	V		1-7	Suitable habitat for these species in the study area is limited and would be associated with woodland or forest dominated by Grey Box, Spotted Gum and Ironbark with open grassy understory. Much of this habitat in the study area has been logged and is in low to moderate condition. This accounts for the limited distribution of the Black-chinned Honeyeater and Brown Treecreeper in the study area despite around 145 hectares of habitat in the project boundary being removed. Impacts would be associated with habitat loss for breeding and foraging life-cycle events including tree hollows used for nesting by Brown Treecreeper.
Black-chinned Honeyeater	V		1-3, 6-7	
Bush stone-curlew	E		1-3	
Grey-crowned Babbler	V		1-4, 6-10	

4.3.3. Direct mortality of native fauna

Fauna injury or death can occur during the clearing phase of construction during the removal of habitat trees and from collision with vehicles during the operation of the project.

Construction impacts

While some diurnal and mobile species, such as birds and large reptiles, may be able to move away from the path of construction tree-clearing other species that are less mobile, those that are nocturnal, or those that have smaller home ranges, are less inclined to move rapidly or disperse large distances away from such activity. This includes threatened species such as roosting microchiropteran bats, Squirrel Glider and Yellow-bellied Glider, Brush-tailed Phascogale, Rufous Bettong, Stephen's Banded Snake and Pale-headed Snake and a number of threatened frogs. RMS has developed a guideline for the procedures to be employed to avoid or minimise mortality on these types of species and other threatened or common fauna during construction (RMS 2012). Further details on the procedures to minimise fauna mortality are outlined in Chapter 5.

Operational impacts

Mortality due to vehicle strike has the potential to affect fauna species at the sub-population level. In general, rates of vehicle strike mortality are likely to be directly proportional to the distance of native vegetation/fauna habitat crossed by the project (Forman *et al.* 2000). However, other factors such as the design of the road (eg through road cutting or road embankment, presence of adjacent stock fences, presence of fauna exclusion fencing or fauna crossing structures) also influence vehicle strike mortality. Estimates of road mortality in Australia for a single pass survey have suggested one bird lost for every 13 kilometres and one mammal lost for every 30 kilometres of road (Disney & Fullagar 1978; Vestjens 1973). Burgin and Brainwood (2008) reported roadkill frequency of 6.32 animals per 100 kilometres in central western NSW and 3.39 animals per 100 kilometres in peri-urban Sydney also from a single pass survey. These authors reported more mammals killed than birds, and identified significantly higher numbers of animals killed on medium traffic volume roads such as major secondary roads and minor highways than on high volume major highways (Burgin and Brainwood 2008).

However, simple counts of road mortality fail to consider the impacts that such mortality can have in the wider populations. These impacts include lost breeding (Forman *et al.* 2000; Taylor & Goldingay 2004) and the impacts on discrete populations where recruitment is reliant on breeding rather than influx of more animals from adjacent populations. An example of this threat is the endangered coastal emu population, which exists as a relatively small population over a wide but restricted area. Any further incremental losses associated with road strike may have significant long-term impacts to the sustainability of the population.

Threatened fauna that have the greatest potential to be negatively affected by vehicle strike over the length of the project are based on published known threats and a review of roadkill databases (RMS and WIRES). These include the Squirrel Glider (Claridge & van der Ree 2004), and Yellow-bellied Glider, Koala (Lassau *et al* 2008), Coastal Emu, woodland species of bird such as the Grey-crowned Babbler (Davidson & Robinson 1992; Robinson

et al. 2001), Rufous Bettong, Brush-tailed Phascogale and Spotted-tailed Quoll (Beckers 2008) and potentially Green-thighed Frog, Wallum Froglet and Wallum Sedge Frog. The project design includes recommendations from the Biodiversity Connectivity Strategy, to avoid and minimise impacts from vehicle strike. Details of the strategy are discussed in Section 4.3.4, Chapter 5 and Appendix A.

4.3.4. Loss of habitat connectivity

The project has potential to isolate remnant vegetation patches and create barriers to the movement of small ground-dwelling mammals, reptiles and amphibians and potentially discrete arboreal mammal populations on a both a patch and landscape scale.

The project design includes a four-lane divided carriageway, with space in the median for upgrade to a six-lane carriageway, if required. The width of the project boundary would vary considerably according to the location, elevation and proximity of service roads and interchanges. Generally, the project width is within a range of 50 to 200 metres. Large sections of the upgrade would occur adjacent to the existing highway. The upgrade and widening of the road would be such that the existing barrier effect of the highway would be substantially increased. Sections of the project that deviate substantially from the existing highway would create a new barrier effect (eg sections 3 to 4 and 9 to 10).

There is currently a high degree of habitat fragmentation across much of the study area. This is due to the broad-scale clearing of native vegetation for agriculture and development including construction of the existing Pacific Highway and network of roads. This fragmentation of habitat is evident in the floodplain regions of the Corindi River, Clarence River and Richmond River. Contiguous areas of forest are generally associated with state forests, national parks and conservation reserves, which have been partitioned in the landscape over time. Any impacts on these lands associated with the project would occur along the outer boundaries of the property and would not divide these larger important areas of habitat. This feature of the project alignment, in addition sections consisting largely of a duplication of the existing highway corridor, suggests that further large-scale fragmentation of habitat on a regional scale has been avoided by the project route selection.

However, the widening of the existing Pacific Highway in some areas would exacerbate the current barrier effect of the highway on regional and local populations of general flora and fauna The loss of connectivity has potential to impact on populations of several listed fauna species as determined by ecological surveys undertaken 2006 to 2012, review of NSW Atlas data identifying broad population hotspots and through consultation with Office of Environment and Heritage.

These species include:

- Coastal Emu - the endangered population of the lower Clarence Valley and Yuraygir area is intersected by the project from Pillar Valley to lower Shark Creek (section 3 and 4). The project would bisect important habitat for pre and post breeding life-cycle activities
- Oxleyan Pygmy Perch - known and potential habitat for the species in Section 1 (Cassons Creek and Redbank Creek), Devils Pulpit to Tabbimoble (Section 7), and between Woodburn and Broadwater (Section 9) including MacDonalds Creek and Broadwater National Park
- Yellow-bellied Glider and Squirrel Glider - important populations exist from Woolgoolga to Wells Crossing (sections 1 and 2), at Tabbimoble (section 6 and 7) and Broadwater National Park (Section 9)
- Rufous Bettong, Common Planigale and Brush-tailed Phascogale - important populations exist from Woolgoolga, Halfway Creek, Wells Crossing, Glenugie and Pillar Valley (sections 1 to 3)
- Spotted-tailed Quoll - a relatively higher density of records of from Woolgoolga and Halfway Creek north to Wells Crossing (sections 1 to 2) and Devils Pulpit to Broadwater (sections 7 to 9) suggesting the likely presence of quoll populations in these areas
- Koala - scattered areas of Primary and Supplementary Koala Habitat identified on both sides of the project boundary between Tabbimoble and Woodburn (Section 7) as well as high densities of koala records between Woodburn and Wardell (sections 9 and 10) including Broadwater National Park. The majority of these records occur to the west of the project boundary but in some locations these cross the project around the Richmond River
- Long-nosed Potoroo in the Wardell Heath (Section 10)
- Giant Barred Frog, Green-thighed Frog and Olongburra Frog (sections 1 to 3 and 6 to 9)

As part of the response to mitigate and minimise this barrier effect for these species, RMS has developed a strategy with the aim of providing connectivity structures and enhancing landscape connectivity where feasible and reasonable in strategic locations. The Biodiversity Connectivity Strategy is detailed in Chapter 5 and Appendix A.

Throughout the largely cleared or fragmented habitats, smaller east-west vegetated corridors are likely to play an important role in the wider corridor network. These include those fragmented by the existing highway such as at Yaegl Nature Reserve or Tabbimoble Nature Reserve to Doubleduke State Forest. The project would increase the level of isolation or fragmentation of some patches of vegetation that follow in an east-west direction. An increase in the width of the road is likely to increase this barrier effect for some species and in some sections where regional corridors have been identified, (such as the Dirty Creek Range to Yuraygir National Park or Bundjalung National Park). This would be the case particularly for ground-dwelling and arboreal mammals. Mobile species such as birds and bats may not be as affected by the increase in road corridor width.

Roads act as a barrier or filter to the movement of vertebrates (eg Mansergh and Scotts 1989; Alexander and Waters 2000; van der Ree 2006). Animal movement may involve daily travel through a home range, seasonal migration associated with changes in habitat use or breeding events, or the dispersal of individuals from their natal areas (Taylor and Goldingay 2011). A barrier effect may result from a behavioural aversion to a road. There have been few studies in Australia to understand this effect, however those that have been done reveal that diverse responses can be expected among mammalian taxa. Rodents of different genera showed a gradient of responses to crossing road clearings, from no inhibition to severe inhibition (Goosem 2001). Squirrel Gliders regularly crossed a high-volume two-lane highway, whereas females appeared to be inhibited from crossing a high-volume four-lane highway with a median strip (van der Ree 2006).

4.3.5. Habitat fragmentation

Fragmentation of habitat would be greatest where the project deviates from the existing Pacific Highway. This occurs on a large scale through sections 3 to 4 and sections 9 to 10. Portions of the landscape in these regions are already largely cleared; particularly the alluvial floodplain areas of the Coldstream River and Richmond River where vegetation is heavily fragmented and a mosaic of different sized remnants exist. However, Section 3 would traverse the western foothills of the Summervale Range from Pillar Valley to Tyndale and this route would fragment remnant open forest habitats in moderate and high quality condition over a distance of around 23 kilometres. This includes fragmentation of a portion of the identified Sandstone Rough-barked Apple (*Angophora robur*) population and known and potential habitat for a range of threatened and common fauna species expected in Sections 3 and 4. Much of this habitat occurs on sandy soil that is identified as having a high density of hollow-bearing trees and generally higher fauna species richness. This habitat includes a range of old growth forests with minimal evidence of past logging particularly between Pine Brush State Forest and the interchange at Tyndale.

The second area of major deviation from the existing highway occurs south of the Richmond River to the interchange with the existing highway north of Wardell, a distance of around 12 kilometres. This would fragment habitats of a local and regional scale of importance. These habitats are of such importance partly due to the already increased isolation of the Wardell Heath from the Blackwall Range and the localised east-west wildlife corridors that are situated north of the Richmond River.

Loss of connectivity between smaller habitat patches can cause the loss of genetic diversity in populations (Forman *et al*. 2003). As fragmentation proceeds, stochastic forces add to potential declines caused by a dwindling supply of habitat. Some species are at greatest risk in fragmented landscapes than others and this relates to the biological characteristics of the species. In this regard species that share similar adaptations to habitat niches and similar life-cycle traits are assumed to be impacted in a similar way, for example microchiropteran bats, gliders, nectarivorous and insectivorous birds, large forest owls.

The threat posed by fragmentation is increased for species with large home ranges, which migrate or disperse over long distances, or for those that have specialised dietary or habitat requirements (Jackson 2000).

In a comprehensive literature review of the effects of fragmentation, Henle et al (2004) showed that sensitivity to habitat fragmentation is caused by similar traits in plants and animals. Indeed species with particular traits may be more sensitive to fragmentation. The outcomes of the review by Henle et al (2004) are presented in Table 4-17. Based on the literature review, these authors documented those ecological traits that showed a positive correlation to fragmentation sensitivity. This data is used to highlight a number of threatened species from the study area which may be more susceptible to the effects of fragmentation. However it is evident from the review that indicators of sensitivity to fragmentation are scale-dependent (eg. Metzer 2000) and that there is no consistent response to habitat fragmentation, such that it is not possible to predict which species would be impacted the most or to what extent.

In general, the isolation effect is likely to be most severe for very small populations and those with specific microhabitat requirements that might not be present in small fragments, or whose rate of population growth is very low. These species are identified in Table 4-17.

Table 4-17: Analysis of sensitivity to fragmentation of threatened species

Ecological traits relating to fragmentation sensitivity	Summary of factors based on tested theories (Henle *et al* 2004)	Threatened listed species potentially prone to increased impacts from fragmentation
Population size	• Smaller populations more vulnerable than larger. • Species at higher trophic levels generally have smaller population size and therefore more vulnerable to fragmentation	• There is limited data on population sizes for flora and fauna in the study area. • Smaller flora populations likely to include *Melaleuca irbyana*, *Lindsaea fraseri*, Long-nosed Potoroo, Eastern Chestnut Mouse, Oxleyan Pygmy Perch, Coastal Emu, large forest owls, diurnal raptors, Spotted-tailed Quoll
Population fluctuation and storage effects	• Theoretical models of population viability generally predict that species unable to maintain stable populations in the face of environmental vagaries (species with high population fluctuations) may be prone to local extinction • In plants, the storage of reproductive potential across generations can promote persistence in species. Storage effects relate to life history features such as long life span and clonal abilities and nutrient recycling in plants • The rate of increase of a population is influenced more by favourable periods than by periods with no recruitment. • Seed bank longevity creates storage effects, as it allows plants to overcome long periods with unsuitable conditions for germination. •	• Plant species such as orchids and grasses (*Arthraxon hispidus*) and semi-aquatic plants which require stable seasonal and annual rainfall events (eg *Maundia triglochinoides*). These species also have lower seed bank longevity when compared to lowland rainforest species and fire adapted heath tree and shrub species. • Heath and sclerophyll forest species have greater storage potential and present stable populations during disturbance. • Suggests that some frogs, such as Green-thighed Frog and Wallum Sedge Frog as well as the Oxleyan Pygmy Perch reliant on certain environmental conditions, may have a lower threshold for fragmentation.

Ecological traits relating to fragmentation sensitivity	Summary of factors based on tested theories (Henle *et al* 2004)	Threatened listed species potentially prone to increased impacts from fragmentation
Dispersal power	• Species with high dispersal power, enabling them to recolonise distant patches beyond the distance of the disturbance, should have a lower extinction risk in highly fragmented habitats. • This theory is scale-dependent.	• Affects species mainly of limited or intermediate mobility including invertebrates such as Pink Underwing Moth and Atlas Rainforest Ground Beetle and stream-dwelling frogs such as Giant Barred Frog. • Oxleyan Pygmy Perch has high dispersal power during favourable environmental conditions but requires appropriate design of structures to colonise new areas • Long-nosed Potoroo low dispersal power due to isolated and discrete habitat types
Reproductive potential / growth rate	• Species with low reproductive potential more sensitive to fragmentation. • Species with low annual survival potentially sensitive to fragmentation	• Brush-tailed Phascogale and Spotted-tailed Quoll have lower annual survival due to the fact that males die-off at the end of the mating season, however reproductive rate is high in these species. • Species with low reproductive potential may include slow growing rainforest plants that rely on specific pollinators.
Sociality and central place foraging	• Species relying on complex social structures for breeding and feeding are more sensitive to fragmentation than predominantly solitary species during non-breeding life-cycle events. • The greater the number of individuals occupying the same central place the greater the area required for supplying food for the group. •	• Yellow-bellied Glider more susceptible to fragmentation than Greater Glider (Recher *et al* 1987). • Squirrel Glider and Coastal Emu also reliant on social structure.

Ecological traits relating to fragmentation sensitivity	Summary of factors based on tested theories (Henle *et al* 2004)	Threatened listed species potentially prone to increased impacts from fragmentation
Body size, trophic position and their interactions	• Large-bodied species are at a greater risk of impact than small-bodied species and intermediate sized animals of lowest risk. • Forest fragmentation, especially edge effects favour medium-sized generalist predators and nest parasites and lead to the demise of predation and host sensitive bird species of the forest interior (Lynch 1987). • Large-bodied species are particularly sensitive in the early stages of habitat loss, but these effects are more evenly distributed in more advanced stages of habitat loss. • Herbivores decline significantly less than predators.	• Large bodied species include Coastal Emu and Powerful Owl • Intermediate sized species include Rufous Bettong, Yellow-bellied Glider, Squirrel Glider, Spotted-tailed Quoll • Predation sensitive bird species of forest interior include Black-chinned Honeyeater • Smaller species at lower risk include rainforest invertebrates • Higher tropic level predators include Powerful Owl, Masked Owl, Barking Owl, Sooty Owl, Spotted-tailed Quoll.
Morphological physiological traits rendering plants disturbance sensitive	• High competitive ability and low response to disturbance are correlated with low fragmentation sensitivity • Shade-tolerant species are fragmentation sensitive because an increased mortality, lower growth rate, and lower dispersal capability compared to edge species lead to a competitive disadvantage under the modified light and increased disturbance regimes that dominate a larger percentage of the area in small compared to large fragments. •	• Many rainforest plant species have highly competitive ability but are shade tolerant these species are likely to be more sensitive to edge effects than fragmentation
Ecological specialisation and microhabitat use	• Species reliant on habitat resources likely to be variable and or patchy in their distribution are prone to impacts from fragmentation. • Specialist species more susceptible than generalists, and in particular species reliant on a small suite of essential microhabitat requirements, such as large tree hollows, small tree hollows or particular density of rocks and logs. These features may not be present in small fragments.	• Includes species reliant on seasonal foraging resources such as Coastal Emu, Swift Parrot, Regent Honeyeater, Little Lorikeet, Grey-headed Flying Fox, Coxens Fig Parrot and Large Fruit-doves • Glossy Black Cockatoo specialist feeder of Sheoak fruit. • Grey-headed flying-fox able to exploit a range of food items over a broad area. • Hollow-dependent fauna more vulnerable, including gliders, microbats, Stephen's Banded Snake and Pale-headed Snake

Conservation reserves

A small number of national parks and nature reserves would be directly impacted by the project; the area of impact is presented in Table 4-18. This impact would contribute to the increased fragmentation of important habitat for flora and fauna.

Table 4-18 Proposed loss of vegetation from national parks and reserves

National park or reserve name	Direct impact (hectares)
Yaegl Nature Reserve	1.3
Broadwater National Park	17.8

4.3.6. Edge effects, noise and light impacts

Edge effects are zones of changed environmental conditions (ie altered light levels, windspeed, temperature and noise) occurring along the edges of habitat fragments. These new environmental conditions can promote the growth of different plants and altered structure (including weeds), allow invasion by pest animals specialising in edge habitats or change the behaviour of resident animals (Moenting & Morris 2006). Edge zones can be subject to higher levels of predation by introduced mammalian predators and native avian predators having a long-term impact on sensitive species.

Species with excellent dispersal abilities, capable of invading and colonizing disturbed habitats, are attracted to edges, and move into the core of natural habitat if a road or utility corridor carries the edge into a previously undisturbed area (Andrews 1990). The edge experiences a different wind and radiation effect, resulting in a different microclimate. If habitats are fragmented considerably, and the ratio of edge to interior favours edges, the habitat would no longer be suitable for the interior species (Ranney *et al.* 1981).

Edge effects have been recorded at distances greater than one kilometre from a road (Forman *et al.* 2000). However, in a review of edge effects for a diversity of habitat types, Bali (2000; 2005) estimated that on average edge effects can generally be identified up to 50 metres from the road edge.

In respect of potential impacts on edge areas from noise and light, there are two sources, firstly construction noise which is associated with vehicles and machinery such as pile drivers and gravel crushing and secondly general traffic noise and road lighting associated with road operation. Lighting from vehicles and roadside lighting would mainly be an operational issue, however, there would only be limited roadside lighting (the project being mostly unlit except for at interchange roundabouts, major bridges and merge and diverge traffic lanes). However, some out of hours construction work would be required for health/safety, and engineering reasons and would require lighting.

Negative effects of traffic noise have been recorded mainly in species that frequently vocalise, including birds and amphibians (van der Zande *et al* 1980, Reijnen *et al* 1997) and species that rely on hearing for hunting such as forest owls. Whether noise could cause road avoidance and other barrier effects in isolation from other factors such as vehicle movements, presence of humans or edge effects remains to be ascertained (Kaseloo

2006). There is some evidence to support less vocal mammal species altering normal movement pattern to avoid traffic noise (Byrnes *et al* 2012).

However, it is important to consider that no multi-species study has found all species to be sensitive. In several studies that cover a wide range of habitat types it has been shown that while some species become less common near the road, others show the opposite effect, and the importance of these (ecotonal) species may also need to be considered in evaluating the impact of roads (Ferris 1979; Adams and Geis 1981).

For example some nocturnal birds and even diurnal raptors are attracted to street lights as a source of increased prey activity, however the Masked Owl (Tyto novaehollandiae) is dependent on hearing for capturing small mammal prey at ground level.

The potential impacts from the project may be greatest of a range of threatened bird and amphibian species in terms of altering vocalisations and interrupting breeding cycles and also a range of small mammal species in terms of negatively affecting movement patterns and habitat connectivity.

The potential indirect impacts associated with edge effects for this project have been calculated using the estimate of 50 metres proposed by Bali (2000; 2005). In recognition that edge affected areas retain some value for biodiversity and are actually used by some threatened species such as Rufous Bettong, this figure is discounted by 60 per cent in the overall calculation. The indirect figure was calculated using GIS and applied where the road would create a new edge through contiguous forest and included the proposed deviations of the project and areas to be duplicated. It does not include very small isolated fragments that are already edge effected. The additional indirect impact associated with edge effects for the project would be around 431 hectares.

Edge effects would be greatest where the project deviates substantially from the existing Pacific Highway. While portions of the habitat in these sections are already fragmented and edge affected, substantial clearing and creation of a new edge would occur in Section 3 along the western foothills of the Summervale Range from Pillar Valley to Tyndale. Large sections of open forest habitat in moderate to high condition would be exposed to edge effects particularly on the eastern edge of the highway. This includes habitat for the endangered Sandstone Rough-barked Apple (*Angophora robur*) and a range of threatened fauna species that are susceptible to edge effects including Squirrel Glider, Brush-tailed Phascogale, Grey-headed Flying-fox, Powerful Owl and Australasian Bittern. Other species found in this area, such as Little Bentwing-bat, Whiptail Wallaby and Rufous Bettong are more tolerant of modified habitats and edge impacts.

New edge areas would be created by the clearing of a corridor through currently contiguous habitats immediately north of the Richmond River. A number of threatened fauna species have been identified in this locality including Koalas.

The effects of creating a new edge through currently contiguous forests on Section 3, 9 and 10 would increase the risk of predation for resident fauna including threatened species, and potentially a reduction in the health of important habitat trees and hollow-bearing trees as an indirect result. The detailed design is to consider the impacts of light shinning in adjacent forest areas and minimise this where possible.

4.3.7. Impacts to groundwater dependent ecosystems

There are several vegetation communities impacted by the project which are considered to be groundwater dependent ecosystems (GDEs). These comprise vegetation occurring on waterways and floodplains which are likely to be reliant on groundwater particularly during drier drought periods. In the study area, there are five vegetation communities and habitats that have been identified as being potentially affected by impacts to groundwater, and the area of each of these in the project boundary comprises:

- Around 13 hectares of freshwater wetlands
- Around 137.1 hectares of sub-tropical coastal floodplain forest
- Around 93.7 hectares of swamp sclerophyll forest
- Around 56.2 hectares of swamp oak floodplain forest
- Around 10.3 hectares of lowland rainforest.

At some locations these communities are in part supported by shallow, groundwater systems that effectively arrest the infiltration of surface waters. These systems are thus surface water reliant with the shallow groundwater acting as a local storage that reduces effective evaporation and sustains each species. Elsewhere groundwater is sourced from further afield and is brought to the surface due to impediment to flow or via a topographic low. These groundwater dependent systems therefore occur in many valleys and also in coastal sand environments.

Road crossings of these GDEs can impact on the subsurface flows by blocking drainage passages and groundwater flows. Potential impacts on groundwater recharge rates from general road construction are generally greatest in areas where significant cuttings are required as they have the potential to intersect the water table and affect groundwater levels downstream.

The greatest impacts to GDEs are likely to occur within freshwater wetlands located in low lying floodplain areas which are intersected or near the project including the Upper Coldstream Wetland (Section 3), Clarence River Estuary (Section 5), Bundjalung National Park Wetlands (Section 6) and the wetland cluster on Tabbimoble Creek (Section 6). These wetlands have already been identified as under pressure from changed hydrological conditions, exotic weeds and grazing. Oxleyan Pygmy Perch habitat is unlikely within these identified wetlands, however significant impacts to Oxleyan Pygmy Perch would be likely should significant changes to the water table height occur in other wetland habitats where Oxleyan Pygmy Perch is likely to occur such as Redbank and Cassons Creek (Section 1), Tabbimoble Swamp Nature Reserve (Section 7) and Macdonalds Creek (Section 8).

As Oxleyan Pygmy Perch are associated with swamps, streams and dune lakes that lie in the coastal lowland ‘wallum’ ecosystems with little or no flow, significant changes to the water table height in these ecosystems would result in a reduction in suitable habitat for the Oxleyan Pygmy Perch.

The construction and operation of the project may also impact water quality and/or require clearing of wetland and GDE vegetation communities which in turn may impact upon the GDE’s detailed above. Section 4.3.7 provides further detail of potential water quality impacts associated with the project, while Section 4.3.1 details potential impacts upon vegetation communities.

4.3.8. Impacts to aquatic ecosystems

The construction and operation of the project has the potential to impact aquatic ecosystems due to changes in hydrological and flooding conditions, changes in water quality, habitat loss and instream barriers.

Waterways modified by the project

A total of 344 water crossing structures (bridges, culverts and pipes) would be constructed across the project. The large majority of these (68 per cent) would be constructed across shallow ephemeral drainage lines consisting of a class 3 or class 4 waterway. The remaining structures would be built across 20 class 1 waterways (10 per cent) and seventy-four class 2 waterways (22 per cent). Given the large number of waterways potentially impacted by the project and the large variation in condition, the impact assessment has focused on high risk areas and key watercourses and tributaries.

High risk areas were deemed regions with a high number of sensitive receiving environments within a single region as well as where there would be severe implications from changes in surface water quality to the receiving environment. A sensitive receiving environment is one that has a high conservation value, or supports human uses of water that are particularly sensitive to degraded water quality (NSW Department of Environment and Climate Change, 2008). In the context of this project, sensitive receiving environments are considered to be:

- Nationally Important Wetlands and State Environmental Planning Policy No 14 (SEPP) wetlands as shown in Section 3.7
- National parks, marine parks, nature reserves and state conservations areas as shown in Section 3.7
- Watercourses with known and potential habitats for threatened fish, including the Oxleyan Pygmy Perch, Eastern Freshwater Cod and the Purple Spotted Gudgeon as shown in Table 3-9
- Class 1 & 2 Waterways, and key fish habitats as identified by the NSW Department of Industry and Investment (NSW Fisheries)
- Recreational swimming areas
- Areas that contribute to drinking water catchments, such as the Rous Water supply catchment
- Areas that are available & or used for aquaculture and commercial fishing as identified in the Land Use Working Paper (RMS, 2012)

Along the length of the project there are numerous areas that are defined as sensitive receiving environments. Where a number of sensitive receiving environments are located in a single region and or where there would be severe implications of changes in surface water quality to the receiving environment, the region has been defined as a high risk area:

- Solitary Islands Marine Park catchment (project section 1). This includes Arrawarra Gully, Corindi River, Blackadder Gully, Cassons Creek, Redbank Creek (including an unnamed tributary) and Dirty Creek
- Upper Coldstream River and associated wetlands (project section 3). This includes the Coldstream River, Pillar Valley Creek, Chaffin Creek, Champions Creek and unnamed tributaries of Glenugie, Pillar Valley and Chaffin creeks
- Broadwater National Park and associated wetlands (project section 8 and 9). This includes Macdonalds Creek and an unnamed tributary of the creek.
- Wardell Heathland (project section 10). Key waterways include Saltwater Creek, Randals Creek and a number of unnamed tributaries of Bingal Creek
- Known and potential areas of threatened fish and/or habitat (various sections). In addition to those waterways listed above, this also includes Arrawarra Creek, Corindi River Floodplain and Halfway Creek in Section 1. Halfway Creek, Wells Crossing, Glenugie Creek and unnamed creeks in Section 2. The Clarence River in Section 5, Mororo Creek, Tabbimoble Creek and unnamed waterbodies in section 6. In section 7, waterways include Tabbimoble Floodway no.1, Nortons Gully, Oaky Creek, and unnamed waterways at station 124.5, 121.7 to 114.0 and at the Pacific Highway near New Italy, Whites Road and Nortons Road. Waterways in section 8 include Tuckombil Canal and Rocky Mouth Creek and section 9, Montis Gully and Eversons Creek. Tuckean Swamp, Tuckean Broadwater and the Richmond River are key waterways in Section 10.

Section 5 of the Water Quality Working Paper identifies specific water quality impacts and mitigation measures for these ‘high risk areas’.

Construction and operation of both permanent waterway crossings (such as bridges and culverts), as well as temporary waterway crossings (such as causeways, fords) are known to have significant impacts upon passage of fish. Short term impacts include localised disturbance to riparian and instream habitats such as increased sedimentation and shading. Long term impacts include the impediment of fish movements within their natural range, habitat changes or pollution. Oxleyan Pygmy Perch are thought to use flood events (emanating from the Richmond and Clarence rivers) to facilitate dispersal, thereby allowing the species to colonise new systems and/or recolonise previously disturbed areas (Knight *et al* 2009).

Waterway crossings have the potential to inhibit the natural flow of floodwaters, impacting the ability of the Oxleyan Pygmy Perch to recolonise areas. Culverts can change the natural flooding conditions by restricting flow resulting in changes to flood levels and velocities, which can increase scouring and impact bed and bank stability.

Construction activity around watercourses has potential to result in temporary changes to flow and loss of aquatic habitat associated with the removal of woody snags, changes to instream substrate and loss of aquatic plants (macrophytes). Inappropriate design or type of water crossing can impede or prevent fish from travelling within their natural range. Furthermore, barriers to fish passage can prevent breeding or re-population of waterways through restricting access of fish to spawning grounds (Fairfull & Witheridge 2003). Several freshwater fish species observed within the study area have life histories, which involve life stages within estuarine and marine environments such as the Long-finned Eel (*Anguilla reinhardtii*), Empire Gudgeon (*Hypseleotris compressa*) and the Striped Gudgeon (*Gobiomorphus australis*).

Permanent water crossing structures from the concept design have been designed to minimise the changes to existing flood behaviour as a result of the project. The design took into consideration the class of waterways, in particular Class 1 waterways as potential habitat for threatened fish ((Fairfull & Witheridge 2003). The connectivity design principles presented in Appendix A state that all Class 1 waterways should be designed as bridges. Due to the dispersal methods and habitat preferences of the Oxleyan Pygmy Perch unnamed ephemeral drainage lines with uncertain Oxleyan Pygmy Perch habitat, were conservatively classified as Class 2 (rather than Class 3 and 4) (refer to Table 4-19). The crossing methods of these watercourses will be further addressed during the detailed design following greater Oxleyan Pygmy Perch survey data and water quality data within these systems. Detailed design of bridges and culverts would ensure that barriers to fish are not created, including the design of bridges to avoid where feasible placement of piers within the waterways.

Construction of the waterway crossings would also result in temporary localised disturbance and potential loss of riparian habitat. This could occur either at the crossing location, or in locations where the road runs closely parallel to the riparian habitats include the zone of land immediately adjacent to creeks or river. Large scale clearing of vegetation could result in erosion and sedimentation, which means more sediment, nutrients, salt, pesticides and other toxicants are transported into rivers and streams deteriorating water quality. Increased sediments in the water increase turbidity and reduce clarity (and light penetration) which restricts photosynthesis of aquatic plants. Sediments in water also absorb heat, therefore increasing water temperatures which can reduce dissolved oxygen as warmer water holds less oxygen than cold water. Increased nutrient loads of nitrogen and phosphorus which are bound to sediments entering the water can result in eutrophication and the occurrence of algal blooms.

The installation of temporary and permanent crossings if not managed appropriately could result in spills of concrete slurry and alkaline discharge from concrete works. This discharge of high pH waters can impact on Oxleyan Pygmy Perch by changing the pH of the receiving waterways outside the specific pH range that Oxleyan Pygmy Perch need for survival.

Table 4-19 Waterways and the location of threatened species

Project section	Waterway	Waterway classification (Fairfull and Witheridge 2003)	Oxleyan Pygmy Perch Mitigation Measures	Comment
1	Arrawarra Gully	Class 3 or 4		
	Corindi River	Class 1	✓	
	Corindi River Floodplain	Class 3 or 4		
	Cassons Creek	Class 1	✓	Oxleyan Pygmy Perch Habitat (NSW DPI), Potential habitat may be present for Purple Spotted Gudgeon.
	Redbank Creek & associated tributaries	Class 1	✓	Oxleyan Pygmy Perch Habitat (NSW DPI) Potential habitat may be present for Purple Spotted Gudgeon.
	Dirty Creek	Class 3 or 4		
	Dundoo Creek	Class 3 or 4		
	Halfway Creek	Class 2		
2	Halfway Creek	Class 1		
	Wells Crossing	Class 1		
3	Pheasant Creek	Class 3 or 4		
	Unnamed tributary of Glenugie Creek (near Station 39700)	Class 3 or 4		
	Coldstream River	Class 1		Freshwater Catfish and Olive Perchlet recorded (not listed but considered ecologically significant). Potential threatened species habitat
	Black Snake Creek	Class 1		
	Pillar Valley Creek	Class 1		Potential threatened species habitat
	Unnamed tributary of Pillar Valley Creek (near station 48000)	Class 3 or 4		
	Chaffin Creek	Class 1		
	Unnamed tributary of Chaffin Creek (near station 54600)	Class 3 or 4		
	Champions Creek	Class 2		
	Edwards Creek (near station 80.2)	Class 3 or 4		
	Shark Creek	Class 1		
	Unnamed tributary of James Creek (near station 84400)	Class 3 or 4		
	Clarence River	Class 1		

Project section	Waterway	Waterway classification (Fairfull and Witheridge 2003)	Oxleyan Pygmy Perch Mitigation Measures	Comment
	Serpentine Channel	Class 1		
	North Arm (Clarence River)	Class 1		
	Mororo Creek (near station 95100)	Class 3 or 4		
6	Mororo Creek (near station 96700)	Class 3 or 4		
	Tabbimoble Creek	Class 1	✓	Potential Oxleyan Pygmy Perch habitat present within Tabbimoble Swamp Nature Reserve upstream (NSW DPI). Potential habitat may be present for Purple-spotted Gudgeon.
7	Tabbimoble floodway no. 1	Class 2	✓	
	Unknown Creek in Tabbimoble State Forest (station 114.0)	Class 1	✓	Oxleyan Pygmy Perch recorded during targeted surveys Potential habitat may be present for Purple-spotted Gudgeon.
	Unnamed drainage lines near station 124500	Class 2	✓	
	Unnamed drainage lines between stations121700 - 122250	Class 2	✓	
	Nortons Gully	Class 2	✓	
	Oaky Creek	Class 2	✓	
8	Tuckombil Canal (becomes Evans River)	Class 1	✓	
	Unnamed Watercourse (Station 134.700)	Class 1	✓	Oxleyan Pygmy Perch recorded during targeted surveys. Potential habitat may be present for Purple-spotted Gudgeon.
	Unnamed tributary of Macdonalds Creek 136450	Class 2	✓	
	Macdonalds Creek	Class 1	✓	Oxleyan Pygmy Perch recorded during targeted surveys. Potential habitat may be present for Purple Spotted Gudgeon.
9	Montis Gully	Class 2	✓	Potential Oxleyan Pygmy Perch Habitat upstream within Broadwater National Park (NSW DPI).

Project section	Waterway	Waterway classification (Fairfull and Witheridge 2003)	Oxleyan Pygmy Perch Mitigation Measures	Comment
	Unnamed tributary of Montis Gully	Class 2	✓	Potential Oxleyan Pygmy Perch Habitat upstream within Broadwater National Park (NSW DPI).
	Eversons Creek	Class 2	✓	
10	Tuckean Swamp (upstream of Richmond River)	Class 3 or 4		
	Tuckean Broadwater (upstream of Richmond River)	Class 3 or 4		
	Richmond River	Class 1		
	Unnamed tributaries of Bingal Creek (at STNs 149.2, 150.6 and 153.9)	Class 3 or 4		
	Saltwater Creek	Class 3 or 4		
	Randals Creek	Class 2		
11	Duck Creek	Class 1		
	Emigrant Creek	Class 1		

Construction works undertaken within 50 metres of Class 1 waterways has the potential to impact on bank stability and water quality through excavation, clearing or placement of construction stockpiles. Potential impacts associated with construction works include loss of suitable bank habitat, loss of in-stream shading and increased sedimentation of the watercourses through surface runoff.

During the construction of the project, temporary crossing of waterways may be created to access the site. At the concept design level there is no specific information on the waterway name or type that would require construction of a temporary crossing. Potential impacts from temporary waterway crossings include:

- Habitat damaged by removal of riparian and instream vegetation as well as disturbance to the bed and bank of the waterway
- Creation of barriers to fish movements
- Bed and bank erosion
- Pollution from erosion and sedimentation.

Measures to mitigate the potential impacts on waterways from construction activities including the construction of temporary crossings are included in Chapter 5.

Water quality

The construction and operation of the project has the potential to impact on water quality. The main impact to water quality during construction comes from stockpiling of earthworks, and actual construction works such as cut and fill.

Stockpiling of earthworks causes a risk to downstream water quality during wet weather if not managed appropriately. Whilst there are numerous locations for stockpile sites (as documented in the Working Paper - Water Quality), those located near a waterway are those most likely to impact on water quality. These locations are:

- Section 1 (station 3.3-3.4) – stockpile near the Corindi River
- Section 2 (station 19.1-19.8) – stockpile near Halfway Creek
- Section 3 (station 45.6-46.0) – stockpile near Pillar Valley Creek
- Section 4 (station 79.5-80.0) – stockpile near South Arm
- Section 5 (station 86.0) – stockpile near James Creek.

Potential impacts include increased turbidity and nutrients in waterway as a result of sediments from earthworks stockpiles being washed into waterways. Stockpiles of vegetation from cutting of trees and shrubs may result in tannins leaching into the waterways and increased organics. This can increase stream Biological Oxygen Demand (BOD) and decrease dissolved oxygen which can affect aquatic life.

Construction of the project would require significant areas of cut and fill which result in large batter areas that can impact water quality. Section 5, 8, 9 and 10 were identified in the Working Paper - Water Quality as having large batter areas in proportion to catchment area and therefore have the greatest risk to impact water quality. These sections contain a number of waterways and SEPP14 wetlands as documented in Section 3.10. The potential impacts to water quality of the watercourse and SEPP14 wetlands include sedimentation, contamination and nitrification.

Increased pollutant load in road runoff is the main impact to water quality associated with the operation of the project. Pollutants in road runoff include nutrients, heavy metals, pesticides, herbicides and hydrocarbons which can impact negatively on the aquatic environment. To minimise the impact of runoff during the operation, runoff from the project would be directed to detention basins before being discharged to drains and then local waterways. Basins would also be located adjacent to wetlands and watercourses to protect waterways from unexpected spills. Ensuring water quality is maintained during construction would help to prevent any increase in the numbers of the aquatic pest species Plague Minnow (*Gambusia holbrooki*) which thrive in disturbed aquatic habitats.

Increased sedimentation can reduce the availability of water refuge areas for aquatic biota and smother important habitat features such as beds of aquatic macrophytes and the substrate itself. Increased turbidity can also result in a reduction of light penetration and in turn reduce the number of aquatic macrophytes or algae, altering the existing aquatic habitat.

It is also possible that nutrients or contaminants present in undisturbed sediments could be released through earthworks or surface run-off. Acid sulfate soils are known to occur within the region, and once disturbed, have the potential to enter water bodies, resulting in habitat degradation, fish disease or kills, losses in food resources, lowered potential for fish migration and recruitment, disturbance to water plant communities and secondary effects on water quality (Stone *et al.* 1998). High nutrient levels could lead to potentially toxic algal blooms resulting in negative impacts to aquatic fauna.

Poor water quality is already known to occur throughout the sections of the study area including black water events within Coldstream River (Section 3) which has resulted in fish kills. Black water events can occur naturally due to the breakdown of large quantities of organic material and can result in low dissolved oxygen levels which can cause stress and eventual death of fish. Anecdotal evidence suggests poor water quality also occurs in Section 4 and 5 due to the use of floodgates and 'cane drains'. Drains and flood gate systems can accumulate acid (from surrounding acid sulfate soils) and other poor water quality conditions which can be flushed into downstream environments after rain. This water quality can have very high acidity, toxic metals and low dissolved oxygen levels. Continued water quality monitoring is important to determine baseline conditions and ensure that the project does not exacerbate existing poor water quality during construction and operation.

Impacts are expected to be minimal due to implementation of measures such as ensuring appropriate design of water storage areas and temporary drainage systems, controlling runoff from construction areas, and the implementation of routine water quality monitoring.

Hydrological conditions

Changes to hydrological conditions can be temporary or long term and may include temporary diversion of waterways, barriers that impede flow and changes to flow velocities. These changes to hydrological conditions can impact both the groundwater and surface water. Changes in hydraulic flow as a result of culverts and bridges (such as flow velocities and levels) can result in barriers to aquatic fauna movements and changes to aquatic habitat including a gradual decrease in water depth and increased sediment and turbidity leading to change in the suitability of the habitat for fish and stream-dwelling frogs.

There are a number of freshwater and estuarine watercourses in the study area that contain permanent or near permanent flows, and as such as support a variety of fish and macroinvertebrate families. Changes to water quality, aquatic habitat and natural flow regimes due to the project can favour aquatic pest species, which can then predate on native species such as Plague Minnow (*Gambusia holbrooki*). This fish species is a significant predator on native fish and tadpoles. Plague Minnow had the greatest abundance in the study area of all fish species, and was recorded in across the total length of the project. The species proliferate in disturbed aquatic habitats and can out-compete and predate upon native species less tolerant of disturbed environments and poor water quality.

Threatened species Oxleyan Pygmy Perch and Purple-spotted Gudgeon have a narrow set of habitat requirements including a habitat preference for low flows between 0-0.3m/s (Knight 2000) however floods or other high flow events are also thought to play an important role for the species, as temporary watercourses of overflows are thought to carry the species between otherwise isolated bodies of water, although the safe limits for Oxleyan Pygmy Perch during flood times is not known.As such an assessment of the impacts to species movements due to increased flow velocities is difficult.

The Working Paper- Hydrology and Flooding discusses specifically the impacts to hydrological response and flood behaviour and mitigation measures associated with the project, particularly with respect to Oxleyan Pygmy Perch. It documents the existing peak velocity and the proposed peak velocity through structures with the project for waterways with known or potential Oxleyan Pygmy Perch habitat. Generally peak velocities remain similar to existing peak velocities, and where increases have been estimated, they are not considered great enough to impact.

Removal of woody debris

The removal of large woody debris or snags is listed under Schedule 6 of the FM Act as a key threatening process. Woody debris plays an important role in freshwater and marine ecosystems by providing essential habitat for aquatic organisms, providing a refuge from predation and a resting place away from the main flow of the waterway and providing important refuge and breeding habitat for fish including threatened species. Woody debris also provides habitat for a number of plants, algae, microorganisms and invertebrates. Tree trunks and fallen branches are also structurally important for stabilising stream beds and banks.

Woody debris is a significant component of aquatic habitat throughout all waterways crossed by the project and while not quantified, was found in the majority of waterways. Construction of the project may reduce the presence and availability of woody debris and snags if not managed appropriately.

Instream barriers

Migration of fish species occurs as part of their life cycle and day to day movements occur as part of their foraging activities. These movement patterns can be impacted on by the presence of instream barriers, either physical or hydraulic. Inappropriate design of both temporary (during construction) and permanent (operation) in-stream structures and/or construction procedures may contribute to the creation or exacerbation of in-stream barriers to aquatic fauna passage. Such barriers could prevent the dispersal of Oxleyan Pygmy Perch if appropriate waterway crossings are not implemented.

During construction of the project, it will be necessary to install and construct culverts at creek crossings. Therefore, temporary works within the stream channels would be required including construction of temporary waterway crossings (or partial crossings) to provide access for construction works (eg machinery). These works would involve placement of construction material across waterways which have the potential to restrict aquatic fauna movement patterns. Instream works could result in the isolation of pools, trapping fish, which are then susceptible to drying or poor water quality.

Inappropriate design of bridges and culverts can present physical, hydraulic and behavioural barriers to aquatic fauna movements. Permanent in-stream barriers created by the project can lead to aquatic habitat separation and fragmentation. This could results in a loss of connectivity and viability of aquatic fauna assemblages.

Impacts to fish communities and threatened fish

The potential aquatic habitat and water quality impacts detailed in the section above have the potential to impact upon aquatic ecosystems, particularly fish. Throughout the study area there are 32 fish and decapods species and the potential for three threatened species (Oxleyan Pygmy Perch, Purple-spotted Gudgeon, and Eastern (Freshwater) Cod. While impacts detailed above are relevant to all fish species, the discussion below is focussed upon threatened fish species that occur or have potential to occur within the study area (Oxleyan Pygmy Perch, Purple-spotted Gudgeon & Eastern Freshwater Cod). Assessments of significance have been undertaken for each of these species, and these are provided in Appendix E.

The presence of known and potential habitat for the Oxleyan Pygmy Perch was identified in Section 1 (Cassons Creek and Redbank Creek), unnamed creeks in the area from Devils Pulpit State Forest to Tabbimoble Swamp Nature Reserve (Section 7), and between Woodburn and Broadwater (Section 9) including MacDonalds Creek and Broadwater National Park.

The potential impacts from the project on threatened fish subject species is discussed in Table 4-20. Where there is insufficient information on the size and extent of the population in order to make an informed decision regarding the significance of the impact, the degree of impact is based on the precautionary principle. There is potential to minimise the likely impacts discussed through appropriate and targeted mitigation and management actions during construction and operation and this is discussed in Chapter 5.

Table 4-20 Likely impacts on threatened fish subject species

Project section	Species	Aspects of species ecology of particular relevance to the project	Likely impacts
Sections 1, 2, 6 to 9	Oxleyan Pygmy Perch	Prefers slow-moving or still waters with dense aquatic vegetation (eg sedges) or undercut, root-filled banks. Many areas of habitat have already been lost or are threatened by coastal development and critical areas of habitat have been listed in a preliminary determination by DII. The species is restricted to aquatic habitats with suitable physicochemical water quality conditions, specifically acidic waters (pH 4.4-6.8) with low conductivity (90 to 830µS/cm).	The project would result in changes to potential aquatic habitat within the study area. Potential impacts may result from changes to the water quality parameters preferred by this species or by creating temporary or permanent barriers to movement and dispersal, particularly in Sections 6-9.
Sections 1, 2, 6 to 8	Purple-spotted Gudgeon	The Purple Spotted Gudgeon are often found in slow moving or still waters of rivers, creeks and billabongs, often amongst weeds, rocks or large woody debris. The species is restricted to aquatic habitats with suitable physicochemical water quality conditions, specifically waters with a pH ranging from 5.6 to 8.8, conductivity of 72 to 4,295µS/cm, dissolved oxygen between 0.6 and 12.8mg/L and low turbidity.	Construction of the project would result in short term impacts on immediate downstream reaches. Potential impacts may result from changes to the water quality parameters preferred by this species or by creating temporary or permanent barriers to movements and dispersal
Section 3	Eastern Freshwater Cod	They are generally associated with areas that have plenty of boulders or large woody debris (snags) and intact riparian vegetation. Potential habitat was observed in the middle section of Coldstream River, Chaffin Creek and Pillar Valley Creek.	Construction of the project would result in short term impacts on immediate downstream reaches associated with potential sediment input during high rainfall events. Potential habitat identified in Section 3

The Oxleyan Pygmy Perch is known to occur within the study area, and suitable habitat was also identified for the Purple-spotted Gudgeon. Potential habitat for both of these species was identified in sections 1 and 2 associated with Redbank Creek and Cassons Creek, within Section 6 around Tabbimoble, and in sections 7 and 8 from Devils Pulpit State Forest to McDonalds Creek south of Woodburn.

Both species have similar and specific habitat requirements described as:

- Depth: less than 1.5 metre
- Flow:-Habitat preference for low flows between 0-0.3m/s however floods or other high flow events may also play an important role for the species, as temporary watercourses of overflows carry the species between otherwise isolated bodies of water
- Substrate: Fine sand and detritus
- Other features: Steep/undercut banks with aquatic vegetation, overhanging and trailing vegetation and submerged leaf litter branches
- Physical parameters: pH 4.5 and 6.5 for Oxleyan Pygmy Perch and 5 and 8 for Purple-spotted Gudgeon, conductivity less than 350µS/cm, dissolved oxygen greater than 2mg/L, low turbidity (tannin stained)
- Riparian and overhanging plant species: *Melaleuca quinquenervia, Banksia ericifolia, Restio tetraphyllus, Gleichenia dicarpa, Gahnia sieberiana* and *Leucopogon lanceolatus*
- Aquatic plant species: *Baumea articulata, Sphagnum falcatulum, Philydrum lanuginosum, Lepironia articulata and Restio pallens*.

Similarly, both species are sensitive to any changes in these water conditions and the associated habitat. There is potential for a change at known and potential sites during both the construction and operational phases of the project. In particular, any increase in total suspended solids, reduction in dissolved oxygen and/or change in pH beyond the tolerance limits of Oxleyan Pygmy Perch is considered to represent an unacceptable change.

Other impacts on potential habitat may be associated with loss of instream and riparian habitat, modified flow regimes and increased abundance of the noxious fish species Plague Minnow. Mitigation measures have been designed to minimise the potential for the project to impact on these species (refer to Section 5).

4.3.9. Weeds and pests

There are currently 11 key threatening processes listed under the TSC Act and the EPBC Act that relate to the invasion and establishment of weeds and pests. Each of these has potential to be exacerbated by construction and operation of the project. They include:

- Invasion and establishment of exotic vines and scramblers
- Invasion of native plant communities by Bitou Bush & Boneseed
- Invasion of native plant communities by exotic perennial grasses
- Invasion of native plant communities by African Olive (*Olea europaea* L. subsp. *cuspidata*)
- Invasion, establishment and spread of Lantana (*Lantana camara*)
- Competition and grazing by the feral European rabbit
- Competition from feral honeybees
- Predation by feral cats
- Predation by the European Red Fox

- Predation by the Plague Minnow (*Gambusia holbrooki*)
- The biological effects including lethal toxin ingestion caused by cane toads

Weed invasion

A total of 154 weed species were recorded from field surveys along the project boundary. Of these, there were 21 declared noxious species under the NSW *Noxious Weeds Act 1993*, relevant to the four local government areas (Table 4-21). Eleven weeds of national significance (WONS) were also noted. One of these, Alligator Weed (*Alternanthera philoxeroides*), was not directly observed but has been noted to occur in Tuckombil Canal (NSW DPI; *pers comm.*).

Table 4-21 Noxious weeds and weeds of national significance

Species	Common name	WoNS	Noxious weeds*							
			CH	CV	RV	B	Section 1-2	Section 3-5	Section 6-8	Section 9-
Alternanthera philoxeroides	Alligator Weed	√	2	2	2	2			√	
Asparagus aethiopicus	Asparagus Fern	√						√	√	√
Asparagus africanus		√							√	
Asparagus plumosus	Climbing Asparagus Fern	√								√
Ageratina adenophora	Crofton Weed		4	4	4	4	√	√	√	√
Ageratina riparia	Mistflower		4	4	4	4			√	√
Ambrosia spp.	Ragweed		5	5	5	5		√		
Ambrosia artemisiifolia	Annual Ragweed		5	5	5	5	√		√	√
Baccharis halimifolia	Groundsel Bush		3	3	3	3	√	√	√	√
Chrysanthemoides monilifera subsp. *rotundata*	Bitou Bush	√	4	4	4	4	√		√	√
Senecio sp.	Fireweed		4							√
Senecio madagascariensis	Fireweed	√	4				√	√	√	√
Xanthium occidentale	Noogoora Burr		4	4	4	4		√		
Anredera cordifolia	Madeira Vine	√							√	
Bryophyllum delagoense	Mother-of-millions			3				√	√	
Bryophyllum pinnatum	Live Plant			3						√
Cinnamomum camphora	Camphor Laurel			4	4	4	√	√	√	√
Ligustrum lucidum	Large-leaf Privet		4	4	4	4			√	√
Ligustrum sinense	Small-leaf Privet		4	4	4	4		√	√	√
Sorghum halepense	Johnson Grass		4	4	4	4			√	
Sporobolus indicus	Parramatta Grass		4	4	4	4			√	
Eichhornia crassipes	Water Hyacinth	√	3	4	4	4			√	
Rubus fruticosus agg.	Blackberry	√	4	4	4	4		√		
Salvinia molesta	Salvinia	√	3	3	3	3		√		√
Lantana camara	Lantana	√	4	4	4	4	√	√	√	√

WoNS – Weeds of National Significance. CH – Coffs Harbour LGA; CV – Clarence Valley LGA; RV Richmond Valley LGA;
B – Ballina LGA. *Noxious Weeds Act 1993 – (Sect 8) weed classes 1-5

During construction there is potential to disperse weed seeds and plant material into adjoining areas of remnant vegetation where weed species do not currently occur. The most likely causes of weed dispersal would be through the movement of soil and attachment of seed (and other propagules) to construction vehicles and machinery involved with clearing of vegetation and stockpiling mulch and topsoil during earthworks. In particular, there is a potential impact of spreading aquatic weeds within the Clarence and Richmond river catchments during construction by earthmoving machinery and water storage equipment, specifically at the bypass of Woodburn over Tuckombil Canal due to the presence of Alligator Weed at this site.

Alligator Weed is a potentially devastating weed that grows in water and on land, affecting both waterways and floodplain areas. It is listed as a weed of national significance and is a major threat to wetlands, rivers and irrigation systems.

Also known from the project study area is Tropical soda apple (*Solanum viarum*). This is an aggressive, prickly, perennial shrub one to two metres high. It invades open to semi-shaded areas including pastures, forests, riparian zones, and roadsides. It reduces biodiversity by displacing native plants and disrupting ecological processes. The species was not identified from the project field surveys, however is known from the North Coast Bioregion and has potential to occur. Seed can be spread by feral animals and birds that feed on the fruit, and via water, soil and equipment. Early detection and management of weeds is discussed in Chapter 5.

Feral honey bees

Feral honey bees are introduced bees which originally escaped from hives and have subsequently established in the wild, usually centred on tree hollows. While the project would not directly increase bee numbers, the clearing of native vegetation would indirectly increase competition by native fauna with bees for pollen, nectar and nesting hollows. Olroyd *et al* (1994) in a survey of box woodland habitat found 0.7 per cent of available hollows were occupied by bees, this occupancy rate has not been quantified for coastal forest communities but could be expected to be higher, particularly in fragmented forests, due to a greater density of trees.

This impact would be exacerbated by the presence of feral bees which are also competing for hollow resources and bee populations are likely to be present on all sections of the project. The loss of tree hollows via occupation by feral honeybees reduces the number of hollows available for native animals to breed and shelter. This is of particular concern for species which are threatened and include Squirrel Glider, Yellow-bellied Glider, Brush-tailed Phascogale and several bird, reptile and frog species as highlights in Table 4-13.

Increased predation by foxes and cats

The project may contribute to increased levels of predation on native fauna from foxes and cats, due to the impact of habitat fragmentation leading to displacement of resident fauna or during juvenile dispersal between habitat patches. The cat and fox are significant predators in Australia that interact with native fauna in various ways, including predation, competition for resources, and transmission of disease. The level of impact is primarily determined by prey availability.

The extent to which roads influence the distribution and abundance of these species and the consequences of these for native fauna, are poorly known. It has been widely accepted that the construction of roads has the potential to facilitate the ingress of predators (including carnivorous mammals, birds and reptiles) into forest environments previously inaccessible to them (Andrews 1990;) or, at least, that the use of roads by feral predators for hunting and movement is commonplace since roads provide easy travelling conditions (Bennett 1991). Andrews (1990) proposed that feral animals are easily introduced into areas where there are roads, as the accompanying edge effect favours species with generalised ecological requirements. There is some evidence of foxes preying on bandicoots at purpose built fauna underpasses that were placed in disturbed habitats (Harris *et al* 2010). However, these authors consider this is less likely to be a significant impact on a larger-scale and where multiple structures are used. Roadkills are more commonplace on heavily used roads and the resulting carcasses are a potential food source for feral predators such as cats and foxes.

Generally, foxes prey upon medium-sized to small prey (eg possums and rats) and consume a significant component of scavenged material and vegetation. Cats also prey upon medium-sized to small prey, but may have a greater proportion of reptiles and birds in their diet (May and Norton 1996). The species at greatest risk to increased predation are predicted to be those within a critical weight range (CWR) of 35 to 55 grams (Burbidge and MacKenzie 1989). This includes a wide range of small to medium-sized mammals including the threatened Rufous Bettong, Long-nosed Potoroo and Common Planigale, all known from the study area.

Plague Minnow (*Gambusia holbrooki*)

As discussed previously, Plague Minnow have potential to enter stressed waterways during construction and operation all through the project. Mitigation measures that limit the disturbance to aquatic habitats and water quality, may minimise the ability for Plague Minnow to outcompete native species, however it is not possible to exclude this species from all waterways.

Rabbits

The clearing of vegetation and associated habitat fragmentation may increase the value of the habitat for rabbits around the project boundary over the long-term. As rabbits tend to colonise more disturbed and modified habitats, any increase in the population of this pest species is more likely to impact on native fauna tolerant of modified habitats. Revegetation of disturbed areas particularly formerly vegetated sites would assist in managing rabbit populations.

Cane Toads

Cane toads have potential to colonise new habitats created by the construction of sediment and water quality ponds both during construction and over the longer-term operation of the road. However these artificial structures are not unlike farm dams which are a common feature of the landscape surrounding the length of the project. It is unlikely that their presence would result in an expansion of the current range of the species, however provision of artificial structures could increase local population numbers. As native fauna could ingest the cane toad, could result in severe illness or death in native fauna. However, this is considered to be a small potential impact.

4.3.10. Spread of pathogens

Pathogens are agents that cause disease in flora and fauna and are usually living organisms such as bacterium, virus or fungus. Several pathogens known from NSW have potential to impact on biodiversity as a result their movement and infection during construction of the project (refer Table 4-22). Of these, three are listed as a key threatening process under either the EPBC Act and/or TSC Act including:

- Dieback caused by Phytophthora (EPBC Act and TSC Act)
- Infection of frogs by amphibian chytrid fungus causing the disease chytridiomycosis (EPBC Act and TSC Act)
- Introduction and establishment of exotic Rust Fungi of the order Pucciniales on plants of the family Myrtaceae (TSC Act).

The potential for pathogens to occur should be considered a high likelihood on all projects sections and treated as a potential risk during construction. This is particularly a risk for the project as all sections cross waterways or floodplain habitats where the risk of transmission is higher. Pathogen management should therefore be implemented throughout all stages of construction.

Table 4-22 Pathogens that may impact on flora and fauna during construction

Pathogen	Description	Potential disease transmission
Phytophthora (*Phytophthora cinnamomi*)	A soil-borne fungus that causes tree death (dieback). Attacks the roots of a wide range of native plant species	Spores can be dispersed over relatively large distances by surface and sub-surface water flows. Infected soil/root material may be dispersed by vehicles (eg earth moving equipment)
Myrtle rust (*Uredo rangelli*)	An introduced fungus that attacks the young leaves, short tips and stems of Myrtaceous plants eventually killing the plant	Myrtle rust is an air-borne fungus that may be spread by moving infected plant material, contaminated clothing, equipment and vehicles.
Fusariumwilt / Panama disease (*Fusarium exysporum*)	Widespread in banana plantations in north coast region including Woolgoolga and Coffs Harbour.	Spread when spores are moved in soil by water, workers, vehicles and movement of infected plant material.
Chytrid fungus (*Batrachocytrium dendrobatidis*).	An infectious disease that affects amphibians worldwide causing death.	Chytrid is a water-borne fungus that may be spread as a result of handling frogs or through cross contamination of water bodies by vehicles and workers.

4.4. Key threatening processes

Key threatening processes are listed under the TSC Act, FM Act and EPBC Act as activities or processes that:

- Adversely affect threatened species, populations or ecological communities, or
- Cause species, populations or ecological communities that are not threatened to become threatened.

Aspects of the project are consistent with a number of the listed key threatening processes, a summary of those of relevance to the project are discussed in Table 4-23.

Table 4-23 Key threatening process relevant to the project

Key threatening process	Listed Act	Type of threat	Potential level of threat	Potential impacts
Alteration to the natural flow regime of rivers and streams and their floodplains and wetlands	TSC Act	Habitat loss/change	High	The project would require extensive fill in low-lying areas which has potential to impact on natural surface and groundwater flows.
Bushrock removal	TSC Act	Habitat loss / change	Moderate	Extensive removal of surface rock in some sections is likely, such as sections 1 to 3 and 6 to 7
Clearing of native vegetation	TSC Act and EPBC Act	Habitat loss / change	Very high	The project would result in the clearing of up to 948 hectares of native vegetation
Competition and grazing by the feral European rabbit	TSC Act and EPBC Act	Pest animal	Low-Moderate	Rabbits common particularly in agricultural landscapes. The project is likely to create areas of suitable habitat during construction and operation. This in turn could lead to increased degradation of edge habitats and reduced plant cover.
The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus*)	TSC Act and EPBC Act	Pest animal	Low	Cane toad could colonise new habitats such as sedimentation basins and water quality ponds. This could result in competition and predation on native fauna and result in intoxication in native fauna that may ingest the species.
Competition from feral honey bees	TSC Act	Pest animal	Moderate	The extensive clearing of vegetation would increase competition for pollen, nectar and tree hollows. In particular when combined with the reduction in hollow-bearing trees that is expected from the project, this would place additional pressure on threatened species dependent on tree hollows.
Infection of native plants by *Phytophthora cinnamomi*	TSC Act and EPBC Act	Pathogen	Moderate	Spores can be dispersed over relatively large distances by surface and sub-surface water flows. Infected soil/root material may be dispersed by vehicles (eg earth moving equipment)
Infection of amphibians with chytrid fungus resulting in chytridiomycosis	TSC Act and EPBC Act	Pathogen	Moderate	Chytrid is a water-borne fungus that may be spread as a result of handling frogs or through cross contamination of water bodies by vehicles and workers.
Introduction and Establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae	TSC Act	Pathogen	Low	Myrtle rust is an air-borne fungus that may be spread by moving infected plant material, contaminated clothing, equipment and vehicles.
Invasion and establishment of exotic vines and scramblers	TSC Act	Weed	Moderate	The project would contribute to increased weed invasion in adjoining habitats during both construction and operation, and as result of ongoing edge effects.

Key threatening process	Listed Act	Type of threat	Potential level of threat	Potential impacts
Invasion of native plant communities by exotic perennial grasses	TSC Act	Weed	High	Several exotic perennial grasses were identified in disturbed and modified agricultural areas. These species are associated with edge effects which has been associated with the project.
Invasion, establishment and spread of *Lantana camara*	TSC Act	Weed	High	The project would contribute to increased invasion potential for lantana in adjoining habitats during both construction and operation, and as result of ongoing edge effects.
Predation by feral cats	TSC Act and EPBC Act	Pest animal	Moderate	The project may contribute to increased predation from feral cats, as a result of increased habitat fragmentation, but also potentially through construction activities such as rubbish accumulation or storage at ancillary facilities.
Predation by the European Red Fox	TSC Act and EPBC Act	Pest animal	Low-Moderate	The project may contribute to additional predation from foxes, primarily through habitat fragmentation, but also potentially through construction activities such as rubbish accumulation or storage at ancillary facilities.
Predation by the Plague Minnow (*Gambusia holbrooki*)	TSC Act	Pest animal	Low-Moderate	The project may contribute to additional predation from Plague Minnow.
Loss of hollow-bearing trees	TSC Act	Habitat loss/ change	High	The project would result in the extensive clearing of hollow-bearing trees. The density of hollow-bearing trees along the project boundary was estimated at between c. 4-7 trees per 0.1 ha plot.
Removal of dead wood and dead trees	TSC Act	Habitat loss/ change	High	The project would result in the removal of dead wood and dead trees in all sections.
Removal of large woody debris from NSW rivers and streams	FM Act	Habitat loss/ change	Moderate	The project would result in the removal of woody debris to construct creek crossings.
Degradation of native riparian vegetation along NSW watercourses	FM Act	Habitat loss/ change	Moderate	The project would require the removal of riparian vegetation to accommodate numerous creek crossing either bridges or culverts.
Increased sedimentation and erosion during construction	FM Act	Habitat loss/ change	Low	There is potential for increased sedimentation to result due to the construction process.
Instream structures and other mechanisms that alter natural flow	FM Act	Habitat loss/ change	Low	The project would result in the construction of numerous box and pipe culverts and bridges which may modify the natural flow of creeks in the study area. This alteration may disrupt natural reproductive cues and natural processes of erosion and sedimentation resulting in a loss of aquatic habitat for fish and macroinvertebrates.

4.5. Regional scale cumulative impacts

Cumulative impacts are caused by the accumulation and/or interaction of multiple stresses affecting the parts and the functions of ecosystems. For the purposes of this assessment, cumulative impacts are defined as the changes to the environment caused by an activity in combination with other past, present, and reasonably foreseeable human activities.

4.5.1. State of the environment

The spatial extent considered in the cumulative assessment for the project is based on the NSW North Coast Bioregion encompassing the local government areas of Coffs Harbour City, Clarence Valley, Richmond Valley and Ballina Shire. The following discussion provides some context to the 'baseline' condition of the region to understand the cumulative impact of the project.

The region was settled in the 1830s and 1840s firstly through clearing for timber and followed by pastoral occupation. The region's abundant natural resources were exploited from the mid twentieth century and now support a significant agricultural and fishery economy. Agricultural activities such as dairy and beef cattle grazing, and sugar cane production were enhanced with the clearing and draining of freshwater and estuarine wetlands, rainforests, heathlands and woodlands.

Tourism, urban and industrial developments have more recently developed in the region, which has experienced population growth. The combined population of the region has been most recently estimated at 172,830 people (Australian Bureau of Statistics 2006).

The project largely follows the existing Pacific Highway, with deviations around floodplain areas such as the Corindi River, Coldstream River and Shark Creek. The existing highway traverses a mix of densely native vegetated habitats through sections 1 to 3, 6 to 8 and 10. The remaining sections generally traverse cleared agricultural landscapes supporting a mosaic of fragmented remnant and regrowth vegetation.

4.5.2. Historical vegetation loss

The data in Table 4-24 below lists the per cent cleared estimate for each Mitchell Landscape type in the Northern Rivers CMA area. To obtain these estimates, the NSW Landscapes coverage (Mitchell 2003) was intersected with a presence/absence layer of native vegetation in NSW.

Table 4-24 Mitchell Landscapes with historical per cent cleared estimates for the Northern Rivers CMA region

Project section	Mitchell (2003) ecosystems	Landscape characteristics (geomorphic, pedologic and vegetation)	Historical percentage cleared*
Section 1	Coastal barriers	Manning-Macleay Beaches and Barriers.	35%
	Manning-Macleay	Manning-Macleay Coastal Alluvial Plain:	64%
		Brooms Head-Kempsey Coastal Ramp:	31%
Sections 2-3	Clarence Basin	Grafton-Whiporie Basin:	35%
Section 3		Summervale Range:	12%
Sections 3-8, Sections 10-11		Clarence-Richmond Alluvial Plains:	75%
Sections 6-7		Ballina Coastal Ramp:	13%
Sections 8-9	Coastal Barriers	Clarence-Richmond Barriers and Beaches: Beaches,	39%

The majority of the vegetation clearing in the Northern Rivers CMA region has historically occurred in the fertile Clarence-Richmond alluvial plains landscape (75 per cent) from which significant parts of the project would traverse (ie sections 2 to 8, 10 and 11). These sections of the project also traverse other landscape ecosystems and are not restricted to the alluvial plains.

Data from the overcleared vegetation types database (DECC 2010a) was reviewed for assessing vegetation clearing as part of the project, specifically relating to the proposed clearing of threatened ecological communities. Portions of the following six threatened ecological communities would be cleared by the project as discussed previously resulting a total loss of 337.7 hectares. The estimate of the historical clearing of these vegetation types from the known former distribution is shown in Table 4-27. In some instances, this includes the total distribution and includes other regions such as Sydney Basin and NSW South Coast in addition to the NSW North Coast Bioregion.

Table 4-25 Estimates historical clearing of threatened ecological communities relevant to the project

Threatened ecological community	Estimated historically cleared
Sub-Tropical Coastal Floodplain Forest of the NSW North Coast Bioregion	40-70%
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions	75%
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions	75%
Coastal Cypress Pine Forest in the NSW North Coast Bioregion	40%
Freshwater Wetlands On Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions	40-80%
Lowland Rainforest in NSW North Coast and Sydney Basin Bioregions	97% (Floyd 1990)

4.5.3. Past and future activities

Pacific Highway Upgrade Program

The contribution made by the project to the potential long-term cumulative impacts to biodiversity in the region has been assessed by considering the extent of native vegetation clearing associated with the projects that make up the entire Pacific Highway Upgrade Program (PHUP). This includes the 11 sections from Woolgoolga to Ballina project and includes the cumulative loss of threatened ecological communities (Table 4-26).

The total clearing of native vegetation approved for all Pacific Highway upgrades from the F3 Freeway near Hexham to the Queensland border is estimated to be around 1267 hectares. The project would see an additional 948 hectares cleared and increase the total clearing for the Pacific Highway upgrade to 2615 hectares. This total includes 621.7 hectares of listed threatened ecological communities to date. In addition to direct clearing of vegetation and fauna habitat, the cumulative impacts on biodiversity from the long-term upgrade of the highway is responsible for increased fragmentation of habitats and potential loss of connectivity, edge effects and weed invasion, loss of threatened flora and fauna and potentially increased predation of native fauna by introduced species, as discussed. The project would contribute to about 36 per cent of the vegetation clearing across the whole Pacific Highway Upgrade Program.

Table 4-26: Extent of native vegetation clearing associated with the PHUP

Project	Direct native vegetation clearing (hectares)	Threatened ecological community clearing (hectares)
Projects completed		
Raymond Terrace bypass duplication	5	2
Raymond Terrace to Karuah	37	4
Karuah Bypass	36	3
Karuah to Bulahdelah	123	9
Bulahdelah to Coolongolook	106	8
Wang Wauk to Bundacree	10	0
Bundacree Creek to Possum Brush	4	1
Coopernook Bypass	2	1
Coopernook to Moorland	8	3
Moorland to Herons Creek	64	5
Bonville Bypass	56	0
Lyons to England Road	2	1
Halfway Creek	12	0
Tandy's Lane Upgrade	1	1
Brunswick Head Bypass	7	5
Brunswick to Yelgun	49	8
Yelgun to Chinderah	30	12
Glenugie Upgrade	65	5

Project	Direct native vegetation clearing (hectares)	Threatened ecological community clearing (hectares)
Ballina Bypass	11	9
Banora Point Upgrade	8	4
Sub-total	*636 hectares*	*81 hectares*
Projects recently approved or currently under construction		
Bulahdelah Bypass	33	3
Kempsey to Eungai	286	63
Sapphire to Woolgoolga Upgrade	120	27
Tintenbar to Ewingsdale	10	2
Devils Pulpit Upgrade	54	12
Oxley Highway to Kempsey	203	36
Warrell Creek to Urunga	255	60
Sub-total	*961 hectares*	*203 hectares*
Projects in the planning phase		
F3 to Raymond Terrace	49	Assessment not completed
Coffs Harbour Bypass	21	Assessment not completed
Woolgoolga to Ballina	948	337.7
Sub-total	*1 018 hectares*	*337.7 hectares*
Total Pacific Highway Upgrade Program	**2615 hectares**	**621.7 hectares**

Regional development projects

The cumulative regional impacts to biodiversity in region between Woolgoolga and Ballina were further assessed by identifying the expected loss of vegetation and threatened ecological communities associated with other proposed and approved projects in each of the LGAs relevant to the project (Table 4-27). These data have been obtained from the NSW Department of Planning and Infrastructure website, accessed February 2012.

Table 4-27 Extent of native vegetation disturbance from projects within the study area

Project	Location	Status	Biodiversity impact*
Coffs Harbour local government area			
Coffs Harbour Base Hospital Site Redevelopment	Victoria Street, Coffs Harbour (east of study area)	DGRs issued	The site is the former location of the Coffs Harbour Base Hospital and accordingly the land is highly modified. Established trees on site would be retained. Other trees on site are generally in poor health and many are weed species. There is very limited ecological value in the site in its current state.
Moonee Beach, Pacific Hwy: Residential subdivision into 35 lots	Lot 211 Pacific Highway Moonee	Assessment	The proposed development would remove 2.5 hectares of native vegetation and disturb remaining biodiversity with potential weed invasion, increased fire risk, and increased soil erosion. Loss of habitat would affect fauna food trees and future hollows and increase wildlife road fatalities.
Alterations and additions to roads and infrastructure of existing Caravan Park	8 Hearns Lake Road , Woolgoolga	Assessment	The extension of caravan park would remove 1.3 hectares of disturbed Dry Blackbutt Open Forest. Seven threatened species have been recorded within and surrounding the site. The project is considered to have no direct adverse impacts on wildlife.
Residential subdivision into 280 lots, Sandy Beach	Pacific Highway, Sandy Beach 13 kilometres South of Woolgoolga	Approved - 20/12/2010	The project would result in the removal or modification of about 27.8 hectares of vegetation and habitats and retention, protection and restoration of about 20.7 hectares of vegetation.
Sandy Beach Mill - Section 2 Residential Subdivision	234 Graham Drive, Sandy Beach: south of Woolgoolga	Approved – 30/09/2010	A number of threatened species are known from the vicinity of the site. However, no threatened species or threatened species habitat is likely to be impacted by this project as it is wholly located on decontaminated mill land which is either lacking in vegetation or supports exotic grasses.
Woolgoolga Residential subdivision into 43 lots	45 Hearnes Lake Road, Woolgoolga	Approved – 15/12/2009	Removal of native vegetation and fauna habitats of up to 5.4 hectares.

Project	Location	Status	Biodiversity impact*
Glades Estate, Moonee Beach residential subdivision in to 524 lots	Glades estate, Pacific Highway, Moonee Beach	Approved - 05/03/2009	In total 53.8 hectares of vegetation would be cleared, the majority of which is grasslands with scattered trees. There would also be an additional loss of around 4.4 hectares of slashed heath and a minor loss of around 0.4 hectares of Swamp Sclerophyll Forest (TEC) from the site. The proposed development would result in some loss of foraging, sheltering and breeding habitat for native fauna occurring in the locality. This includes the loss of hollow-bearing trees, primary koala feed trees and increased habitat fragmentation and disturbance.
Coffs Harbour Multi unit housing	111 Ocean Parade , Coffs Harbour	Approved – 28/02/2007	The site consists of around 400m² of native vegetation of which 70% is cleared to accommodate the project. The vegetation on the site may form part of the foraging area occasionally visited by threatened micro-bats including the threatened Eastern Bent-wing Bat and individual plants on the site may occasionally be visited by threatened fruit eating birds and Grey-headed Flying-fox.
Clarence Valley local government area			
Yamba Welding and Engineering project	School Road Yamba	DGRs issued	No information on vegetation removal/fauna impact in project application report available.
Kungala Quarry project	690 Kungala Road, Kungala	DGRs	No information on vegetation removal/fauna impact in project application report available.
Cabin and camping facilities – tourist park, Wooli	Tourist Park, Wooli , 379 North Street, Wooli	Approved - 12/07/2010	Flora and Fauna: About 80% of the site's vegetation has been cleared or highly modified. However, several clusters of Eucalypts provide important feeding, nesting and roosting sites for fauna. These areas are to be retained. There are no clearing estimates.
Blue Dolphin redevelopment - Tourist and Residential Development	Yamba Road, Yamba	Approved - 06/07/2007	There are 103 native plant species and three hollow-bearing trees on site which would be impacted by this development. No estimate of vegetation clearing provided.
Richmond Valley local government area			
Dumaresq Substation to Lismore 330kV Transmission Line and Associated Works	Bonshaw, Tenterfield, Casino, Lismore. Also located in the following LGAs: Inverell Kyogle Lismore Tenterfield	Proponent Reviewing Submissions	A desktop review identified 245 threatened species listed under the TSC Act that could potentially occur within the study area. The Commonwealth Protected Matters Search Tool identified one Ramsar site, five threatened ecological communities, 145 threatened species and 38 migratory species that may occur within the study area. It is likely that some clearing of native vegetation would be required however no clearing estimates provided. There is the potential for secondary impacts such as increased erosion, sedimentation or weed invasion.
Richmond Valley Power Station and Gas project	Casino to north-west of project (44 km north-west of Woodburn)	Approved 3/6/2010	The potential impacts to flora associated with the proposed project in the absence of specific mitigation measures include clearing of threatened ecological communities and clearing of potentially undetected threatened flora species.

Project	Location	Status	Biodiversity impact*
Ballina Shire local government area			
125 lot residential subdivision, Lennox Head	North Creek Road, Lennox Head 12 kilometres north of Ballina	DGRs issued	No Preliminary Environmental Assessment available.
Residential Subdivision and Village Centre (Concept Plan), Skennars Head	The Coast Road, Ballina	DGRs issued	No information in Preliminary Environmental Assessment on vegetation removal/fauna impact.
Pacific Pines Estate, Lennox Head	North Creek Road, Lennox Head 12 kilometres north of Ballina	Approved 12/11/2008	Freshwater Wetland EEC, Hairy joint grass and Square-stemmed spike rush located on the site. No information on vegetation removal/fauna impact.
Lismore to Mullumbimby Electricity Network Upgrade	Lismore-Ballina-Byron	Approved 22/07/2010	Majority of route in existing cleared easement. Likely to require clearing of vegetation although no clearing estimates provided.

4.5.4. Mitigation of cumulative impacts

The project would contribute to about 36 per cent of the vegetation clearing across the whole Pacific Highway Upgrade Program. Within this context it is important to note that the program has spanned over 15 years from planning to construction. Within this time RMS has developed and incorporated considerable knowledge through adaptive management and critical evaluation of road design, to provide effective mitigation measures and procedures to manage biodiversity impacts. This progressive knowledge has culminated in the development of numerous policies and best practice guidelines for appropriate avoidance and management of potential biodiversity impacts during construction and operation as well as a policy for offsetting impacts.

The following chapter outlines the proposed mitigation and management process that would be adopted through the life of the project to assist in managing cumulative impacts.

5. Mitigation and management

5.1. Objectives and framework

It is proposed to progress the project to detailed design and construction by staging successive upgrades, with each stage comprising one or more of the 11 project sections discussed. To ensure a consistent approach to the mitigation, management and offsetting of biodiversity for each future construction stage, an overarching management strategy has been developed.

The strategy has been designed to address the potential impacts identified in Chapter 4, being:

- Loss of vegetation, threatened species and fauna habitat
- Fauna mortality during construction
- Edge effects and weeds
- Habitat fragmentation, barrier effects and fauna mortality during operation
    - Impacts on aquatic habitats, changed hydrology and fish passage.

In addressing these potential impacts, the objectives of the strategy are to:

- Maintain and protect existing biodiversity as a priority wherever possible
- Maintain and protect species and populations of national and state conservation significance
- Maintain existing water quality and hydrological flow regimes
- Minimise the loss of vegetation and habitat
- Minimise pollution and degradation
- Maintain habitat connectivity and facilitate fauna movements and dispersal of species in important fauna areas for both terrestrial and arboreal fauna
- Minimise fauna mortality, injury and direct damage to individual plant species
- Provide habitat and opportunities for displaced fauna
- Monitor the effectiveness of mitigation measures and provide an adaptive management framework
- Offset unavoidable/residual impacts to significant biodiversity.

To meet these objectives, the biodiversity assessment provides three key strategies as the framework for delivery of management, monitoring and offsetting requirements for the project. These are outlined in Figure 5-1 with the blue squares identifying those processes which would be delivered as part of the EIS.

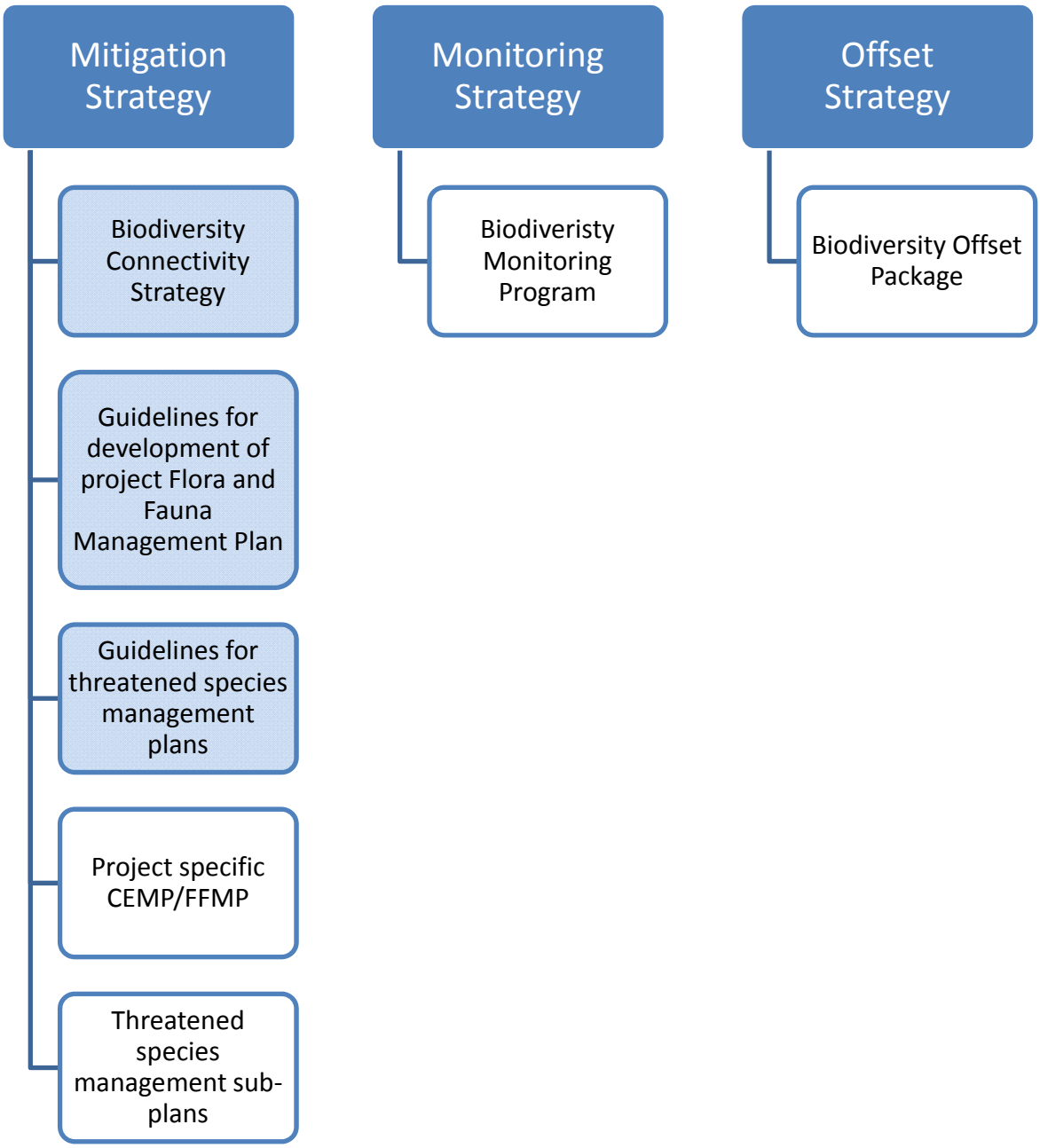
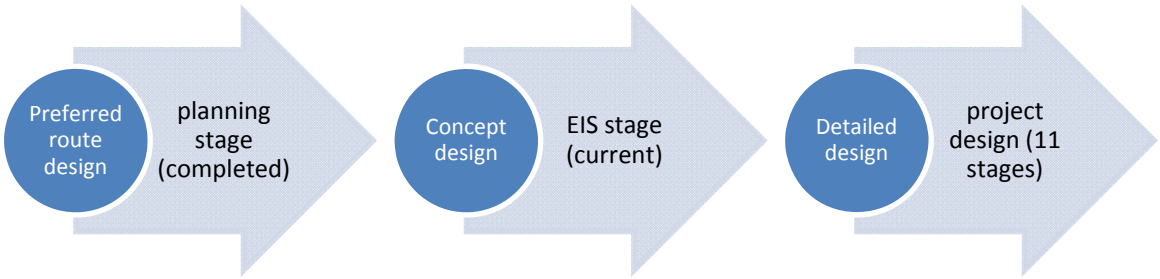


Figure 5-1: Strategic biodiversity mitigation and offset framework (the blue squares are delivered as part of the EIS).

5.2. Mitigation strategy

5.2.1. Biodiversity Connectivity Strategy

A biodiversity connectivity strategy has been developed for the project which aims to address the barrier effect that an unmitigated highway would have on fauna movements. The strategy has been developed and would continue to develop through a number of stages as outlined below.



The concept design / EIS stage aimed to focus on target species outcomes for the whole project and provide a series of detailed design principles based on these outcomes to take to the next stage of the project.

The goal of the strategy was to maintain connectivity in the landscape, as well as enhance connectivity where feasible and reasonable near the road corridor. Additionally, the Biodiversity Connectivity Strategy presents opportunities for protection of revegetation at key sites adjoining the project boundary to enhance connectivity. The strategy also outlines future research and adaptive monitoring needs for fauna crossing structures. The format of the strategy is presented as follows:

- Guiding principles: **basis for developing whole of project connectivity goals and influence decision making**
- Connectivity strategy goals: **provides a focus for the strategy that is appropriate at a local and regional level**
- Decision-making framework: **presents a framework for meeting the connectivity goals including identification of the issues and how these have been met, outlines future monitoring needs and strategic connectivity enhancement opportunities**
- Connectivity design measures: **details the structures proposed, fencing requirements and further recommendations and design principles for consideration at detailed design.**

Finally the strategy outlines measures to be adopted for the detailed design in the form of connectivity design principles. The summary of crossing structures for each project section includes dedicated and combined fauna crossing structures. This summary is based on the concept design for the project, and the locations are subject to some refinement during detailed design. Any changes are to be made in line with the design principles identified in the Strategy.

Fauna exclusion fencing

The connectivity design measures provide recommended locations for fauna exclusion fencing. These locations are based on ensuring exclusion of fauna from known roadkill hotspots (including emu road kill research) and directing fauna to dedicated and combined crossing structures. The connectivity design principles outline measures for exclusion fencing including fence design specifications and length of fencing around dedicated and combined structures. The detailed design should refer to the connectivity design principles for final fence design.

Exclusion fencing is recommended for portions of sections 3 and 4 to exclude emus from the road corridor and to direct emus and other fauna to the bridge underpass structures. It is recognised that fencing would be problematic in low-lying areas of sections 3 and 4 subject to flooding and that fencing in these areas should be placed higher on fill embankments to reduce impacts of flooding on the fauna fence. Dense landscape plantings could be used in these locations to screen fences or if stock fencing is also required to act a natural barrier. Preferred plant species are to include those that are tolerant of occasional water logging and can be densely planted, such as *Melaleuca* spp. and *Casuarina glauca*.

Arboreal crossing structures

During detailed design tree surveys are to be conducted at proposed rope and glider crossing zones to determine the most appropriate location to place the structure at a site specific scale. The design would place arboreal crossing structures at grade level, where average tree heights exceed 20 metres, and/ or taller trees are naturally positioned close to the road edge. Preference will be given to riparian habitats if possible and the tree survey will identify hollow-tree density in arboreal crossing zones.

Widened medians

Widened medians are located in the design at key areas for aerial connectivity. The design of fauna exclusion fencing and drainage or fauna underpass structures in widened medians would minimise vegetation clearing.

Landscape plans

Landscape planning will exclude placement of emu food plants along the road corridor in sections 3 and 4. These species include the following genus *Dianella, Gahnia, Lomandra* and *Ficus* in addition to Bangalow Palm (*Archontophoenix cunninghamiana*) and soy, oats or rye grass cover crops. Initial plantings of soy and / or oats would be targeted at key emu crossing locations to help with attracting emus to these crossing structures.

In general, landscape plans would avoid dense plantings of grasses and graminoids in road verge areas in sections 2 and 3 to discourage use by Rufous Bettong and minimise potential roadkill of this species. Additional planting of trees around glider crossings and widened medians would be conducted to act as a long terms replacement of these structures.

Bridge and culvert design

Instream structures such as bridges and culverts are to be designed and managed to minimise any potential impact to flow regimes and fish passage. Fish passage requirements for waterway crossings are detailed by Fairfull and Witheridge (2003). Each waterway crossing is to be designed to ensure no physical, hydraulic and behavioural barriers to aquatic fauna movements. The preferred structure for crossing waterways is to be consistent with Witheridge (2002) where the use of bridges or bebo arch is the preferred structure for Class 1 (major fish habitat waterways). Therefore waterways that contain known threatened species or contain critical habitat are to be crossed by bridges.

There are 21 waterways classified as Class 1, with bridge structures proposed at 19 of these. The remaining two waterway crossings would be addressed in the detailed design. Therefore where bridges are the proposed method of crossing the following design and management measures apply:

- Bridges are to be single span bridges with piers located outside the main channel
- Bridge structures to be designed to prevent an increase of backup of water during times of flood, that would enable Plague Minnow to access waterbodies where they are currently not found (eg Broadwater National Park)
- Construction would not alter or reduce flow where there are existing or potential Oxleyan Pygmy Perch populations (primarily within Sections 7, 8 and 9) which would negatively impact on this threatened species by draining the waterbodies.
- The proposed road surface would drain away from known Oxleyan Pygmy Perch habitat to reduce potential for pollution.
- Stockpiling of material for bridgeworks at known areas of Oxleyan Pygmy Perch would be undertaken after April to avoid the breeding seasons of October to March.
- Operational spill basins are to be installed at key locations (ie near Broadwater National Park) and other key drainage lines that lead directly into threatened fish habitat.
- Batch plant will be located outside well away from Oxleyan Pygmy Perch habitat due to the risk of high alkaline runoff occurring (through spill/overtopping event)

For waterways not deemed Class 1, or where use of culverts is unavoidable these will follow best practice design standards (Fairfull and Witheridge) such as:

- Use of Multi-cell box culverts
- Be aligned with downstream channel to minimise bank erosion
- Designed to prevent significant flow alterations
- Designed to allow fish movements during low flow
- Light penetration as great as possible
- Wet cells would have a minimum water depth of 0.2-0.5 metres to encourage fish passage

Other commitments in the design of bridges and culverts include:

- Creek crossing structures designed to maximise light and habitat features within the passage. To achieve this, the design of bridge and culverts will encourage the deposition of sediment creating similar bed substrate to adjacent creek and the planning of specific plant species
- Pools would be constructed or retained upstream and downstream of the waterway crossings to provide resting and refuge habitat near the crossing structures
- Water quality and pollution control measures would be implemented to treat runoff before release in surrounding waterways
- Multi-cell box culvert/culverts designed to prevent significant alterations to flow patterns and to allow fish movements during low flow periods.
- Natural stream flow and velocity would be maintained as closely as possible
- Surface level of causeway be the same or lower than the natural level of the stream bed to reduce interference with flow
- Habitat within a culvert be as natural as possible (eg allow rock and bed material to infill culvert base)
- There is maximum light penetration
- Maintain fauna and fish passage standards as detailed in the connectivity strategy, including maintaining minimum design widths, including for natural banks, while also providing for scour protection and cut and fill batters
- Bridges will be designed and sized to limit peak flood velocities to less than 1 metre per second in commonly occurring flood events, similarly to the bridge design over Macdonalds Creek where Oxleyan Pygmy Perch have been recorded.

Bridge construction will consider the impact of high pH runoff on Oxleyan Pygmy Perch habitats as a result of concreting activities. There could be a high risk that runoff can increase pH of the receiving waterway if discharged from concreting sites. To reduce this risk to low, the following mitigation measures are proposed and further discussed in the Water Quality Paper:

- Using pre-formed concrete piles and girder elements to minimise the need for concrete pouring in floodways'
- Reinforced form work incorporating water tight seals at all joints
- A shroud suspended under the bridge deck to intercept any spills that might occur in the event of any form work seepage
- Timely off-site disposal of any seepage caught in the shroud by the on-site supervision team
- Covering recently poured bridge decks with impermeable and durable plastic to prevent alkaline run-off entering waterways.

Temporary watercourse crossings

Temporary watercourse crossings will be required during construction to facilitate equipment and personnel access to the construction works. Temporary crossings may include bridges, arches, multi-celled culverts, box culverts and pipe culverts. Where temporary access tracks occur over drainage lines with no flow, fords may be installed. The potential impacts of these temporary watercourse crossings on aquatic ecology values depends upon the type of waterway crossing, the duration that the crossing is in place and the traffic that will use the waterway crossing.

Wherever possible, existing crossings will be used, however where this is not feasible, the construction and operation of these temporary crossings will be designed to minimise impacts to the existing aquatic ecology and water quality values. During detailed design locations for temporary crossings, the type of crossing, the duration each crossing would be established for the management and mitigation measures for each crossing location. General temporary waterway access track mitigation measures have been provided below:

- Installation and subsequent decommissioning of temporary crossings would be undertaken outside of Oxleyan Pygmy Perch spawning seasons (October to March).
- Temporary crossings would be constructed from clean fill using pipe or box culvert cells to carry flows.
- All temporary works (eg crossings, flow diversion barriers etc) would be removed as soon as practicable and in a way that does not promote future channel erosion.
- Where necessary creeks may need to be temporarily diverted to allow structures to be placed in order to minimise impacts to water quality
- The preferred temporary structure for crossing waterways would be consistent with Witheridge (2002) where the use of bridges is the preferred structure for Class 1 (major fish habitat waterways).
- Scour protection works will be established at temporary crossings as required
- At the completion of construction, the temporary crossings will be removed and rehabilitated.

Creek realignments

Two permanent creek re-alignments are proposed as part of the project, at Picanniny Creek and Eversons Creek, other creek realignments may also be required as detailed design is progressed is progressed and would be undertaken in close consultation with DPI Fisheries. The detailed design would include the requirements for the diversion and ensures that its specification meets guidelines for waterway design, watercourse diversions and specific environmental management measures including a detailed rehabilitation plan. The Hydrology Working Paper provides general design criteria for creek realignments to minimise impacts.

Picaninny Creek is classified as Class 3 - Minimal Fish Habitat; however there is still the potential that the relocation of Picanniny Creek could strand fish when the creek section is isolated.

Eversons Creek is a Class 2 – Moderate Fish Habitat, and the diversion could strand fish when the creek section is isolated. While Picanniny Creek is classified as Class 3 – Minimal Fish Habitat, there is also potential to strand fish during the diversion process.

Stranded fish must be captured and translocated following the DPI Fisheries Guidelines – *A Guide to Acceptable Procedures and Practices for Aquaculture and Fisheries Research*. Specific mitigation measures associated with the relocation of Picaninny Creek would be developed as part of the detailed design, however general mitigation measures have been provided below:

- Fish to be captured from the creek using appropriate gear for the watercourse and species present. These methods may include electrofishing, seine nets, bait and fyke traps.
- Threatened fish species are unlikely to occur within Picaninny Creek, however, translocation will be done in the cooler months to minimise stress to the fish (as fish are less active in the cooler months).
- Captured fish to be handled, transported and released in a manner that minimises any damage and stress to the fish (such as handling the fish with wet hands)
- Fish will be released into an equivalent watercourse with similar water quality and habitat conditions.

The capture of fish and subsequent translocation will require a Fisheries Permit and Animal Ethics Approval.

Avoiding loss of vegetation and habitat

Disturbance and clearing of vegetation as a result of the project would be unavoidable, however opportunities to minimise the loss of native vegetation and fauna habitat would be prioritised during all aspects of the detailed design, in particular:

- Avoiding and minimising vegetation removal wherever possible.
- Sensitive selection of ancillary facilities within the context of the ancillary site. A prior site inspection will be conducted to survey and map hollow-bearing trees and check for large nests for species such as raptors, including Osprey and also Black-necked Stork at these sites
- Construction compounds and stockpile sites will be sited in cleared or sparsely treed portions of the ancillary facility sites where feasible and reasonable, to avoid unnecessary clearing of vegetation and threatened flora species
- Sedimentation basins and water quality ponds would be placed in the optimal location for treating surface runoff. During detailed design, the location of water quality treatment measures would consider the competing environmental requirements of minimising vegetation removal, particularly where there is the potential for threatened plant species, threatened fauna habitat or in identified regional wildlife corridors.

5.2.2. Flora and Fauna Management Plan

RMS has developed *Biodiversity Guidelines: Protecting and Managing Biodiversity on RTA projects* (RTA 2011a). These guidelines are intended for RMS project managers, staff and contractors (including ecologists and landscape designers). They are a tool to help minimise impacts on biodiversity during construction and maintenance works.

Reference is to be made to the biodiversity guidelines in addition to the RMS *Vegetation Clearing and Fauna Management Practice Note: Pacific Highway Projects* (RMS 2012) when preparing environmental specifications for contracts and for the development of project specific Construction Environmental Management Plans (CEMP's), including flora and fauna management sub-plans (FFMP's). An outline of the content of the biodiversity guidelines is shown in Table 5-1 and each management guide described below.

An overall project Flora and Fauna Management Plan would be prepared to detail consistent guidance on the general management measures required for flora and fauna across all stages of the project. An outline of the content of the Flora and Fauna Management Plan is provided in Table 5-1. This document would be completed prior to the commencement of construction.

In addition to the Flora and Fauna Management Plan a series of sub-plans are required to address specific threatened flora and fauna management issues on relevant project sections. Details of the sub-plans are described in Section 5.2.3.

Table 5-1 Content of RMS Biodiversity Guidelines for developing project CEMPs and FFMP's

Management guide	Outline of content
1. Pre-clearing process	Guidance for the pre-clearing process that will be conducted before any clearing takes place to minimise the impact on native flora and fauna.
2. Exclusion zones	Guidance for determining and establishing exclusion zones to prevent damage to native vegetation and fauna habitats and prevent the distribution of pests, weeds and disease.
3. Re-establishment of native vegetation	Guidance for the re-establishment of native vegetation through managing site conditions, material sourcing and procurement, and seed and plant stock installation and establishment.
4. Clearing of vegetation and removal of bushrock	Guidance for minimising the impact of habitat removal, such as vegetation clearing and bush rock removal, on native flora and fauna.
5. Re-use of woody debris and bushrock	Guidance for maximising the re-use of woody debris and bushrock to minimise loss and/or damage to native flora and fauna habitats.
6. Weed management	Guidance for preventing or minimising the spread of noxious and environmental weed species on all RMS project sites and during maintenance works.
7. Pathogen management	Guidance for preventing the introduction and/or spread of disease causing agents such as bacteria and fungi.
8. Nest boxes	Guidance for works that involve the removal of hollow-bearing trees. Guidance for minimising the impact of hollow loss by providing supplementary fauna habitat in the form of artificial hollows (nest boxes).
9. Fauna handling	Guidance for minimising impacts on fauna as a result of being handled by humans and prevent injury to people handling fauna.

Management guide	Outline of content
10. Aquatic habitats and riparian zones	Guidance for limiting impacts on aquatic flora and fauna and their habitats, and to ensure the movement of fish up and downstream is maintained at all times during works in a waterway.

Guide 1: Pre-clearing process

The pre-clearing process would involve the development of a Construction Environmental Management Plan (CEMP) by the Contractor. This would include pre-clearing field surveys to confirm the appropriate management measures to minimise impacts to biodiversity. The results of the pre-clearing surveys would feed into the management measures specified in the CEMP. The following items need to be adequately addressed by the CEMP and the pre-clearing surveys:

- Pre-clearing surveys would be undertaken by an experienced ecologist to identify the location and extent of important habitats in the construction footprint to be salvaged for reuse/relocation, such as bushrock, hollow trees and woody debris
- Prior to clearing in all sections thorough surveys would be conducted along the route for large bird nests, particularly for listed species such as the Black-necked Stork, Eastern Osprey, Square-tailed Kite and Little Eagle during the nesting and breeding season (July to December). Appropriate management and protection/mitigation measures should be implemented if the species is present in or directly adjacent to the project footprint including buffer and exclusion zones, translocation of nests or establishment of adjacent nesting platforms if deemed necessary
- Identify and mark habitat features to be protected during construction
- Check for the presence of threatened flora and fauna species on a site immediately before clearing begins. This includes a targeted survey for threatened flora during the appropriate season
- Provide input into the location and extent of exclusion zones
- Identify nearby habitats on both sides of the existing highway along the length of the proposal suitable for the release of fauna that may be encountered during the pre-clearing process or habitat removal
- Develop planning and procedures for the staged habitat removal process
- Ensure that the location of any threatened flora and/or fauna species, threatened ecological communities and habitat are mapped and identified in the CEMP
- Develop an unexpected threatened species finds procedure to be included in the CEMP as outlined in the RMS Biodiversity Guidelines (RTA 2011) An unexpected finds procedure details the actions to be taken when a threatened flora or fauna species is unexpectedly encountered on site during construction.
- Determine any additional management measures that may need to be incorporated into the CEMP
- No parking of vehicles and/or machinery and storage of equipment and resources under the dripline of any trees (incorporate into CEMP)
- For further details regarding the pre-clearing process and the scope of the CEMP with regards to biodiversity protection refer to the RMS Biodiversity Guidelines (RTA 2011).

Guide 2: Exclusion zones

The location of exclusion zones would be determined and established to avoid damage to native vegetation and fauna habitats and prevent the distribution of pests, weeds and disease. Basic temporary fencing would be installed to indicate the limits of clearing. Permanent fauna exclusion fencing for the project (as described in the design principles for the connectivity strategy), where reasonable and feasible, will be installed prior to clearing to function as exclusion fencing.

The location and type of exclusion fencing to be installed would be identified on plans in the CEMP and the function and importance of the exclusion zones communicated to construction personnel. For further information regarding the establishment of exclusion zones refer to the RMS Biodiversity Guidelines – Guide 2 Exclusion Zones (RTA 2011).

Where construction barrier fencing is used, for example jersey kerbs, it is important to consider nocturnal fauna movements by placing gaps in the barrier at a minimum of every 500 metres. Alternatively barrier fencing with gaps incorporated into the design are effective, particularly near riparian areas Temporary frog fencing during construction should consist of heavy duty, UV protected material and trenched into the ground.

Guide 3: Re-establishment of native vegetation

A landscape management plan would be developed as part of the CEMP which provides specific details for the re-establishment of native vegetation on batters, cut faces, surrounding sediment basins and other areas disturbed during construction including approaches to connectivity structures. This would include details for the appropriate removal and restoration of temporary creek crossings. The landscape management plan will need to consider a range of constraints and opportunities associated with the project including collection and propagation of local seed, salvage and reuse of topsoil, leaf litter and woody debris, threatened species habitat, wildlife connectivity zones and local vegetation community composition. The landscape management plan would be developed in line with the design principles identified in the Connectivity Strategy (Appendix A).

Detailed guidelines for the re-establishment of native vegetation on road projects are provided in the RMS Biodiversity Guidelines- Guide 3 (RTA 2011) and supporting documentation, and includes the following:

- Ecologists and landscape architects would work together on the preparation of the landscape management plan that clearly identify the locations and composition of revegetation activities
- Allocate sufficient time for the collection of local seed and propagation of tube stock to be used in revegetation
- Where possible identify local native topsoil and leaf litter which is free of invasive weed species and store for use in revegetation works
- Allow sufficient time to prepare the ground for revegetation
- Soils in areas to be revegetated should match surrounding soil conditions as closely as possible unless adjacent areas are weedy or contaminated
- Ensure areas to be revegetated have an appropriate level of natural drainage
- Avoid compaction of soils in areas identified for revegetation and where compaction has occurred, the soil should be loosened

- When planting consider seasonal risks of frost, drought, flooding and sun exposure to avoid damaging plants and to encourage growth
- Adhere to relevant specifications and guidelines including but not limited to the RTA Landscape Planting QA Specification R179, RTA Seed Collection QA Specification R176, the Florabank Guidelines, Model Code of Practice and Construction Quality Technical Direction 007, Quality Alert 7 – Hydro-seeding, hydro-mulching and other slope stabilisation methods
- Inspection, monitoring and maintenance of revegetated areas would be conducted following the completion of construction in accordance with the landscape management plan. The aims and objectives of the landscape management plan would include appropriate milestones for the rehabilitation including the identification of condition benchmarks to be achieved within the rehabilitation areas. Outline the roles and responsibilities in landscape management and revegetation plans including the schedule for monitoring and maintenance activities
- Revegetation actions around dedicated fauna crossing structures should consider the height and density of vegetation so as not to screen the structure from view, but also aim to provide some cover for fauna approaching and exiting the structure. It is important for landscaping at entrances not to intrude / shadow the window of the entrance. Landscaping should use locally indigenous species and should target key fauna food resources to encourage usage either side of the structure and thus provide the habitat linkage to the structure

Guide 4: Clearing of vegetation and bushrock

A staged habitat removal process would be implemented consistent with the procedures identified in the RMS Biodiversity Guidelines (RTA 2011). The staged habitat removal process would be incorporated into the CEMP and communicated to construction personnel. The staged habitat removal procedure is summarised in Table 5-2.

Table 5-2 Staged habitat removal process (adapted from RTA 2011)

Stage	Details
1. Contact vet and/or wildlife carers	Vet and/or wildlife carers need to be contacted prior to construction commencing to ensure they are willing to assist in treating injured animals if necessary. Their contact details would be included in the CEMP, and be given to the site manager and clearly displayed in the site office.
2. An experienced and licensed wildlife carer and/or ecologist would be present	An experienced and licensed wildlife carer and/or ecologist should be present on site during all habitat removal activities to capture and relocate fauna that may be encountered (refer to Section 0).
3. Remove non-habitat vegetation first	Progressive habitat removal would take place around habitat identified and marked during the pre-clearing process. Remove non-hollow-bearing trees, undergrowth, feed-trees, regrowth and grass. Do not fell trees towards exclusion zones.

Stage	Details
4. Leave habitat for a minimum of 48 hours	Identified habitat (eg hollow-bearing trees) would be left for at least 48 hours after removing non-habitat vegetation to allow fauna to escape. A licensed wildlife carer and/or ecologist would check hollow-bearing trees are not being used by fauna before felling. If necessary, fauna may need to be trapped and relocated to pre-determined habitat identified for fauna release. For example, if a Koala was using a habitat tree and had not escaped in the 48 hour timeframe, a trap or other capture mechanism (used in a way to minimise stress and harm to the animal) would need to be setup to capture animal before felling tree. During the 48 hour period stag watching needs to be undertaken (especially at night for nocturnal species and near water) to identify any presence of animals occupying stag trees.
5. Remove habitat	Fell habitat trees as carefully as possible to avoid injury to any unexpected fauna still remaining in trees. Use equipment that would allow the habitat trees to be lowered to the ground with minimal impact (eg claw extension and swivel head harvester). Do not fell trees towards exclusion zones.
6. Inspect habitat	An experienced and licensed wildlife carer and/or ecologist would inspect habitat once it is removed eg after a tree is felled). Animals that emerge would be captured, inspected for injury then relocated to pre-determined habitat identified for fauna release.
7. Relocate habitat	All hollows have the potential to support fauna and would be placed in adjacent habitat until the following day for further inspection by a licensed wildlife carer and/or ecologist to verify no fauna is present. If possible, the hollows would be permanently relocated in adjacent areas in accordance with the RMS Biodiversity Guidelines (RTA 2011). Inspect woody debris for fauna immediately before chipping to avoid injury or death to fauna that may be present.
8. Reporting	The construction project manager and/or environment manager would ensure that the outcomes of the clearing process are recorded. Reporting is usually the responsibility of an ecologist or environment officer. Reports are to be submitted to relevant personnel (eg environment manager or RMS regional environment staff).

Guide 5: Re-use of woody debris and bushrock

Woody debris and bushrock would be re-used on site for habitat improvement where applicable and would be detailed in the landscape management plan/CEMP. Suitable areas for re-use may include the approaches to dedicated fauna underpasses, and beneath bridge structures and rehabilitation areas. Guidelines for the re-use of woody debris and bushrock are provided in the RMS Biodiversity Guidelines (RTA 2011), and require:

- Implementing the removal, stockpiling, transportation and relocation of woody debris and/or bushrock in a manner that minimises disturbance to native vegetation or bushrock
- Engaging an ecologist in the pre-clearing phase of the proposal to provide advice on the re-use of woody debris and bushrock including potential negative impacts and positioning of woody debris and bushrock at the relocation areas
- When relocating woody debris, placing it evenly across the site whilst keeping topsoil disturbance to a minimum
- Avoiding the spread of any weeds or pathogens that may be in the soil when relocating woody debris and bushrock from stockpiles
- Mulching would include only native vegetation and separate stockpiles need to be established for weedy vegetation and the native vegetation to be mulched. Manage

stockpiles in accordance with RTA's Stockpile Site Management Guideline, RTA Environmental Protection (Management System) QA Specification G36 and RTA Vegetation QA Specification R178

- Preparing a mulch tannin management plan for the project where tannins are likely to be generated.

Guide 6: Weed management

A weed management plan would be developed as part of the CEMP, the RMS Biodiversity Guidelines (RTA 2011) and the Introductory Weed Management Manual (Natural Heritage Trust 2004) provide guidance for developing weed management plans. As part of the weed management plan a site assessment by an ecologist or person trained in weed identification and management would be required to assess the extent and severity of weed species in the construction footprint with particular emphasis on noxious weed species.

The weed management plan would include descriptions and mapping of major weed infestations during pre-clearing surveys and appropriate management actions to be undertaken for each infestation. The details of the weed management plan will vary for each site but should include:

- Taxa and potential sources of the weed species
- Weed management priorities and objectives
- Sensitive environmental areas within or adjacent to the site
- Location of weed infested areas
- Treatment and removal methods for all weed species of national significance
- Mechanical weed control methods such as slashing or mowing, as well as a range of herbicides to avoid the development of herbicide resistance
- Measures to prevent the spread of weeds
- A monitoring program to measure the success of weed management
- Strategic management with adjacent landowners
- Appropriate disposal of weed infested materials and soils to be identified in the CEMP
- Communication strategies to improve contractor awareness of weeds and weed management

In addition to the above general guidance, the NSW DPI has expressed concern over the known presence of Alligator Weed in the study area. The species has been identified previously in Tuckombil Canal (Section 8). Early detection of the species is necessary during the preparation of project specific CEMP and surveys are recommended in Project sections 7 to10. If present, the CEMP should reference the DPI Alligator Weed control manual (van Oosterhout 2007).

Guide 7: Pathogen management

No pests and diseases are known from the project boundary, but could potentially be present. There have been reports of Myrtle Rust spreading from the coast to more western districts. Measures to prevent the introduction and/or spread of pests and disease causing agents such as bacteria and fungi need to be incorporated into the CEMP for each project section. A background search of government-maintained websites for the most up-to-date hygiene protocols for each pathogen and for the most recent known locations of contamination should be undertaken prior to construction.

Advice from government departments regarding the most practical hygiene management measures would be required if pathogens are found to be present. Testing from a National Association of Testing Authorities (NATA) approved laboratory may be required to confirm the presence of pathogens in the soil and/or water. If pathogens are identified exclusion zones with fencing and signage to restrict access into contaminated areas would be required.

Detailed prevention methods are provided in the RMS Biodiversity Guidelines – Guide 7 Pathogen Management (RTA 2011) and include:

- Provide vehicle and boot wash down facilities and ensure vehicles and footwear is free of soil before entering or exiting the site
- The risk of spreading pathogens and the mitigation measures required on site should be regularly communicated to staff and contractors during inductions and toolbox talks
- Construction works would be programmed to move from uninfected areas to any known infected areas
- Restrict vehicles to designated tracks, trails and parking areas
- The above pathogen management measures need to be implemented throughout the entire construction period.

Guide 8: Nest boxes

As there would be removal and loss of hollow-bearing trees from the project, it is proposed that nest boxes be installed to compensate for this loss. Guidance regarding the dimensions of nest boxes, installation and maintenance are provided in the RMS Biodiversity Guidelines- Guide 8 Nest Boxes (RTA 2011).

A nest box management strategy would be developed as part of the CEMP. The number and type of nest boxes required would be determined during the pre-clearance surveys based on the number, quality and size of the hollows that would be removed. The nest box management plan would detail the specifications for nest box dimensions, installation requirements, locations of nest boxes and ongoing monitoring and maintenance. The nest box strategy would require the installation of 70% of nest boxes prior to the removal of any vegetation.

Guide 9: Fauna handling

To prevent injury and mortality of fauna during the clearing of vegetation and drainage of farm dams an experienced and licensed wildlife carer and/or ecologist will be present to supervise vegetation clearing and capture and relocate fauna where required. Further details regarding fauna handling and vegetation clearing procedures are provided in the RMS Biodiversity Guidelines (RTA 2011). The following will be implemented to avoid injury and mortality of fauna:

- Allow fauna to leave an area without intervention as much as possible
- In circumstances where the handling of fauna is completely unavoidable, best practice methods need to be followed as outlined in the RMS Biodiversity Guidelines – Guide 9 Fauna Handling (RTA 2011)
- Include the procedures in project inductions for construction staff to implement if fauna is found or injured on site and also the importance of not feeding any wildlife that may be encountered on construction sites
- Never deliberately kill a snake as all snakes are protected under the NSW *National Parks and Wildlife Act 1974*
- Keep records of fauna captured and relocated
- Report any injury to or death of a threatened species to the RMS environmental staff.

Guide 10: Aquatic habitats and riparian zones

Measures to be adopted to minimise the potential impact of the project on general aquatic values of construction and operation including temporary crossings are detailed in the following table.

Table 5-3 Mitigation measures to be incorporated into FFMP for aquatic habitats and riparian zones

Mitigation measures	Description
Prevention / minimisation of in-stream barriers and water quality management	• As per the connectivity strategy culverts and diversion structures would be designed and sized to meet best management practice guidelines by a waterway engineer for each waterway crossing and the selected types of culverts will consider wildlife passage (including fish and turtle) • Streams to be crossed perpendicular to flow and where possible crossing sites selected to avoid unstable banks, bends in the channel, deep pools and confluences with other channels • Construction traffic will be restricted to access tracks, fenced prior to the start of construction and maintained until construction is complete. • Construction activities will ensure that areas within 50 m of Class 1 waterways are adequately stabilised prior to the spawning seasons of October to December to minimise potential for sediment pollution in waterways • Provision of scour protection on both sides of the waterway at any constructed works and temporary and permanent crossing structures within 50 m of Class 1 waterways or within the range of the Oxleyan Pygmy Perch as identified in Appendix A and the concept design report • Ensure chemicals and fuels are appropriately stored and bunded • Discharges from sediment basins and/or treatment wetlands during construction that do not meet the water quality parameters for Oxleyan Pygmy

Mitigation measures	Description

	Perch habitat (as identified through pre-construction water quality monitoring) should not be discharged into waterway but rather sprayed into adjacent open grass areas or used for construction purposes such as dust suppression to avoid changing water depth and physico-chemical conditions in potential threatened fish habitat
	• Where it is not feasible to irrigate to land to completely re-use sediment basin water then as a last resort discharge water of sediment basin to Oxleyan Pygmy Perch waterways will be treated to ensure it has the correct ph <6.5 and total suspended solids of <50mg/L.
	• Water quality monitoring to assess the effectiveness (and where necessary amend) water, sediment and erosion management strategies that aim to protect the Oxleyan Pygmy Perch and Purple-spotted Gudgeon, their habitat and other aquatic flora and fauna species. Water quality monitoring program will be undertaken in line with details in Appendix B and involve:
	  • Monitoring before, during and after construction. Baseline monitoring will be undertaken before construction to document the pre-existing condition for important waterways in project sections 1-2 and 6-10.
	  • Development of local water quality objectives based on characterisation of baseline conditions (over appropriate spatial and temporal scales)
	  • Regular water quality compliance monitoring during construction
	  • Review of water quality conditions in respect to known requirements for threatened species (such as the Oxleyan Pygmy Perch and Purple-spotted Gudgeon)
	  • Undertaking actions to control (and where necessary remediate) any potential impacts arising as a result of construction activities
	• If construction works result in the temporary isolation of pools for any period of time and they become susceptible to drying or poor water quality then any resident native fish that are trapped are to be relocated to areas not being disturbed away from impacts.
	• No turbid water generated from the construction corridor or construction area is to be discharged to any waterway

Riparian and aquatic habitat management	• Prior to any disturbance of the banks a thorough inspection for aquatic fauna such as turtle nests should be conducted • Minimise instream and riparian disturbance and minimise the removal of sediment, woody snags or debris from a stream or stream channel. Trimming or 'lopping' of branches and logs should be considered as a first option before moving • Minimise the risk of instream and riparian weeds through the implementation of a vegetation clearing and revegetation management strategy • Appropriate plant species would be incorporated into the rehabilitation of disturbed aquatic habitats and drains as a result of construction, in regions of suitable Oxleyan Pygmy Perch habitat. • The bed and banks are to be reinstated to a condition similar to or better than the original condition ensuring that there are no adverse impacts on the aquatic values (different measures may be required for each crossing). Banks are to be graded to a slope that is no steeper than existing site conditions

Mitigation measures	Description
Sedimentation and erosion management	• All standard sediment and erosion control measures for downstream water quality management will be implemented • All appropriate sediment and erosion control measures would be put in place during the construction process and may include sediment and erosion control curtains in the waterways to control turbidity generated during the construction and restoration process • Develop and conduct water quality monitoring.
Instream woody debris management	• Large woody debris should be retained to the greatest extent possible • Any instream woody debris removed during construction is to be replaced at the completion of the works within the same waterways from which it was removed. This will ensure that there is no net loss of instream structural habitat

5.2.3. Threatened species sub-plans

The general survey, avoidance, management and monitoring requirements for flora and fauna during construction would be detailed in the whole of project FFMP based on a consistent approach to be adopted across all projects. Impacts on threatened species would be generally managed via the FFMP however there are a number of project and species specific management measures that would be manged via a number of threatened species sub-plans. These plans would focus on species identified as potentially signficantly impacted by the project. The proposed content of these plans is described in Table 5-4. A common aspect of each plan will be the provision of key goals for mitigation measures, thresholds for corrective actions and proposed corrective actions.

Table 5-4 Project specific mitigation measures for threatened species

Mitigation measures	Description
Threatened Flora Management Plan	• The plan would specifically address project sections where populations of threatened flora are known to have plants immediately adjacent to the project footprint, including *Angophora robur* (Section 3 and 4)*, Melaleuca irbyana* (Section 7) and *Eucalyptus tetrapleura* (Section 2)*.* Additional species identified in Chapter 6 as significantly impacted by the project would also be addressed. • Detailed design measures – to include identification and marking in relevant project sections by physically surveying and mapping the specific location of individuals and patches along the edges of the project boundary. The objective of the survey is to provide accurate input into the detailed design to further avoid and minimise removal of the species and inform the management actions of the FFMP. • Pre-clearing measures – to include a clearing protocol, translocation trial, seed collection, storage and propagation to use in revegetation of disturbed habitats • Construction measures – to include details for protection of retained plants, planting and maintenance and monitoring procedure during construction. • Post-construction measures to include a revegetation monitoring program and performance criteria, reporting and adaptive management.
Rainforest Invertebrates Management Plan (Pink Underwing	• Detailed design measures - Conduct a targeted survey of both species within and surrounding the project boundary in section 10 and 11 during detailed design to identify the extent of the population and map the distribution of suitable habitat adjacent to the corridor. In particular potential breeding habitat

Mitigation measures	Description
moth and Atlas Rainforest Ground Beetle)	should be identified concerning habitat containing the caterpillars' food plant, *Carronia multisepalea.* This information is required to inform the detailed design, construction FFMP and translocation and habitat rehabilitation program. • The surveys will aim to map the species distribution and correlate presence with the habitat characteristics at identified sites in order to accurately model the distribution of potential habitat in proximity to the project. The detailed design is to consider the distribution of potential habitat and avoid or minimise impacts where possible. The identified potential habitat would be targeted for translocation of individuals and habitat rehabilitation as compensation for the loss of habitat from the project. • Pre-clearing measures – refer to sections 10 and 11. Outline capture and relocation actions for Rainforest Ground Beetle and Pink Underwing Moth larvae focusing on identified suitable habitat as per identified in the detailed design tasks above. • Construction measures – capture and relocation conducted. Conduct habitat rehabilitation and revegetation of suitable habitat in proximity to the project including the planting of the host plant for the Pink Underwing Moth. • Post-construction measures - details of a monitoring program for translocated individuals and retained habitat adjacent to the corridor. The monitoring program would include the collection of baseline data and would continue through construction and operation for a period of three years post-construction. The plan would include clear key milestones, performance indicators, corrective actions and timeframes for the completion of all actions outline. The plan would address the success of habitat rehabilitation as well as the translocation success by monitoring populations of the target species.
Emu management plan	• Detailed design - As exclusion fencing may not be appropriate in emu habitat areas subject to flooding and inundation (eg. Pillar Valley creek), the location of emu exclusion fencing is to be detailed in the emu management plan and transferred to the final design. The plan should also consider fence design around bridges design to exclude domestic stock but allow emus to cross. • Pre-clearing measures: the detailed landscape plan is to include provision for dense plantings of Melaleuca and Casuarina species, and other suitable species to act as a natural barrier fence and to also direct emus to crossing areas where exclusion fencing is not possible. The natural brush fence will be placed along the toe of the batter to direct emus to crossing locations. These plantings would form a natural dense barrier up to 4 to 5 metres wide. The locations for planting the fence, species and density are to be detailed in the management plan. • The natural brush barrier fence is to be established immediately following the acquiring of the properties through sections 3 and 4 and well in advance of clearing of vegetation to assist in educating emus to use crossing points. Gaps would be placed where the dedicated and combined structures are to finally be located. This is designed to allow time for the vegetated barrier to achieve suitable height and also to educate emus to use the designated crossing locations prior to construction. The management plan is to outline where fencing is to occur, how permanent and temporary fencing should be used and where it should be used. • Baseline monitoring of emu movements is to commence prior to clearing in Section 3 and 4. • Construction measures: Roadside plantings in emu habitat (Section 3 and 4) should not be within the first 40 metres of the road unless there is fauna exclusion fencing in place or as part of the exclusion barrier. In particular, common landscape species such as *Lomandra* and *Dianella* spp. should not be used as represent food plants for emus and may attract them to the road edge • Plantings under dedicated and combined bridges in emu crossing zones (Section 3 and 4) including the approaches to the crossing are to use grasses

Mitigation measures	Description
	or low ground covers and avoid dense plantings of trees including low trees such as Acacia or Casuarina. This is to leave the opening clear. Ground cover crops such as soybean and oats or rye grass could be used on disturbed ground around the approaches to the bridge to attract emus to the crossing zone as these represent known food plants • Landscape planning will exclude placement of emu food plants along the road corridor in sections 3 and 4. These species include the following genus *Dianella, Gahnia, Lomandra* and *Ficus* in addition to Bangalow Palm (*Archontophoenix cunninghamiana*) and soy, oats or rye grass cover crops. Initial plantings of soy and / or oats would be targeted at key emu crossing locations to help with attracting emus to these crossing structures. • Post-construction measures: Conduct a trial to test the use of tethered twirling spirals, silver on one side and red or blue on the other. These can be trialled on different bridge underpasses targeted at attracting emus. These would have to be constructed in some way that could endure and would not harm other investigating wildlife, • Monitoring of the effectiveness of the proposed crossing structures for emus is to be conducted. The method and approach to monitoring would be outlined in the Emu management plan and consider the results of the pilot program for satellite / GPS tracking in addition to other techniques such as camera monitoring. Thresholds for action regarding the need for additional structures will need to be included in the plan. The monitoring should also consider the collection of pre-construction baseline data as outlined above.
Oxleyan Pygmy Perch management plan	• Measures to avoid and mitigate impacts to threatened fish species in particular the Purple-spotted Gudgeon and Oxleyan Pygmy Perch and their habitat are to be documented in the sub-plan. These measures are relevant to Project sections 1 to 4 and 6 to 10. • Outline a methodology and program for survey of potential habitat for this species at a minimum at least 6 months prior to construction in the appropriate season. This is required as the species distribution is known to change over time and the data would inform the FFMP and monitoring program. • Outline the proposed program for monitoring the species at identified known locations, to include a before-after-control-impact design and continue during construction and operation for a period of five consecutive monitoring periods. • Outline the proposed adaptive management actions to be implemented for this species in the event that any changes to the identified populations or habitat conditions are demonstrated and can be attributed to the project construction or operation. • The plan must include clear key milestones, performance indicators, corrective actions and timeframes for the completion of all actions outlined • The plan should provide recommendations regarding the location of batch plant sites to be located outside and away from Oxleyan Pygmy Perch habitat where sediment erosion will not runoff into waterway (due to the risk of high alkaline runoff) • Avoid in-stream works on known and potential habitat (refer to section 3.10.6) for Oxleyan Pygmy Perch or Purple-spotted Gudgeon to minimise sedimentation impacts. In stream works should be timed in a manner that minimises impacts to aquatic fauna. The in-stream construction works should avoid the critical spring-summer period (October – December) where feasible and reasonable as this represents the typical water temperatures between 19-34°C and high rainfall period when aquatic habitats are flowing and the spawning season for many fish species including the Oxleyan Pygmy Perch and Purple-spotted Gudgeon

Mitigation measures	Description
	• Where feasible and reasonable, existing pools should be retained upstream and downstream of crossings within known occurrences of the Oxleyan Pygmy Perch to provide resting and refuge habitat near crossing structures.
Threatened frog management plan	• Focus is on Giant Barred Frog, Green-thighed Frog, and Olongburra Frog. • Pre-construction measures – outline a program for survey or potential habitat for these species at a minimum at least 6 months prior to construction to identify potential waterways and swamp habitat locations relevant to specific project sections and to inform the FFMP. • Record riparian / habitat condition baseline data at identified sites near the project to inform construction and post-construction monitoring program. • Construction measures – identify known sites and apply protection measures during construction, specify monitoring methods and timing for species and habitat condition and monitoring mitigation measures and reporting in line with the FFMP. • Post-construction measures – outline methods for monitoring species and habitat condition during post-construction.
Koala management plan	• Detailed design measures – Conduct a targeted survey in relevant project sections to identify the presence and status of koala populations near the project alignment. This should focus on Sections 6-10 which represent a high density of koala records and known koala populations. The surveys are to focus near the project alignment and the data used to inform the proposed detailed design for connectivity structures to ensure that the proposed structures for koalas are consistent with the field data.
Glider management plan	• Detailed design phase: conduct targeted surveys for Squirrel Glider and Yellow-bellied Glider in section 1-3 and 6-8 to inform the FFMP, nest box management plan and the detailed design. Currently the arboreal crossing locations and widened medians targeting these species have been placed based on field data and species atlas data and were used to inform the concept plan. Further input is required on the distribution of glider populations close the project and on either side of the alignment in order to inform the detailed design and appropriate placement of the arboreal crossing structures and widened medians. • The surveys are to include a tree-survey within each of the widened medians and at the proposed corssing locations to identify the height of the trees for input into the detailed design. The retention of larger trees is a priroirty and these need tobe identified and protected in the median as well as at identified connectivity zones. • Construction and post-construction measures would be outlined in the nest box management plan.
Lowland Rainforest sub-plan	• Detailed design phase: Conduct surveys in section 8-11 for Lowland Rainforest to more accurately identify the distribution, condition and area of this community in proximity to the alignment. The survey should concentrate on classifying the community according the criteria used under the EPBC act to identify the patches which meet the Commonwealth listed separately to the State listed community. The data from the survey would provide input into the FFMP and the compensatory habitat measures for this community and for dependent threatened fauna species such as the Pink Underwing Moth.

5.2.4. Effectiveness of mitigation measures

A range of mitigation measures have been identified to minimise the impact of habitat loss and fragmentation on threatened fauna species potentially impacted by the project. These include:

- Vegetation management measures (implementation of pre-clearing and clearing procedures and weeds and disease management)
- Connectivity measures (installation of fauna underpasses, overpasses and arboreal crossing structures, fauna fencing and retention of vegetated medians)
- Provision of nest boxes.
- Management of aquatic habitats for threatened fish.

Vegetation management

The procedures used for pre-clearing and clearing surveys and management of weeds and disease pathogens have been documented in the RMS biodiversity guidelines (RTA 2011) and are based on best practice procedures. The Biodiversity Guidelines were developed in consultation with the NSW Office of Environment and Heritage (OEH), NSW Department of Primary Industries (DPI) (Fisheries), biodiversity specialists and RMS staff including project managers, construction personnel and designers. Consultation was facilitated through a number of workshops carried out in 2009.

Connectivity measures

The work to improve connectivity for wildlife as part of the major Pacific Highway and Hume Highway upgrades in NSW has raised the importance of wildlife issues for road projects in Australia. Lessons learnt from studies on the use by wildlife of the numerous mitigation measures installed along RMS projects have been adopted around Australia and internationally.

In an international review of the effectiveness of road crossing structures van der Ree *et al.* (2007), cites numerous studies that demonstrate evidence of fauna using underpasses and overpasses at an individual level. However this author indicates that there is some uncertainty whether structures are successful for stabilising the viability of all populations.

In Australia there are several published studies also providing measurable evidence for the effectiveness of purpose built fauna crossing structures. This includes arboreal mammals (Goldingay *et al* 2011 and Goldingay *et al* 2012), small to medium sized terrestrial mammals, amphibians and reptiles (SMEC, 2007). Among these are several threatened fauna such as Koala, Spotted-tailed Quoll, Squirrel Glider and possibly the Long-nosed Potoroo and Black Bittern.

Land bridges are known to provide passage for macropods (Bond and Jones, 2007), particularly when fencing is used to funnel fauna and especially when land bridges contain attractive palatably grass. These structures have also been reported as important for small birds which are sensitive to fragmentation (Jones and Bond 2010).

In NSW, the RMS has commissioned several long-term studies involving radio-tracking of koalas pre-, during and post-construction to investigate the effectiveness of underpasses, overpasses and exclusion fencing incorporated into the Pacific Highway Upgrade, including at Lindsays Cutting (Moon 1998) and Pine Creek State Forest, near Coffs Harbour, at Raymond Terrace and Bulahdelah, north of Newcastle, and along the Yelgun to Chindera realignment in north-eastern NSW and Bonville upgrade (Lassau *et al* 2012). These studies have demonstrated the effectiveness of overpasses and underpasses (minimum 2.4 x 2.4 metres) for koalas crossing the highway. The knowledge gained from these studies has led to the inclusion of fauna furniture such as raised vertical and horizontal logs to encourage use and ensure the safety of Koalas from predators.

Fauna crossing structures are particularly effective when used with fauna exclusion fencing that direct fauna away from the road and towards the structure. Various researchers have found that as a result of absent, broken or ineffective fences around crossing structures, that increased accounts of road kill were likely for species such as koala, macropods, possums, native rats and frogs (Taylor and Goldingay 2003; SMEC, 2007; Goldingay *et al* 2011). Table 5-5 provides a list of common and threatened fauna species that have been reported using fauna crossing structures, a number of which are identified as potentially impacted by the project.

Table 5-5 Common and threatened fauna species recorded using fauna crossing structures.

Structure type	Known fauna groups and common fauna	Known threatened species
Land bridges (overpasses)	• Frogs, birds, macropods introduced mammals, rats and mice, possums, lizards and snakes • Red-necked wallaby, Northern brown bandicoot, Long-nosed bandicoot and Echidna	Spotted-tail Quoll (Fitzgerald, 2004)
Bridges, in stream structures	• Frogs, birds, macropods native rodents, bats, gliders, arboreal mammals, large and small ground-dwelling mammals, introduced mammals, monotremes, lizards, snakes and invertebrates.	Koala (AMBS, 2001; Abson and Lawrence, 2003) Eastern False Pipistrelle (Abson and Lawrence, 2003)
Underpasses (culverts)	• Arboreal mammals, small mammals, rodents macropods, bats, introduced mammals, frogs, lizards, snakes, turtles, birds, Invertebrates and molluscs • Common Brushtail Possum, Swamp Wallaby, Eastern Water Dragon, Long nosed bandicoot, Echidna, Bush Rat, Brown Antechinus	Long-nosed Potoroo (AMBS, 2001; Taylor and Goldingay, 2003) Red-legged Pademelon (Goosem, 2005) Spotted-tail Quoll (AMBS, 2001)
Canopy bridges	• Small ground-dwelling mammals, large possums and pygmy possums • Common Ringtail Possum, Common Brushtail Possum,	Squirrel Glider (Bax, 2006)
Glider poles	Sugar Glider, Squirrel Glider	Squirrel Glider (Goldingay, *et al* 2011)

Table 5-6 provides a quick reference guide to the suitability of mitigation measures to restore connectivity across the road for selected fauna groups. This is only intended as a general guide because the requirements of species within each group will vary.

Table 5-6 Reference guide to effectiveness of fauna crossing structures (source RTA 2011)

Structure type	Amphibians	Arboreal mammals	Birds and Bats	Flightless birds	Invertebrates	Macropods	Platypus	Reptiles	Small mammals
Overpasses									
Road tunnel	1	1	1	1	1	1	1	1	1
Land bridge	2*	1*	2	2	2	1	2*	2*	1
Land bridge with minor road	3*	2*	2	2	2	3	3*	3*	3
Canopy bridge	4	1	4	4	4	4	4	3	4
Glider pole	4	1,4*	4	4	4	4	4	4	4
Underpasses									
Bridge and viaduct	1	2	1	1	1	1	1	1	1
Large culvert	2*	3	2	2	2	1	2	1	1
Small-medium sized culvert	2	3	4	4	3	3	2	2	1
Drainage culvert	3	4	4	4	4	4	2	3	3
Amphibian / reptile culvert	2	4	4	4	4	4	3	2*	3
Tunnel / pipe	3	4	4	4	3	4	2	3	2
Vegetated crossings									
Widened median	4	1,4*	3*	3	3	3	4	3*	3*
Canopy connectivity	4	1	2	3	2	4	4	3	3

Legend

1 = Demonstrated use by fauna group

2 = Likely to be used by fauna group

3 = May be used by fauna group, but use has not been demonstrated

4 = Not likely to be used by fauna group

* = Specific conditions, see text

Special conditions that may affect usage of structures by fauna groups are:

- Australian frogs have been recorded very occasionally in box culverts (3 x 1.5 m, 3 x 3 m) and more frequently under bridges
- The optimal solutions for birds and bats, and especially the most sensitive species, are land bridges and road tunnels where a natural and continuous cover of vegetation can be maintained
- Koalas have been detected using land bridges, under bridges and larger culverts (eg minimum 2.4 x 1.2 metres and 3.0 x 3.0 metres), but may be less inclined to use tunnel/pipe underpasses
- Spotted-tailed Quoll have been reported using land bridges and underpasses (2.4 x 2.4 metres) and although not proven may also be inclined to use smaller pipes
- Some structures have reported use by fauna but limited data may be available on complete crossing or effectiveness for populations.

While the EIS assesses the project for a four lane divided highway, the connectivity strategy and provision of connectivity mitigation measures has been based on design of a six lane highway if required in the future. In this scenario, the extra two lanes would be placed in the centre of the alignment ensuring that crossing structures are not increased in length. The proposed widened medians have been designed such that a minimum of 25 metres in the median would be retained if the six lane scenario was constructed in the future.

Nest boxes

A range of native animals require the natural hollows that develop in trees and some shrubs for shelter and/or breeding. A comprehensive list is given in Gibbons and Lindemayer (2002). Nest boxes are not a substitute for natural hollows and are best used in areas depleted of natural hollows. Nest boxes have been used extensively by a range of hollow-dependent fauna (Harper et al 2004; and review in Goldingay and Stevens 2009)

Summary

Identified mitigation measures proposed against the various potential impacts are presented in Table 5-7. The summary indicates that although the mitigation measures are generally effective for the impacts that are likely to occur, they are not sufficient with respect to the clearing of native vegetation. This includes endangered and critically endangered ecological communities and habitat for threatened species and populations.

The inclusion of a detailed connectivity strategy including provision for dedicated and combined underpass and overpass structures has a high degree of effectiveness for a wide range of fauna groups as determined by scientific research and documented design standards. However there is limited data on the impacts of gene flow by large projects and also limited data on a number of species in particular emus.

In theory, access to identified important habitats can be provided for emus via appropriately placed and adequately sized crossing structures (ie bridges and arches) in addition to exclusion fencing, which should also act as directional fencing leading to the crossing structures. However there is a risk in this approach in that it relies on effectiveness of these mitigation measures when there is no current scientific evidence to indicate that wild emus are capable of finding and using crossing structures or can be directed by fencing. In the absence of scientific certainty the benefit of providing crossing structures remains to be proven.

Table 5-7 Assessment matrix of mitigation

Mitigation measure	Vegetation clearing, habitat loss & edge effects	Fragmentation / barrier effects	Weeds / pests	Changed hydrology	Aquatic disturbance & barriers to fish passage
Detailed design		√		√	√
Flora and Fauna Management Sub Plan	√	√	√	√	√
Biodiversity Connectivity Strategy		√			√
Pre-clearing process	√	√			√
Exclusion zones	√	√			√
Re-establishment of native vegetation	√	√	√		
Clearing of vegetation and removal of bushrock					
Re-use of woody debris and bushrock	√				√
Weed management	√		√		√
Pathogen management	√		√		√
Nest boxes	√				
Fauna handling	√				
Aquatic habitats and riparian zones				√	√
Adequate mitigation?	**No**	**No**	**Yes**	**Yes**	**Yes**

5.3. Biodiversity monitoring strategy

The effectiveness and success of the proposed biodiversity mitigation and management measures would be assessed using a measurable and targeted operational monitoring program for biodiversity. An outline of the monitoring program is provided as Appendix B. This program would be finalised following project approval to incorporate any specific conditions of consent. The program would then be implemented prior to the commencement of construction of each section of the project. The aim of the program is to monitor the effectiveness of the mitigation and management measures proposed for threatened species, including general and project specific measures. The program objectives include:

- A targeted monitoring methodology for threatened species adjacent to the project footprint
- An adaptive monitoring program to assess the effectiveness of the proposed mitigation measures and allow their modification if necessary. Monitoring is to be undertaken during construction (for construction-related impacts) and from opening of the project to traffic (for operation/ongoing impacts) until such time as the effectiveness of mitigation measures can be demonstrated to have been achieved over a minimum of three successive monitoring periods following establishment of vegetation planted as part of mitigation and after opening of the project to traffic
- Assessing changes to habitat usage, to identify if this is a result of the project

- Details of contingency measures that would be implemented in the event of changes to habitat usage patterns directly attributable to the construction or operation of the project
- Provision for annual reporting of monitoring results.

5.4. Biodiversity offset strategy

A Biodiversity Offset Strategy has been adopted for the project. The strategy would allow a consistent and transparent approach to be adopted for the entire project and allow actions to be commenced to source suitable offsets. A Biodiversity Offset Strategy has been prepared (Appendix C) that identifies the method for determining the offset amounts and location and the most effective options for implementing the offsets. The strategy takes into account the identified loss of vegetation types and also considers the condition of the habitat being lost, the species being impacted and the regional scale cumulative impacts. The strategy has been designed for consistency with the principles for biodiversity offsets in NSW.

The objective of the Biodiversity Offset Strategy is to deliver a package of offsets to achieve a neutral or net beneficial biodiversity outcome for the region as a result of the project. The strategy would be applied consistently across the project to offset the impacts identified in this assessment. Where there is scope to reduce the impacts through the detailed design phase for each of the 11 sections, the refined construction footprint would be considered in the calculations of offsets.

6. Significance assessments

6.1. Overview

This chapter discusses the assessment of significance relating to threatened biodiversity. The assessment provides a consistent and systematic approach to determining whether the project is likely to significantly affect threatened species, populations or ecological communities, or their habitats either directly or indirectly.

Details of the individual species significance assessments for the EP&A Act (NSW) and the EPBC Act (Commonwealth) are provided in 0. This chapter provides a summary of the conclusions only. In reaching the conclusions of the significance assessments, impacts were considered more significant if:

1. Areas of high conservation value would be affected
2. Individual animals and/or plants and/or subpopulations that are likely to be affected by the project play an important role in maintaining the long-term viability of the species, population or ecological community
3. Habitat features that are likely to be affected by the project play an important role in maintaining the long-term viability of the species, population or ecological community
4. Duration of the impacts is long-term to the point where there is limited opportunity for recovery of species
5. Impacts are permanent and irreversible and not able to be mitigated with a high degree of confidence.

6.2. Methodology

Significance assessments have been conducted for species, populations and communities that have been positively identified or that have a moderate or high potential to occur in the study area.

For threatened biodiversity listed under the *Threatened Species Conservation Act 1995*, this section details the heads of consideration for threatened species assessment as suggested in the Department of Environment and Conservation/ Department of Primary Industries *draft Guidelines for Threatened Species Assessment* (Department of Environment and Conservation and Department of Primary Industries 2005). The guidelines present methods to consider the impacts on biodiversity of projects assessed under Part 3A as updated by Part 5.1 of the *Environmental Planning and Assessment Act 1979*, including presenting heads of consideration for determining the significance of impacts.

For threatened biodiversity listed under the *Environment Protection and Biodiversity Conservation Act 1999,* significance assessments have been completed in accordance with the *Matters of National Environmental Significance Significant Impact Guidelines 1.1* (Department of the Environment, Water, Heritage and the Arts 2009).

Species with similar taxonomy or ecological requirements have been assessed together, for example tree-roosting microchiropteran bats.

In assessing the significance of the impacts, consideration has been given to the distribution of threatened species and the areas of potential habitat. For example some species, populations or communities are restricted to discrete project sections such as *Angophora robur*, Lowland Rainforest or Coastal Emu. Conversely some species are widespread and occur across all project sections, eg microchiropteran bats which use a range of habitats and are dependent on specific microhabitat features which are widespread and not restricted by localised conditions.

Where there is reasonable doubt regarding the likely impacts, or where detailed information is not available, a significant impact has been assumed as a precautionary approach.

In the case of a threatened plant species, where multiple populations occur in the study area, each population was assessed separately. In this instance, a local population was identified as those individuals occurring as a cluster of individuals and that could reasonably be expected to be cross-pollinating within the population and were assessed on a project section by section basis.

6.3. NSW significance assessment

Full details of the assessment of significance under the *Environmental Planning and Assessment Act 1979* (EP&A Act) are presented in Appendix E. The conclusions of the EP&A Act assessment of significance are provided in Table 6-1. The project sections identified are where the species has been confirmed or may potentially occur. The project sections identified in bold correspond with an identified significant impact where this may differ between local populations.

Table 6-1 Summary of NSW significance assessments

Species	Common name	TSC Act / FM Act	Project Section*	EP&A Act questions of significance*						Likely significant impact
				1	2	3	4	5	6	
THREATENED FAUNA										
Wetland birds										
Anseranas semipalmata	Magpie Goose	V	2-6, 8-11	N	N	N	N	N	N	No
Ephippiorhynchus asiaticus	Black-necked stork	E	1-11							
Grus rubicundus	Brolga	V	1-11							
Irediparra gallinacea	Comb-Crested Jacana	V	3-9							
Ixobrychus flavicollis	Black Bittern	V	1-3, 6-7, 9							
Amaurornis molucanna	Pale-vented Bush Hen	V	9-10							
Botaurus poiciloptilus	Australasian Bittern	E	1-4, 7-11							
Stictonetta naevosa	Freckled Duck	V	3-5							
Rostratula australis	Australian Painted Snipe	E	1-11							
Large forest owls										
Ninox strenua	Powerful Owl	V	1-11	Y	N	N	N	N	N	No
Ninox connivens	Barking Owl	V	1-11							
Tyto novaehollandiae	Masked Owl	V	1-11							
Tyto tenebricosa	Sooty Owl	V	1-2							

Species	Common name	TSC Act / FM Act	Project Section*	EP&A Act questions of significance*						Likely significant impact
				1	2	3	4	5	6	
Frugivorous rainforest birds										
Ptilinopus magnificus	Wompoo fruit-Dove	V	1-2, 6-11	Y	N	N	N	N	N	No
Ptilinopus regina	Rose-crowned Fruit Dove	V	1-2, 8-11							
Ptilinopus superbus	Superb fruit-Dove	V	1-2, 8-11							
Coracina lineata	Barred cuckoo-shrike	V	1-2, 6-11							
Cyclopsitta diophthalma coxeni	Double-Eyed Fig-Parrot	E	9-11							
Cave-roosting microbats										
Miniopterus australis	Little Bent-wing Bat	V	1-11	Y	N	N	N	N	N	No
Miniopterus schreibersii oceanensis	Eastern Bent-wing Bat	V	1-11							
Myotis macropus	Southern Myotis	V	1-11							
Vespadelus troughtoni	Eastern Cave Bat	V	1-11							
Tree-roosting microbats										
Chalinolobus nigrogriseus	Hoary Wattled Bat	V	1-11	Y	Y	N	N	N	N	Yes
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	1-11							
Kerivoula papuensis	Golden-tipped Bat	V	1-11							
Mormopterus beccarii	Beccari's Freetail-Bat	V	1-11							
Mormopterus norfolkensis	Eastern Freetail-Bat	V	1-11							
Nyctophilus bifax	Eastern Long-Eared Bat	V	1-11							
Saccolaimus flaviventris	Yellow-bellied Sheathtail-Bat	V	1-11							
Scoteanax rueppellii	Greater Broad-nosed Bat	V	1-11							
Arboreal snakes										
Hoplocephalus bitorquatus	Pale-headed Snake	V	1-3, 6-8	Y	Y	N	N	Y	N	Yes
Hoplocephalus stephensii	Stephens' banded snake	V	1-3, 6-8							
Diurnal raptors										
Hieraaetus morphnoides	Little Eagle	V	1-11	N	N	N	N	N	N	No
Lophoictinia isura	Square-tailed Kite	V	1-11							
Erythrotriorchis radiatus	Red Goshawk	E	1-11							
Other fauna										
Calyptorhynchus lathami	Glossy black-cockatoo	V	1-7	Y	N	N	N	N	N	No
Dromaius novaehollandiae	Coastal Emu	E2	3-5	Y	Y	Y	N	Y	Y	Yes
Lichenostomus fasciogulari	Mangrove Honeyeater	V	4-5, 8-10	N	N	N	N	N	N	No
Pandion haliaetus	Eastern Osprey	V	1-11	N	N	N	N	N	N	No
Pezoporus wallicus wallicus	Ground Parrot	V	8-10	N	N	N	N	N	N	No
Potorous tridactylus	Long-nosed Potoroo	V	8-10	N	N	N	N	N	N	No
Tyto capensis	Eastern Grass Owl	V	1-11	N	N	N	N	N	N	No
Syconycteris australis	Common Blossom-Bat	V	8-11	N	N	N	N	N	N	No
Aepyprymnus rufescens	Rufous Bettong	V	1-8	N	N	N	N	Y	N	No
Cercartetus nanus	Eastern Pygmy-Possum	V	1-11	N	N	N	N	Y	N	No
Petaurus australis	Yellow-bellied Glider	V	1-9	Y	Y	N	N	Y	N	Yes
Petaurus norfolcensis	Squirrel Glider	V	1-11	Y	Y	N	N	Y	N	Yes

Species	Common name	TSC Act / FM Act	Project Section*	EP&A Act questions of significance*						Likely significant impact
				1	2	3	4	5	6	
Phascogale tapoatafa	Brush-tailed Phascogale	V	1-9	Y	Y	N	N	Y	N	Yes
Phascolarctos cinereus	Koala	V	9-11	Y	Y	N	N	Y	N	Yes
Planigale maculata	Common Planigale	V	1-11	N	Y	N	N	N	N	No
Crinia tinnula	Wallum Froglet	V	1-11	N	Y	N	N	N	N	No
Litoria brevipalmata	Green-thighed Frog	V	1-10	N	Y	N	N	N	N	No
Mixophyes iteratus	Giant Barred Frog	E	**1-3, 6-10**	Y	Y	N	N	N	N	Yes
Pteropus poliocephalus	Grey-headed Flying-fox	V	1-11	N	Y	N	N	N	N	No
Dasyurus maculatus	Spotted-tailed Quoll	E	1-11	Y	Y	N	N	Y	N	Yes
Lathamus discolor	Swift Parrot	E	1-11	Y	Y	N	N	N	N	Yes
Anthochaera phrygia	Regent Honeyeater	E	1-11	Y	Y	N	N	N	N	Yes
Petalura litorea	Coastal Petaltail	E	7-10	N	N	N	N	N	N	No
Glossopsitta pusilla	Little Lorikeet	V	1-11	N	Y	N	N	N	N	No
Climacteris picumnus	Brown Treecreeper	V	1-7	Y	N	N	N	N	N	No
Melithreptus gularis gularis	Black-chinned Honeyeater	V	1-3, 6-7							
Burhinus grallarius	Bush stone-curlew	E	1-3							
Pomatostomus temporalis temporalis	Grey-crowned Babbler	V	1-4, 6-10							
Nurus atlas	Atlas Rainforest Ground Beetle	E	9-11	Y	Y	Y	N	Y	N	Yes
Phyllodes imperialis	Pink Underwing Moth	E	9-11	Y	Y	Y	N	Y	N	Yes
THREATENED FLORA										
Acronychia littoralis	Scented Acronychia	V	9-11	N	N	N	N	N	N	No
Angophora robur	Sandstone Rough-barked Apple	V	3-4	N	Y	Y	N	Y	N	Yes
Arthraxon hispidus	Hairy Joint Grass	V	9-11	Y	Y	N	Y	Y	N	Yes
Archidendron hendersonii	White Lace Flower	V	9-11	Y	Y	Y	N	N	N	Yes
Centranthera cochinchinensis	Swamp Foxglove	E	1-11	N	N	N	N	N	N	No
Cryptocarya foetida	Stinking Cryptocarya	V	9-11	Y	Y	N	N	N	N	Yes
Cyperus aquatilis	Water Nutgrass	E	6-7	?	?	N	Y	Y	N	Yes
Dendrobium melaleucaphilum	Spider Orchid	E	1-11	N	N	N	N	N	N	No
Desmodium acanthocladum	Thorny Pea	V	8	N	N	N	N	N	N	No
Endiandra hayesii	Rose Walnut	E	9-11	?	?	N	Y	Y	N	Yes
Endiandra muelleri subsp. bracteata	Green-leaved Rose Walnut	E	9-11	?	?	N	Y	Y	N	Yes
Eucalyptus tetrapleura	Square-fruited Ironbark	V	2	N	N	N	Y	N	N	No
Grevillea quadricauda	Four-tailed grevillea	V	3	Y	N	N	N	N	N	No
Isoglossa eranthemoides	Isoglossa	E	9-11	N	N	Y	N	N	N	No
Lindsaea incisa	Slender Screw Fern	E	**1-3**, 6-11	Y	Y	N	N	N	N	Yes
Macadamia tetraphylla	Macadamia	V	10	Y	Y	N	N	N	N	Yes
Marsdenia longiloba	Slender Marsdenia	E	1-11	N	N	N	Y	N	N	No
Maundia triglochinoides	-	V	**1-3, 6-7**	Y	Y	N	N	N	N	Yes
Melaleuca irbyana	Weeping Paperbark	E	1-4, **6-8**	Y	Y	N	N	N	N	
Oberonia titania	Red flowered King of the Fairies	V	1-11	N	N	N	N	N	N	No
Olax angulata	Square-stemmed Olax	V	1-3	N	N	N	N	N	N	No

Species	Common name	TSC Act / FM Act	Project Section*	EP&A Act questions of significance*						Likely significant impact
				1	2	3	4	5	6	
Peristeranthus hillii		V	9-11	N	N	N	N	N	N	No
Prostanthera cineolifera	Singleton Mint Bush	V	7	Y	Y	Y	N	Y	N	Yes
Prostanthera palustris	*Swamp Mint Bush*	V	7	N	N	N	Y	N	N	No
Quassia sp. 'Moonee Creek'	Moonie Quassia	E	1-3, 9-11	N	N	N	N	N	N	No
Syzygium hodgkinsoniae	Red Lily Pilly	V	8-11	N	N	N	N	N	N	No
Tinospora tinosporoides	Arrow Head Vine	V	10	N	N	N	N	N	N	No
THREATENED FISH										
Nannoperca oxleyana	Oxleyan Pygmy Perch	E	1-2, 6-11	Y	Y	N	N	N	N	Yes
Mogurnda adspersa	Purple-spotted Gudgeon	E	1-2, 6-11	Y	N	N	N	N	N	No
Maccullochella ikei	Eastern Freshwater Cod	E	3-5	Y	N	N	N	N	N	No
ENDANGERED ECOLOGICAL COMMUNITIES										
Subtropical Coastal Floodplain Forest		E		-	Y	-	N	Y	N	Yes
Swamp Sclerophyll Forest		E		-	Y	-	N	Y	N	Yes
Swamp Oak Floodplain Forest		E		-	Y	-	N	Y	N	Yes
Freshwater Wetlands		E		-	Y	-	N	N	N	No
Lowland Rainforest		E		-	Y	-	Y	Y	N	Yes
Coastal Cypress Pine Forest		E		-	?	-	Y	N	N	Yes

. * Y= Yes (negative impact), N = No (no or positive impact), X = not applicable, ? = unknown impact, (-) indicates this question does not apply.

*Significance Assessment Questions as set out in the *Threatened Species Conservation Act 1995/ Environmental Planning and Assessment Act 1979.*

1. How is the project likely to affect the lifecycle of a threatened species and/or population?
2. How is the project likely to affect the habitat of a threatened species, population or ecological community?
3. Does the project affect any threatened species or populations that are at the limit of its known distribution?
4. How is the project likely to affect current disturbance regimes?
5. How is the project likely to affect habitat connectivity?
6. How is the project likely to affect critical habitat?

6.4. Commonwealth significance assessment

6.4.1. Endangered communities and threatened species

Full details of the assessment of significance for endangered communities and threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* are presented in Appendix E. The conclusions of the EPBC Act assessment of significance are provided in Table 6-2.

Table 6-2 Summary of Commonwealth significance assessments

Species	Common name	Project Section	Important pop^	EPBC Act significant impact questions*									Likely significant impact
				1	2	3	4	5	6	7	8	9	
CRITICALLY ENDANGERED ECOLOGICAL COMMUNITY													
Lowland Rainforest of Australia				Y	Y	Y	Y	N	Y	N	-	-	Yes
ENDANGERED FAUNA													
Cyclopsitta diophthalma coxeni	Double-Eyed Fig-Parrot	9-11	-	N	N	N	N	N	N	N	N	N	No
Lathamus discolor	Swift Parrot	1-11	-	N	Y	N	Y	N	N	N	N	N	Yes
Xanthomyza phrygia	Regent Honeyeater	1-11	-	N	Y	N	Y	N	N	N	N	N	Yes
Phyllodes imperialis	Pink Underwing Moth	9-11	-	Y	Y	N	Y	Y	Y	N	N	N	Yes
Petalura litorea	Coastal Petaltail	7-10	-	N	N	N	N	N	N	N	N	N	No
Dasyurus maculatus maculatus	Spotted-tailed Quoll	1-11	-	N	N	?	Y	?	N	N	N	N	Yes
Mixophyes iteratus	Giant Barred Frog	1-4, 6-10	-	Y	N	?	Y	N	N	N	N	N	Yes
Botaurus poiciloptilus	Australasian Bittern	1-4, 7-11	-	N	N	N	N	N	N	N	N	N	No
Rostratula australis	Australian Painted Snipe	1-11	-	N	N	N	N	N	N	N	N	N	No
ENDANGERED FISH													
Nannoperca oxleyana	Oxleyan Pygmy Perch	1-2, 6-11	-	N	Y	?	N	N	N	N	N	N	Yes
Maccullochella ikei	Eastern Freshwater Cod	3-5	-	N	N	N	N	N	N	N	N	N	No
ENDANGERED FLORA													
Acronychia littoralis	Scented Acronychia	9-11		N	N	N	N	N	N	N	N	N	No
Isoglossa eranthemoides	Isoglossa	9-11		N	N	N	N	N	N	N	N	N	No
Quassia sp. 'Moonee Creek'	Moonie Quassia	1-3, 9-11		N	N	N	N	N	N	N	N	N	No
VULNERABLE FAUNA													
Chalinolobus dwyeri	Large-eared Pied Bat	1-7	No	N	N	N	N	N	N	N	N	N	No
Erythrotriorchis radiatus	Red Goshawk	1-11	No	N	N	N	N	N	N	N	N	N	No
Pteropus poliocephalus	Grey-headed Flying-Fox	1-11	No	N	N	N	N	N	N	N	N	N	No
Litoria olongburensis	Olongburra Frog	1-11	No	N	N	N	N	N	N	N	N	N	No
Phascolarctos	Koala	1-3, 6-	No	N	Y	N	Y	N	N	N	N	N	Yes

Species	Common name	Project Section	Important pop^	EPBC Act significant impact questions*									Likely significant impact
				1	2	3	4	5	6	7	8	9	
cinereus		11											
Potorous tridactylus	Long-nosed Potoroo	8-10	No	N	N	N	N	N	N	N	N	N	No
VULNERABLE FLORA													
Angophora robur	Sandstone Rough Barked Apple	3-4	Yes	Y	Y	Y	Y	N	N	N	N	N	Yes
Arthraxon hispidus	Hairy Joint-grass	8-11	Yes	Y	Y	Y	Y	Y	N	N	N	N	Yes
Cryptocarya foetida	Stinking Cryptocarya	8-11	Yes	Y	Y	Y	Y	N	Y	N	N	N	Yes
Desmodium acanthocladum	Thorny Pea	8	No	N	N	N	N	N	N	N	N	N	No
Endiandra hayesii	Rusty Rose Walnut	8-11	Yes	Y	Y	Y	Y	N	Y	N	N	N	Yes
Eucalyptus tetrapleura	Square fruited Ironbark	2	Yes	N	Y	N	N	N	N	N	N	N	No
Grevillea quadricauda	Four-tailed Grevillea	3	No	N	Y	N	N	N	N	N	N	N	No
Macadamia tetraphylla	Rough-shelled Bush Nut	7-11	No	Y	Y	N	Y	N	Y	N	N	N	Yes
Marsdenia longiloba	Slender Marsdenia	1-11	No	N	N	N	N	N	N	N	N	N	No
Prostanthera cineolifera	Singleton Mint Bush	7	Yes	Y	Y	Y	Y	N	N	N	N	N	Yes
Prostanthera palustris	Swamp Mint Bush	7	No	N	N	N	N	N	N	N	N	N	No
Syzygium hodgkinsoniae	Red Lily Pilly	8-11	No	N	N	N	N	N	N	N	N	N	No
Tinospora tinosporoides	Arrow Head Vine	10	No	N	N	N	N	N	N	N	N	N	No

^ Important Population as determined by the *Environment Protection and Biodiversity Conservation Act 1999*, is one that for a vulnerable species:

a is likely to be key source populations either for breeding or dispersal
b is likely to be necessary for maintaining genetic diversity
c is at or near the limit of the species range.

*

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

6.4.2. Migratory species

Full details of the assessment of significance under the *Environment Protection and Biodiversity Conservation Act 1999* are presented in Appendix E. The conclusions of the assessments of significance on migratory species are provided in Table 6-3.

Table 6-3 Summary of Commonwealth significance assessment for migratory species

Migratory species	EPBC Act status	Important population in project area	Likely significant impact
Osprey (*Pandion haliaetus*)	Marine; Migratory (BONN)	No	No
Great Egret (*Egretta alba*)	Marine; Migratory (CAMBA, JAMBA)	No	No
Cattle Egret (*Ardea ibis*)	Marine; Migratory (CAMBA, JAMBA)	No	No
White-bellied Sea-Eagle (*Haliaeetus leucogaster*)	Marine; Migratory (CAMBA)	No	No
Satin Flycatcher (*Myiagra cyanoleuca*)	Marine; Migratory (BONN)	No	No
White Throated Needletail (*Hirundapus caudacutus*)	Marine; Migratory(CAMBA, JAMBA, ROKAMBA)	No	No
Rainbow Bee-eater (*Merops ornatus*)	Marine; Migratory (JAMBA)	No	No
Black-faced Monarch (*Monarcha melanopsis*)	Marine; Migratory (BONN)	No	No
Rufous Fantail (*Rhipidura rufifrons*)	Marine; Migratory (BONN)	No	No
Lathams Snipe (*Gallinago hardwickii*)	Marine; Migratory(CAMBA, JAMBA, ROKAMBA)	No	No
Australian Painted Snipe (Rostratula australis)	Marine; Migratory (CAMBA); Vulnerable	No	No
Spectacled Monarch (*Monarcha trivirgatus*)	Marine; Migratory (BONN)	No	No
Swift Parrot	Migratory	No	No
Regent Honeyeater	Migratory	No	No

1. Important Population as determined by the *Environment Protection and Biodiversity Conservation Act 1999*, is one that for a vulnerable species:

a is likely to be key source populations either for breeding or dispersal
b is likely to be necessary for maintaining genetic diversity
c is at or near the limit of the species range.

7. Conclusions

The project is located in a landscape that has been significantly altered by past land-uses and under continued pressure from population growth and development. Much of the native vegetation in the study area has been cleared or modified for agriculture and rural development, with the exception of the Summervale Range and associated footslopes, Wardell heath and state forests and conservation reserves of the region. This history of clearing in the region has placed greater importance on vegetation and habitat retained in the landscape, particularly in floodplain areas. Much of this vegetation is now listed as a threatened ecological community under both the *Threatened Species Conservation Act 1995* and the *Environment Protection and Biodiversity Conservation Act 1999* and provides habitat for a range of threatened flora, fauna and fish species.

The project would have a significant impact on aspects of the biodiversity of study area. There would be a loss of around 948 hectares of remnant vegetation in moderate to good condition, one third of which (337.7 hectares) consists of listed threatened ecological communities. The scale of this impact highlights the importance of mitigating and managing long-term indirect impacts to rare and high quality habitats and maintaining existing connectivity in the landscape.

This biodiversity assessment identifies matters which are relevant to the assessment of impacts to threatened species, populations, and ecological communities or their habitats arising from the project being assessed under Part 5.1 of the *Environmental Planning and Assessment Act, 1979*. Significance assessments indicate that the project is likely to have a significant impact on five endangered ecological communities, including the Critically Endangered Lowland Rainforest ecological community; at least 11 threatened flora species (11 listed under TSC Act and six of these also listed under EPBC Act); 14 threatened fauna species (14 TSC Act and six of these are also listed under the EPBC Act) in addition to the coastal Emu endangered population. Although mitigation measures would reduce impacts for these species and communities, they are not likely to ameliorate the impact entirely.

A summary of the survey and assessment process is provided in Appendix M.

7.1. Guiding principles for threatened species assessment

Under the *draft Guidelines for Threatened Species Assessment* (Department of Environment and Conservation and Department of Primary Industries 2005) under Part 5.1 of the *Environmental Planning and Assessment Act 1979*, the objective of the biodiversity assessment process is to provide information to enable decision-makers to ensure that developments deliver the following environmental outcomes:

- Maintain or improve biodiversity values (ie there is no net impact on threatened species or native vegetation)
- Conserve biological diversity and promote ecologically sustainable development
- Protect areas of high conservation value (including areas of critical habitat)
- Prevent the extinction of threatened species
- Protect the long-term viability of local populations of a species, population or ecological community
- Protect aspects of the environment that are matters of national environmental significance.

7.1.1. Key thresholds

The final step in the biodiversity assessment process is to provide justification of the project based on key thresholds. These key thresholds and the principles discussed have been taken into consideration in assessing the impacts on threatened species, populations and communities. The conclusion of the assessment with respect to addressing the key thresholds follows.

Table 7-1 Key thresholds and biodiversity assessment conclusions

Environmental outcomes	Conclusions
Whether or not the project, including actions to avoid or mitigate impacts or compensate to prevent unavoidable impacts would maintain or improve biodiversity values	The term maintain or improve is defined in the draft Guidelines for Threatened Species Assessment (Department of Environment and Conservation and Department of Primary Industries 2005) under Part 3A (repealed) of the Environmental Planning and Assessment Act 1979 as "*there is no net impact on threatened species or native vegetation*." Given that the project would result in clearing of native vegetation including (Critically) Endangered Ecological Communities and threatened species and their habitat, it is unlikely that this objective can be met and therefore it would be necessary to offset this impact to fulfil this outcome, as proposed.
Whether or not the project is likely to reduce the long-term viability of a local population of the species, population or ecological community	Mitigation and management measures have been recommended in this assessment in order to avoid and minimise impacts to biodiversity and as a result the long-term population viability of most threatened biota would be protected. However there is no conclusive scientific knowledge on the ability of each of the assessed species to sustain a loss of the magnitude expected or resilience to change including adaptation to the proposed mitigation measures. As such, there is a risk that the project could have a significant impact on several threatened flora and fauna, most notably the coastal emu endangered population and the critically endangered

Environmental outcomes	Conclusions
	Lowland Rainforest of Subtropical Australia present in the study area.
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	The North Coast Bioregion supports high biodiversity and a considerable number of the State and Commonwealth listed threatened species and ecological communities. Measures to avoid and mitigate key threatened processes have been duly considered through the route planning process and biodiversity management guidelines and recommendations. This thorough process would ensure the long-term protection of the majority of the threatened species identified as known or likely to occur in the study area. There is no conclusive scientific knowledge on the ability of each of the assessed species to sustain a loss of the magnitude expected or resilience to change including adaptation to the proposed mitigation measures. As such, there is a risk that the project could have a significant impact on several threatened flora and fauna, most notably the coastal emu endangered population and the critically endangered Lowland Rainforest of Subtropical Australia present in the study area.
Whether or not the project would adversely affect critical habitat	There is no critical habitat defined within the study area. However the vegetation within the study areas does have high conservation value given its listing as Endangered under the *Threatened Species Conservation Act 1995* and critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999.* Vegetation within portions of the study area is recognised in general of having high conservation value for some threatened species.

8. References

Abson, R. & Lawrence, R.E. (2003) Slaty Creek wildlife underpass study: Final Report. Centre for sustainable regional communities, Latrobe University. Bendigo.

Adams, L. W. and A. D. Geis. (1981). Effects of highways on wildlife. Federal Highway Administration Technical Report No. FHWA/RD-81/067.

Allison, F. R. & Hoye, G. A., (1998). *Eastern Freetail-bat* .pp. 484-485 in *The Mammals of Australia* (ed. by Strahan, R.). Australian Museum/ Reed Publications, Sydney.

AMBS Consulting (2001). An investigation of the use of road overpass structures by arboreal marsupials. Final Report, Prepared for NSW Roads and Traffic Authority, January 2001.

Andrews, A. (1990). Fragmentation of habitat by roads and utility corridors: a review. *Australian Zoologist* 26, 130-42.

Anstis, M. (2002). *Tadpoles of South-eastern Australia. A Guide with Keys*, New Holland Publishers, Sydney

Arthington, A. (1996) Recovery Plan for the Oxleyan Pygmy Perch, *Nannoperca oxleyana*. Centre for Catchment and In-stream Research Griffith University, Final Report to the Australian Nature Conservation Agency.

Australian Bureau of Statistics (2006) '2006 Census Data by Location'. Accessed online at http://www.censusdata.abs.gov.au/ABSNavigation/prenav/LocationList?newgeography=Local+Government+Area&level1=1&collection=Census&period=2006&areacode=&geography=Local+Government+Area&method=&productlabel=&producttype=&topic=&navmapdisplayed=true&javascript=true&breadcrumb=L&topholder=0&leftholder=0&currentaction=102&action=102&textversion=false&subaction=1

Australian Koala Foundation (2008). Richmond Valley Koala Habitat Atlas. Report prepared for the Richmond Valley Council.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC and ARMCANZ) (2000). *Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy*, Australian and New Zealand Environment and Conservation Council. Canberra. Accessed online at http://erin.gov.au/water/quality/nwqms/index.htmlExternal Link

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

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

Bax, D. (2006). Karuah ByPass Fauna Crossing. Thiess Pty Ltd and Roads and Traffic Authority, Sydney, NSW.

Beckers, D. (2008). Good from bad: is there an upside to roadkills? Pp 103-104 in Too Close for Comfort: contentious issues in human-wildlife encounters, edited by Daniel Lunney, Adam Munn and Will Meikle. 2008. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

Bennett, A. F. (1991). Roads, roadsides and wildlife conservation: a review. In 'Nature Conservation 2: The Role of Corridors'. (Eds D. A. Saunders and R. J. Hobbs.) pp. 99-1 18. (Surrey Beatty & Sons: Sydney.)

Biodiversity Assessment and Management (2012a) Ballina to Woodburn Pacific Highway Upgrade: Targeted Threatened Flora Study.

Biodiversity Assessment and Management (2012b). Ballina to Woodburn Pacific Highway Upgrade: Targeted Threatened Invertebrate Study.

Biosis (2007). Terrestrial and Aquatic Ecology Investigations for the Concept Design. Prepared for Hyder Consulting.

Blakers, M., Davies, S.J.J.F. and Reilly, P.N. (1984). The Atlas of Australian Birds. RAOU and Melbourne University Press, Melbourne.

Bond, A.R and Jones, D.N. (2008). Temporal trends in the use of fauna-friendly underpasses and overpasses. Wildlife Research 35, 103-112.

Braithwaite, L. W. (1984). The identification of conservation areas for possums and gliders within the Eden wood pulp concession district. In *'Possums and Gliders'*. (Eds A. P. Smith and I. D. Hume.). *Australian Mammal Society*: Sydney. pp. 501-508.

Brooker, M.I.H, Slee, A.V., Connors, J.R. and Duffy, S. (2002). EUCLID – Eucalypts of southern Australia. CD. CSIRO Publishing, Melbourne.

Burbidge A.A. & McKenzie N. L. (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications*. Biological Conservation* (50), 143–98.

Butler, G., (2009). *Environmental water monitoring in unregulated rivers – Review of the ecology and environmental water requirements of the endangered Eastern Freshwater Cod.* NSW Office of Water, Sydney

Byrnes, P., Goosem, M., Turton, S.M. (2012). Are less vocal rainforest mammals susceptible to impacts from traffic noise? *Wildlife Research* **39**, 355-365.

Chenoweth Environmental Planning and Landscape Architecture. (2008). Wongaling Corridors Fauna Crossings. Prepared for Terrain NRM. Check? Pg 169

Churchill, S. (1998). *Australian Bats*. Reed New Holland. Frenchs Forest, N.S.W.

Clancy, G.P (1991). The biology and management of the Osprey (*Pandion haliaetus cristatus*). Species Management Report No.6, NPWS Hurstville, Sydney.

Clancy, G.P (2010). The distribution of the Black-necked Stork Ephippiorhynchus asiaticus australis in New South Wales since 1790. *Corella* 34(7) 7-10.

Clarence Valley Council (2010). Biodiversity Management Strategy 2010. NSW. Grafton.

Clarence Valley Council (2010). Comprehensive koala plan of management for the Ashby, Woombah and Iluka localities of the Clarence Valley LGA.

Coffs Harbour City Council (1999). Coffs Harbour City Council Koala Plan of Management. Reported prepared by the NSW National parks and Wildlife Service and Coffs Harbour City Council

Connell Wagner (2008). Iluka Road to Woodburn; Upgrading the Pacific Highway – Ecological Assessment Working Paper.

Cotterell, E. (1998). Fish Passage in Streams: Fisheries guidelines for design of stream crossings. Fish Habitat Guideline FHG 001, Fisheries Group, Queensland Department of Primary Industry. pp.44.

Cuttle, P. (1982) Life history strategy of the dasyurid marsupial *Phascogale tapoatafa*. In *Carnivorous marsupials* (ed. M. Archer), pp. 13–22. Sydney: Royal Zoology Society of New South Wales.

Davey, S. M. (1984). Habitat preferences of arboreal marsupials within a coastal forest in southern New South Wales. In 'Possums and Gliders'. (Eds A. P. Smith and I. D. Hume.). Australian Mammal Society: Sydney. pp. 509-516.

Davies K.F., Margules C.R. and Lawrence J.F. 2000.Which traits of species predict population declines in experimental forest fragments? Ecology 81: 1450–1461.

Debus, S.J.S. (1997). Vocal behaviour of the Southern Boobook *Ninox novaeseelandiae* and other nocturnal birds. In Czechura, G. & Debus, S. (Eds), *Australian Raptor Studies II*. Birds Australia Monograph 3, Birds Australia, Melbourne, pp. 71-85.

Debus, S.J.S. and Chafer, C.J. (1994). The Powerful Owl *Ninox strenua* in New South Wales. *Aust. Birds* 28 (Suppl.):S21-S38.

Debus, S.J.S. (1995). Surveys of large forest owls in northern New South Wales: methodology, calling behaviour and owl responses. *Corella* **19**: 38-50.

Debus, S.J.S. (2001). Surveys of the Barking Owl and Masked Owl on the North-west Slopes of New South Wales. *Corella* **25**: 5-11.

Debus, S.J.S., Agnew, L.R. & Schulz, M. (2001). Surveys of the Grass Owl *Tyto capensis* in coastal New South Wales. *Aust. Bird Watcher* **19**: 94-102.

Debus, S.J.S., Agnew, L.R. & Schulz, M. (2001). Surveys of the Grass Owl *Tyto capensis* in coastal New South Wales. *Aust. Bird Watcher* **19**: 94-102.

Debus, S.J.S., Maciejewski, S.E. & McAllan, I.A.W. (1998). The Grass Owl in New South Wales. *Aust. Birds* **31**: 29-45.

Department of Environment and Climate Change (DECC) (2007). Landscape selection process: key altitudinal, latitudinal and coastal corridors for response to climate change. Report prepared by the NSW Department of Environment and Climate Change for the Northern Rivers Catchment Management Authority.

Department of Environment and Climate Change (DECC) (2008a). *Conservation Assessment of wetland in the Clarence Lowlands IBRA Subregion*. Department of Environment and Climate Change NSW. South Sydney.

Department of Environment and Climate Change (DECC) (2008b). Hygiene protocol for the control of disease in frogs. Information Circular Number 6. Department of Environment and Climate Change NSW. South Sydney.

Department of Environment and Climate Change (DECC) (2008c). *Recovery Plan for the Koala (Phascolarctos cinereus)*. Department of Environment and Climate Change NSW. Sydney.

Department of Environment and Climate Change (DECC) (2009a). *Threatened Species Survey and Assessment Guidelines: Field Survey Methods for Fauna – Amphibians*, Department of Environment and Climate Change. NSW Department of Environment and Climate Change, NSW, Sydney.

Department of Environment and Climate Change (DECC) (2009b).*There were always people here: a history of Yuraygir National Park.* Department of Environment and Climate Change. Sydney South.

Department of Environment and Conservation (DEC) (2003). Key Habitats and Wildlife Corridors in North East New South Wales. NSW Department of Environment and Conservation. Accessed online at http://maps.nationalparks.nsw.gov.au/keyhabs/default.htm

Department of Environment and Conservation (DEC) (2004). Threatened Biodiversity Survey and Assessment: Guidelines for developments and activities (working draft), NSW Department of Environment and Conservation, Hurstville, NSW.

Department of Environment and Conservation and Department of Primary Industries (DEC & DPI) (2005). Draft Guidelines for Threatened Species Assessment. Department of Environment and Conservation, Hurstville

Department of Environment, Climate Change and Water (DECCW) (2009). 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.

Department of Environment, Climate Change and Water (DECCW) (2010a). Environmental Outcome Assessment Methodology. Accessed online at http://www.environment.nsw.gov.au/vegetation/eoam.htm

Department of Environment, Climate Change and Water (DECCW) (2010b). Biobanking Assessment Methodology. Biobanking Threatened Species Profile Database. Assessed online at http://www.environment.nsw.gov.au/biobanking/biobankingtspd.htm

Department of Environment, Climate Change and Water (DECCW) (2010c). Threatened Species Profile Database. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au/index.aspx separate species to add

Department of Environment, Climate Change and Water (DECCW) (2010d). The Draft Mid-North Coast Regional Conservation Plan. Accessed online at http://www.environment.nsw.gov.au/biodiversity/regconsplans.htm

Department of Environment, Climate Change and Water (DECCW) (2010f). Northern Rivers Regional Biodiversity Management Plan. *National Recovery Plan for the Northern Rivers Region*, Department of Environment, Climate Change and Water, NSW, Sydney.

Department of Environment, Water, Heritage and the Arts (DEWHA) (2009). Matters of National Environmental Significance: significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999, ACT, Barton.

Department of Industry and Investment (DII) (2010). Preliminary identification of critical habitat for the Oxleyan Pygmy Perch (Nannoperca oxleyana). Public consultation document.

Department of Primary Industries (2005). Oxleyan pygmy perch: Recovery Plan and background paper. NSW Department of Primary Industries Fisheries Management Branch, Port Stephens, NSW.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2009). EBPC Act Protected Matters Search Tool. Department of the Environment, Water, Heritage and the Arts. Canberra. ACT. Accessed online at http://www.environment.gov.au/epbc/pmst/index.html

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2010a). What is protected under the EPBC Act? - Matters of national environmental significance. Accessed online at http://www.environment.gov.au/epbc/protect/index.html

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2010b). Search for a Nationally Important Wetland. Accessed online at http://www.environment.gov.au/cgi-bin/wetlands/search.pl?smode=DOIW

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2011). Survey guidelines for Australia's threatened fish. Commonwealth of Australia, 60pp.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2012a). Census of Australian Vertebrate Species: Biocodes (CAVS). Accessed online at http://www.environment.gov.au/biodiversity//abrs/online-resources/fauna/cavs/index.html

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

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2012c). Lowland Rainforest and Landholders: Protecting the critically endangered Lowland Rainforest of Subtropical Australia.

Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (2012d). Species Profile and Threats Database (SPRAT). Accessed online at http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Department of Sustainability, Environment, Water, Population and Communities (DSEWPAC 2012e). Environment Protection and Biodiversity Conservation Act, 1999: Environmental Offsets Policy.

Doerr, V.A.J., Doerr, E.D, and Davies, M.J. (2011). Dispersal behaviour of Brown Treecreepers predicts functional connectivity for several other woodland birds. *Emu* 111, 71-83.

Dwyer, P.D. (1995). Common Bentwing-bat *Miniopterus schreibersii*. **in:** R. Strahan (ed.) *The Mammals of Australia*. Reed Books Australia, Chatswood. pp 494-5.

Dytham, C. (2005). *Choosing and Using Statistics: A Biologists Guide (2nd Ed.).* Blackwell Publishing: Malden, MA.

Eby, P. and Law, B. 2008. Ranking the feeding habitat of Grey-headed flying foxes for conservation management. Department of Environment, Heritage, Water and the Arts, Canberra.

Ecology lab (2009). Wells Crossing to Iluka Road Upgrading the Pacific Highway Concept Design Report-Aquatic Ecology Working Paper.

Ecos Environmental (2006). Vegetation survey of the investigation area for the upgrade of the Pacific Highway between Iluka Road to Woodburn (incorporating summer survey). Prepared for Connell Wagner Pty Ltd.

Ecosense Consulting (2008). Independent ecological review of the route options incorporating vegetation community survey and targeted aquatic survey.

Ecotone Ecological Consultants (2006). Woolgoolga to Wells Crossing; Upgrading the Pacific Highway – Advanced Terrestrial Flora and Fauna Assessment Working Paper.

Ehmann, H. (1997). Wallum Froglet. Pg 48-55 *in Threatened Frogs of New South Wales: Habitats, Status and Conservation* Edited by H. Ehmann 1997. FATS Group Publication, Sydney.

Environment Australia (2001). A Directory of Important Wetlands in Australia, Third Edition. Environment Australia, Canberra.

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.

Ferris, C. R. 1979. Effects of interstate 95 on breeding birds in northern Maine. Journal of Wildlife Management. 43: 421-427.

Fitzgerald, M. Shine, R and Lemckert, F (2003). Life history attributes of the threatened Australian snake (Stephen's banded snake Hoplocephalus stephensii, Elapidae). Biological Conservation 119 (2004) 121–128

Floyd A (1990a) Australian rainforests in New South Wales. Volume 1. (Surrey Beatty and Sons: Sydney.)

Floyd A (1990b) Australian rainforests in New South Wales. Volume 2. (Surrey Beatty and Sons: Sydney.)

Frederick, H and Johnson, CN (1996) . Social Organisation in the Rufous Bettong, Aepyprymnus Rufescens. *Australian Journal of Zoology* ***44*** (1): 9–17.

Frith, H.J., F.H.J. Crome & B.K. Brown (1977). Aspects of the Biology of the Japanese Snipe *Gallinago hardwickii*. *Australian Journal of Ecology*. **2**:341-368.

Geolyse (2005). Flora and Fauna Assessment Options Volume 1: Phase 1 and Phase 2 investigations. Proposed Woodburn to Ballina Pacific Highway Upgrade.

Geolyse (2007). Phase Three Fauna Studies Summer Winter and Spring Field Investigations. Prepared for Hyder Consulting.

GHD (2007). Pacific Highway Upgrade – Woolgoolga to Wells Crossing: Preferred Route Aquatic Ecology Survey.

Gibbons, P., Ayers, D., Seddon, J., Doyle, S., Briggs, S., (2008). BioMetric Version 2.0. A Terrestrial Biodiversity Assessment Tool for the NSW Native Vegetation Assessment Tool. Operational Manual. Department of Environment and Climate Change NSW, unpublished.

Gibbons P and Lindenmayer D (2002). *Tree hollows and wildlife conservation in Australia*. CSIRO Publishing.

Goldingay R.L and Taylor, B.D. (2009). Gliding performance and its relevance to gap crossing by the squirrel glider (Petaurus norfolcensis). Australian Journal of Zoology; 57, 97-104.

Goldingay R.L. and Kavanagh R.P. (1991). The Yellow-bellied Glider: a review of its ecology, and management considerations, in D. Lunney (Ed.) Conservation of Australia's Forest Fauna. pp. 365-375. Mosman, NSW.

Goldingay, R.L. and Kavanagh, R.P. (1990) . Socioecology of the Yellow-Bellied Glider, Petaurus-Australis, at Waratah-Creek, NSW***.*** *Australian Journal of Zoology* ***38*** (3): 327–341.

Goldingay, R.L., and Stevens R.J.(2009). Use of artificial tree hollows by Australian birds and bats. *Wildlife Research* 86 (81-97).

Goldingay, R.L., Taylor, B.D., and Ball, T., (2011). Wooden poles can provide habitat connectivity for a gliding mammal. *Australian Mammalogy*, **33**, 36-43.

Goldingay, R., Rohweder, D., Taylor, B. (2012). Will arboreal mammals use rope bridges across a highway in eastern Australia. Australian Mammology 2012.

Goosem, M. (2005) Effectiveness of rope bridge arboreal overpasses and faunal underpasses in providing connectivity for rainforest fauna, International conference on Ecology and Transportation 2005 Proceedings. Pp. 304-322.

Harden, G.J. (ed.) (1992). *Flora of New South Wales* Vol.3. Royal Botanic Gardens. NSW University Press, Sydney.

Harden, G.J. (ed.) (1993). *Flora of New South Wales.* Vol.4. Royal Botanic Gardens. NSW University Press, Sydney.

Harden, G.J. (ed.) (2000). *Flora of New South Wales* Vol .1. Royal Botanic Gardens. NSW University Press, Sydney.

Harden, G.J. (ed.) (2002). *Flora of New South Wales* Vol.2. Royal Botanic Gardens. NSW University Press Sydney.

Harper, M.J., McCarthy, M.A and van der Ree, R. (2004). The use of nest boxes in urban vegetation remnants by vertebrate fauna. *Wildlife Research* 32(6) 509-516.

Hayes, I., and Goldingay. R.L. (2009). Use of fauna crossing structures in north-eastern New South Wales. Australian Mammalogy; 31, 89-95.

Henle, K., Davies, K.F., Kleyer, M, Margules, C., Settele, J. (2004). Predictors of species sensitivity to fragmentation. *Biodiversity and Conservation* 13: 207-251.

Henry, S.R. & Craig, S.A. (1984). Diet, ranging behaviour and social organization of the yellow-bellied glider *(Petaurus australis* Shaw) in Victoria. **In:** Smith, A. & Hume, I.D., eds. *Possums and gliders*. Surrey Beatty & Sons Pty Ltd. Canberra. pp 331-341.

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

Hoye G.A. and Richards G.C. (1995). Greater Broad-nosed Bat *Scoteanax rueppellii*. pp. 527–528 *in* R. Strahan (Ed.) *The Mammals of Australia*. Reed Books, Chatswood, NSW.

Hughes, R.L. (1962). Reproduction in the macropod marsupial *Potorous tridactylus* (Kerr). *Australian Journal of Zoology*. **10** (2):192-224.

Hyder Consulting (2007).Upgrading the Pacific Highway H10 – Woodburn to Ballina Oxleyan Pygmy Perch Options Report.

Hyder Consulting (2008). Woodburn to Ballina; Upgrading the Pacific Highway - Technical Review of the Ecological Investigations for the Route Selection Process.

Hyder Consulting (2009) Pacific Highway Upgrade – Devils Pulpit Project – Technical Working Paper – Ecology. Roads and Traffic Authority NSW.

Johnson, LAS & Hill, KD (1990). New taxa and combinations in *Eucalyptus* and *Angophora* (Myrtaceae). *Telopea* **4** (1): 37-108.

Kaseloo, P. A. (2006). Synthesis of noise effects on wildlife populations. In 'Proceedings of the 2005 International Conference on Ecology and Transportation'. (Eds C. L. Irwin, P. Garrett and K. P. McDermott.) pp. 33–35. (Center for Transportation and the Environment, North Carolina State University: Raleigh, NC.)

Kavanagh, R. P. (1984). Seasonal changes in habitat use by gliders and possums in south-eastern New South Wales. In 'Possums and Gliders'. (Eds A. P. Smith and I. D. Hume.). *Australian Mammal Society:* Sydney. pp. 527-543.

Kavanagh, R.P. and Bamkin, K.L. (1995). Distribution of nocturnal forest birds and mammals in relation to the logging mosaic in south-eastern New South Wales, Australia. *Biological Conservation* **71** (1): 41-53.

Kavanagh, R.P., Debus, S., Tweedie, T. and Webster, R. (1995). Distribution of nocturnal forest birds and mammals in north-eastern New South Wales: relationships with environmental variables and management history. *Wildlife Research* **22** (3): 359-377.

Kavanagh, R.P., and Murray, M. (1996). Home range, habitat and behaviour of the Masked Owl (Tyto novaehollandiae) near Newcastle, NSW. Emu 96(4) 250-257.

Kavanagh, R. P & Peake, P. (1993). Survey procedures for nocturnal forest birds: an evaluation of variability in census results due to temporal factors, weather and technique. Australian Raptor Studies. P. Olsen. Melbourne, Australasian Raptor Association/ Royal Australasian Ornithologists Union. Pp: 86-100.

Keith, D. (2004). *Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT*. Department of Environment and Conservation. Hurstville. NSW.

Knight, J.T. (2000). *Distribution, populations structure and habitat preferences of the Oxleyan pygmy perch* Nannoperca oxleyana *(Whitley 1940) near Evans Head, north-eastern New South Wales*. Page(s) 141. Hons. Thesis. Southern Cross University, Lismore. Unpublished.

Knight J.T., Glasby T.M. & Brooks L.O. (2007) A sampling protocol for the endangered freshwater fish, Oxleyan Pygmy Perch *Nannoperca oxleyana.* Whitley, *Australian Zoologist* **34**(2):148-157.

Knight, J.T. and Arthington, A.H. (2008). Distribution and habitat associations of the endangered Oxleyan pygmy perch, *Nannoperca oxleyana* Whitley, in eastern Australia. Aquatic Conservation Marine and Freshwater Ecosystems 18 (7): 1240-1254.

Knight, J.T., Nock, C.J., Elphinstone, M.S., and Baverstock, P.R (2009). Conservation implications of distinct structuring in the endangered freshwater fish *Nannoperca oxleyana* (Percichthyidae). Marine and Freshwater Research, 2009, 60: 34-44.

Law B.S. (1994**).** Banksia nectar and pollen: Dietary items affecting the abundance of the common blossom bat, Syconycteris australis**,** in southeastern Australia in NSW. *Australian Journal of Ecology 19*(4): 425-434.

Law, B, Mackowski, C, Schoer & L, Tweedie, T. (2000) Flowering phenology of myrtaceous trees and their relation to climatic, environmental and disturbance variables in northern New South Wales. Austral Ecology **25** (2):160–178.

Lewis Ecological Surveys (2006). Proposed Pacific Highway Upgrade between Iluka Road and Woodburn: Targeted Frog Survey. Prepared for Connell Wagner Pty Ltd.

Lewis, B.D. and Rohweder, D.A. (2005) Distribution, habitat, and conservation status of the giant barred frog (Mixophyes iteratus) in the Bungawalbin Catchment. Pacific Conservation Biology **11**(3): 189-197.

Lumsden, L.F. and Bennett, A.F. (2004). Scattered trees in rural landscapes: foraging habitat for insectivorous bats in south-eastern Australia. *Biological Conservation **122*** (2): 205-222.

Lunney, D. and Barker, J. (1986). The occurrence of *Phoniscus papuensis* (Dobson) (Chiroptera: Vespertilionidae) on the south coast of New South Wales. *Australian Mammalogy* **9**, 57–58.

Lynch J.F. (1987). Responses of breeding bird communities to forest fragmentation. In: Saunders D.A., Arnold G.W., Burbidge A.A. and Hopkins A.J.M. (eds), Nature Conservation:

The Role of Remnants of Native Vegetation. Surrey Beatty, Chipping Norton, Australia, pp. 123–140.

Lytle, D.A. (2001). Disturbance regimes and life-history evolution. The American Naturalist; 157 (5), 525-536.

Maciejewski, S. E. (1997). The Grass Owl *Tyto capensis* in north-eastern New South Wales. *Birds* Pp. 54-70 in *Australian Raptor Studies II.* G. Czechura and S. Debus (eds). *Birds Australia Monograph 3.* Birds Australia, Melbourne.

Mansergh, I. (1983). The status, distribution and abundance of Dasyurus maculatus (tiger quoll) in Australia, with particular reference to Victoria. *Australian Zoologist* **21**, 109–122.

Marchant, S., & P.J. Higgins (eds) (1993). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 2: Raptors to Lapwings.* Oxford University Press, Melbourne

May, S.A and Norton, T.W. (1996). Influence of fragmentation and disturbance on the potential impact of feral predators on native fauna in Australian forest ecosystems. *Wildlife Research*,(23),387-400

Menkhorst P.W., Weavers B.W. and Alexander J.S.A. (1988). Distribution, Habitat and Conservation Status of the Squirrel Glider *Petaurus australis* (Petauridae: Marsupialia) in Victoria. *Australian Wildlife Research* **15**(1): 59-71.

Mitchell, P.B. (2003). NSW Ecosystems database mapping unit descriptions. Unpublished report to the NSW National Parks and Wildlife Service, Hurstville.

Moon, C. (1998). 'Lindsays cutting koala monitoring program'. Pp. 53–81 in Proceedings of A Conference on the Status of the Koala in 1998. Australian Koala Foundation, Brisbane.

Morgan, G. (2001a) Landscape health in Australia : a rapid assessment of the relative condition of Australia's bioregions and subregions : prepared by Gethin Morgan for Environment Australia and the National Land and Water Resource Audit. Environment of Australia ; National Land and Water Resources Audit, Turner, A.C.T.

Morgan, G. (2001b). Delineation and description of the Eastern Environmental Subregions (provinces) in New South Wales Study. NSW NPWS. Hurstville.

Mount King Ecological Surveys 1993. Fauna survey of the Kempsey and Wauchope Forestry Management Areas. A report to the Forestry Commission of New South Wales, Sydney.

National Parks and Wildlife Service (NPWS) (1999a). Forest Ecosystem Classification and Mapping for Upper and Lower North East CRA Regions. Unpublished report by the CRA Unit, Northern Zone National Parks and Wildlife Service to the Joint Commonwealth NSW Regional Forest Agreement Steering Committee. NPWS 1998 database? Pg 21

National Parks and Wildlife Service (NPWS) (1999b). Threatened Species Information: Yellow Bellied Glider. Threatened Species Unit, Policy and Science Directorate. Hurtsville.

National Parks and Wildlife Service (NPWS) (2001) Key habitats and corridors Not sure how to reference pg 21 should it be (DEC), (2003).

National Parks and Wildlife Service (NPWS) (2002a). Threatened Species of the Upper North Coast of NSW: Fauna. NSW National Parks and Wildlife Service, Hurstville.

National Parks and Wildlife Service (NPWS) (2002b). Threatened Species of the Upper North Coast of NSW: Flora. NSW National Parks and Wildlife Service, Hurstville.

National Parks and Wildlife Service (NPWS) (2005o

National Parks and Wildlife Service (NPWS) (2009a) Sherwood Nature Reserve Forest Plan of Management, March 2009. Prepared by the NSW National Parks and Wildlife Service, Department of Environment of Climate change, Sydney, NSW.

National Parks and Wildlife Service (NPWS) (2009b) Munro island Nature Reserve Plan of Management, September 2009. Prepared by the NSW National Parks and Wildlife Service, Department of Environment and Climate change, Sydney, NSW

National Parks and Wildlife Service (NPWS) (2009c) Yaegl Nature Reserve Draft Plan of Management, January 2009. Prepared by the NSW National Parks and Wildlife Service, NSW Department of Environment and Climate Change, Sydney, NSW.

National Parks and Wildlife Service (NPWS) (2009d) Clarence Estuary Nature Reserve Draft Plan of Management, September 2007. Prepared by the NSW National Parks and Wildlife Service, NSW Department of Environment and Climate Change, Sydney, NSW.

National Parks and Wildlife Service (NPWS) (2009e) Mororo Creek Nature Reserve and Chatsworth Hill State Conservation Area Draft Plan of Management, March 2009. Prepared by the NSW National Parks and Wildlife Service, NSW Department of Environment and Climate Change, Sydney, NSW.

NRCMA (2005). Northern Rivers Catchment Action Plan, Northern Rivers Catchment Management Authority, Grafton.

NSW Fisheries (1999). Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures. eds. S. Fairfull and S.Carter, NSW Fisheries. Pg 112

NSW Fisheries (1999). *Policy and Guidelines: aquatic habitat management and fish conservation 1999*. eds A Smith & D Pollard. NSW Fisheries. Taylors Beach. NSW. Which cite ? pg 112

NSW Fisheries (2004) *Eastern (Freshwater) Cod (Maccullochella ikei) Recovery Plan.* Accessed online at http://www.environment.gov.au/biodiversity/threatened/publications/recovery/m-ikei/pubs/m-ikei.pdf

NSW National Parks and Wildlife Service (1999b). *Threatened Species Information: Brush-tailed Phascogale*, National Parks and Wildlife Service Hurstville.

NSW National Parks and Wildlife Service (1999c). *Threatened Species Information: Yellow-bellied Glider*. National Parks and Wildlife Service. Hurstville.

NSW National Parks and Wildlife Service (2005) *Northern Directorate – Common Planigale Planigale maculata,* http://maps.nationalparks.nsw.gov.au/keyhabs/pdf/CommonPlanigale.pdf

NSW North Coast Regional Biodiversity Strategy (DECC 2010f).

Nye, E.R., Dickman, N.R., Kingsford, R.T. (2007). A wild goose chase – temporal and spatial variation in the distribution of the Magpie Goose (*Anseranus semipalmata*) in Australia. *Emu,* 107, 28-37.

Oldroyd, B.P., Lawler, S.H., and Crozier, R.H. (2004). Do feral honey bees (*Apis mellifera*) and regent parrots (*Polytelis anthopeplus*) compete for nest sites? Australian Journal of Ecology; 19(4); 444–450.

Office of Environment and Heritage (OEH) (2011). Principles for the use of biodiversity offsets in NSW. Accessed online at http://www.environment.nsw.gov.au/biocertification/offsets.htm

Office of Environment and Heritage (OEH) (2012a). BioMetric: Terrestrial Biodiversity Tool for the NSW Property Vegetation Planning System. Accessed online at http://www.environment.nsw.gov.au/projects/biometrictool.htm

Office of Environment and Heritage (OEH) (2012b). NSW Bionet: Atlas of NSW Wildlife. Hurstville. NSW. Accessed online at http://www.bionet.nsw.gov.au/

Office of Environment and Heritage (OEH) (2012c) *Threatened Species Profile Search:* Water Nutgrass. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au extension

Office of Environment and Heritage (OEH) (2012d). *Threatened Species Profile Search:* Giant Barred Frog. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012e). *Threatened Species Profile Search:* Hoary Wattled Bat. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012f). *Threatened Species Profile Search:* Eastern Long-Eared Bat. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012g). *Threatened Species Profile Search:* Rufous Bettong . Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012h). *Threatened Species Profile Search:* Common Planigale . Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012i). *Threatened Species Profile Search:* Wallum Froglet. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012j). *Threatened Species Profile Search:* Green-thighed Frog. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012k). *Threatened Species Profile Search:* Stephens' banded. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Office of Environment and Heritage (OEH) (2012l). *Threatened Species Profile Search:* Wallum Sedge Froglet. Accessed online at http://www.threatenedspecies.environment.nsw.gov.au

Parnaby H. and Mills D. (1994). A record of the Golden-tipped Bat from the escarpment forests of southern New South Wales. *Australian Zoologist* **29**, 245–249.

Phillips, S.S. (2000). Tree Species Preferences of the Koala *Phascolarctos cinereus* as a Basis for the Delineation of Management Areas for Recovery Planning in New South Wales. Unpublished report prepared for the Koala Recovery Plan.

Pizzey, G and Knight, F. (1997). *The Graham Pizzey & Frank Knight field guide to the birds of Australia / Graham Pizzey*; illustrated by Frank Knight Angus & Robertson: HarperCollins, Pymble, N.S.W.

Pusey, B., Kennard, M., & Arthington, A. (2004) Freshwater Fishes of North-Eastern Australia. CSIRO Publishing, Collingwood.

Quin D.G. (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**(4): 471-505.

Recher H.F., Shields J., Kavanagh R. and Webb G. (1987). Retaining remnant mature forest for nature conservation at Eden, New South Wales: a review of theory and practice. In: Saunders D.A., Arnold G.W., Burbidge A.A. and Hopkins A.J.M. (eds), Nature Conservation: The Role of Remnants of Native Vegetation. Surrey Beatty, Chipping Norton, Australia, pp. 177–194.

Reed, R.N., Shine, R., (2002). Lying in wait for extinction: ecological correlates of conservation status among Australian snakes. *Conservation Biology* 16, 451–461.

Reijnen, R., R. Foppen, and G. Veenbaas. 1997. Disturbance by traffic of breeding birds: evaluation of the effect and planning and managing road corridors. Biodiversity and Conservation 6: 567-581.

Resource and Conservation Division (2001) Comprehensive Regional Assessment Floristic Types Information (CRAFTI)

Robert, C & Petersen J.R. (1992). The RCE: a Riparian, Channel and Environmental Inventory for small streams in the agricultural landscape. *Freshwater Biology* **27**(2): 295-306.

Royal Botanic Gardens and Domain Trust (2012). PlantNET - The Plant Information Network System of The Royal Botanic Gardens and Domain Trust, Sydney, Australia. Accessed online at http://plantnet.rbgsyd.nsw.gov.au

Royal Zoological Society of NSW, Mosman. Forman, R. T. T. and L. E. Alexander (1998). Roads and their major ecological effects. Annual Review of Ecology and Systematics 29: 207-231.

Roads and Maritime Services (2011). Guideline for Biodiversity Offsets. NSW Roads and Maritime Services, Sydney.

Roads and Traffic Authority (RTA) (2005a). Woolgoolga to Wells Crossing Route Options Report.

Roads and Traffic Authority (RTA) (2005b). Wells Crossing to Iluka Road Route Options Development Report.

Roads and Traffic Authority (RTA) (2005c).Woodburn to Ballina Route Options Development Report.

Roads and Traffic Authority (RTA) (2005d).Woodburn to Ballina Upgrade Preferred Route Report.

Roads and Traffic Authority (RTA) (2006-2011)

Roads and Traffic Authority (RTA) (2006a). Woolgoolga to Wells Crossing Preferred Route Report.

Roads and Traffic Authority (RTA) (2006b). Wells Crossing to Iluka Road Preferred Route Report.

Roads and Traffic Authority (RTA) (2006c).Iluka Road to Woodburn Concept Design Report.

Roads and Traffic Authority (RTA) (2008a). Woolgoolga to Wells Crossing Concept Design Report, April 2008. Roads and Traffic Authority of NSW: Sydney.

Roads and Traffic Authority (RTA) (2008b). Iluka Road to Woodburn Preferred Concept Design Report, July 2008. Roads and Traffic Authority of NSW: Sydney.

Roads and Traffic Authority (RTA) (2008c). Woodburn to Ballina upgrade Concept Design Report, March 2008. Roads and Traffic Authority of NSW: Sydney.

Roads and Traffic Authority (RTA) (2009). Wells Crossing to Iluka Road Concept Design Report, January 2009. Roads and Traffic Authority of NSW: Sydney.

Roads and Traffic Authority (RTA) (2010). *Draft Wildlife Connectivity Guidelines: improving wildlife connectivity on RTA projects* not sure where to find pg 203 pg 182 (M&R)

Roads and Traffic Authority (RTA) (2010). Upgrading the Pacific Highway, Wells Crossing to Iluka Road Discussion paper on Tyndale to Maclean alternative route, Roads and Traffic Authority, Grafton.

Roads and Traffic Authority (2011a) Biodiversity Guidelines – Protecting and managing biodiversity on RTA projects, Roads and Traffic Authority of New South Wales.

Roads and Traffic Authority (RTA) (2011b). Tyndale to Maclean Alternative Alignment Decision Report, August 2011. Roads and Traffic Authority of NSW: Sydney.

Ryan, B. (2001). An Investigation of the use of road overpass structures by arboreal marsupials, Mammals Society conference, Brisbane, Australia.

SEMC (2007) Review of mitigation measures used to deal with the issue of habitat fragmentation. Department of the Environment and Water Resources. Symonston. ACT.

Schulz, M (1997). The Little Bent-wing Bat Miniopterus australis roosting in a tree hollow. Australian Zoologist 30(3): 329.

Schulz, M and Eyre, T.J. (2000). Habitat selection by the rare golden-tipped bat *Kerivoula papuensis. Australian Mammalogy*. **22**(1): 23-33.

Scotts, D (2003). Key habitat corridors for forest fauna. A landscape framework for conservation in north-east New South Wales. Occasional Paper 32, NSW National Parks and Wildlife Service, Sydney.

Sheringham, P & Westaway, J (1995). Significant Vascular Plants of Upper North East NSW: report to the Natural Resources Audit Council. New South Wales National Parks and Wildlife Service. Hurstville.

Simpson, K. & Day, N. (1999). Field Guide to the Birds of Australia. Penguin Books, Ringwood.

SKM (2009). Wells Crossing to Iluka Road; Upgrading the Pacific Highway – Concept Design Report; Terrestrial Ecology Working Paper, Sinclair Knight Merz.

Smith, A.N. (2011) Waterbirds and their habitat on the Clarence River floodplain: a history. *Australian Zoologist.* **35**(3) 788-809.

Soderquist TR and Ealey L (1994). Social interactions and mating strategies of a solitary carnivorous marsupial, Phascogale tapoatafa in the wild, Wildlife Research 21,. 527-42.

Soderquist, T., and Gibbons, D. (2007). Home range of the powerful owl (*Ninox strenua*) in dry sclerophyll forest. Emu 107(3), 177-184.

State Forests of NSW (1995) *Flora Survey Report Casino Management Area Northern Region*, State Forests of NSW.

Steenbeeke, G. (1998). *Clarence Rare Plant Species Information*. Accessed online at http://www.nor.com.au/environment/clarencecatchment/vegetation/rares/rarein.htm.

Stone, Y., Ahern, C.R. and Blunden, B. (1998). Acid Sulfate Soil Manual. Prepared for: NSW Government. New South Wales Acid Sulfate Soils Management Advisory Committee (ASSMAC)

Stanisic, J., (2006) Survey for the land snail *Thersites mitchellae* Woodburn-Ballina Pacific Highway Upgrade. Prepared for Geolyse Pty Ltd. Biodiversity Assessment and Management, Queensland.

Strahan, R. (1998) (Ed.). The Mammals of Australia**.** New Holland Publishing Pty Ltd. Sydney.

Taylor, B. D., and R. L. Goldingay. (2003). Cutting the carnage: wildlife usage of culverts in the north-eastern New South Wales. *Wildlife Research*, **30**, (5): 529-537.

Taylor, B. D., and R. L. Goldingay. (2009). Can road-crossing structures improve population viability of an urban gliding mammal? *Ecology and Society* **14**, (2): 13.

Taylor, B.D. and Goldingay, R.L. (2010). Roads and wildlife: impacts and implications for wildlife management in Australia. *Wildlife Research*, **37**, (4): 320-331.

Thackway, R. and Cresswell, I.D. (1995). An interim biogeographic regionalisation for Australia: a framework for setting priorities in the National Reserves System Cooperative Program, Version 4.0. Australian Nature Conservation Agency, Canberra.

Traill B and Coates TD (1993), Field observations on the brush-tailed phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae), Australian Mammalogy, 16, 61-65.

Umwelt Environmental Consultants (2003). Pathways to a Living Estuary: Estuary Management for the Clarence Estuary. Report No. 1485/R04/V3. Prepared for Clarence River County Council.

van der Ree, R., van der Grift, E., Gulle, N., Holland, K., Mata, C., and Suarez, F. (2007). Overcoming the barrier effect of roads – how effective are mitigation strategies? An international review of the use and effectiveness of underpasses and overpasses designed to increase the permeability of roads for wildlife. In 'Proceedings of the International Conference on Ecology and Transportation'. (Eds C. L. Irwin, D. Nelson and K. P. McDermott.) pp. 423–433. (Center for Transportation and the Environment, North Carolina State University: Raleigh, NC.)

van der Zande, A. N., W. J. ter Keurs, and W. J. Van der Weijden. 1980. The impact of roads on the densities of four bird species in an open field habitat–evidence of a long distance effect. Biological Conservation 18: 299-321.

van Oosterhout (2007). Alligator weed control manual. Eradication and suppression of alligator weed (Alternanthera philoxeroides) in Australia. http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/profiles/alligator/alligator-weed-control-manual

Weston, N.G. (2003). The provision of canopy bridges to reduce the barrier effect of linear barriers on arboreal mammals in the wet tropics of north-eastern Queensland. Masters thesis James Cook University, Townsville.

Wetland Care Australia (2005). Crystal Waters Wetlands Sapphire Beach Plan of Management. Crystal Waters Landcare Group & Wetland Care Australia. Ballina.

Woinarski, J.C.Z., S.C. Tidemann & S. Kerin (1988). Birds in a tropical mosaic: the distribution of bird species in relation to vegetation patterns. *Wildlife Research*. 15:171-96.