Roads and Traffic Authority

Pacific Highway Upgrade - Oxley Highway to Kempsey

Flora and Fauna Working Paper

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6. Mitigation and management

The management of adverse impacts arising from the Proposal has been addressed according to the hierarchy of avoidance; mitigation and offsetting of residual impacts, consistent with the approach outlined in the DEC/DPI (2005) guidelines.

Impacts of the Proposal on biodiversity values have been avoided or minimised to an extent through the planning process. Conservation of the biological diversity of the local area has been a key issue during the route identification and selection process and the concept design development. This includes:

- Identifying and mapping in the initial phases of the route selection process of known areas of high biodiversity significance, including national parks, state forests and other conservation reserves, State listed wetlands, areas of threatened species habitat, potential endangered ecological communities and mapped fauna movement corridors. This information was confirmed from existing vegetation community mapping, DECCW databases, and subsequent field surveys. It formed a key component of the route selection process by providing constraints for the identification of the preferred route.
- Undertaking further detailed field surveys during the concept design and environmental assessment phase to determine the potential impacts of the Proposal. This facilitated the amendment of the concept design to minimise potential impacts and allowed for the development of appropriate management measures to mitigate against those impacts.

To further minimise and mitigate impacts on the biodiversity values of the study area the following mitigation measures have been incorporated into the Proposal design or would be implemented during the construction and operational phases of the Proposal. The preparation of a comprehensive offset strategy is also proposed to compensate for residual impacts that could not be mitigated.

6.1 Minimising vegetation clearance and habitat loss

Disturbance and removal of areas of native vegetation and habitat is unavoidable during the construction phase. However, measures could be implemented to prevent further disturbance and minimise the impacts on the native vegetation and habitat and resident fauna.

These mitigation measures would be detailed in a flora and fauna management plan for the Proposal.

Some of the measures that would be implemented to minimise the loss of native vegetation and habitat and to protect resident native fauna include:

- Vegetation clearing would be restricted to only those areas where it is necessary.
- Areas of native vegetation that need to be cleared would be clearly marked on maps and identified with parawebbing or flagging tape in the field to ensure that clearing does not occur beyond the area necessary for the Proposal.
- Locating the construction compounds and materials stockpile areas in areas that are currently cleared or disturbed wherever possible. This would reduce the need to clear additional areas of natural vegetation.

- Clearing of vegetation and fauna habitat would be carried out in accordance with the two stage clearing procedures that have been developed for Pacific Highway upgrade projects in consultation with DECCW. This would include:
  - Pre-clearing surveys by a qualified ecologist of all hollow-bearing trees within the Proposal footprint to determine which trees are occupied by fauna.
  - Leaving habitat trees to the second stage of clearing to increase the possibility of fauna relocating prior to removing the trees.
  - Ensuring an experienced wildlife handler is present to manage and retrieve any displaced wildlife during clearing activities.
  - Relocating displaced fauna to similar habitat at the closest available safe location.
- Where practicable, clearing activities would not take place during the spring/early summer breeding period and would also avoid mid-winter when bats enter torpor. Additional care would be required if clearing coincides with the breeding season for the koala (extending from August to December) when individuals are highly active in search of mates.
- Hollow logs, leaf litter and woody debris and large boulders that provide refuge for native fauna removed during construction would be redistributed during rehabilitation works. This would minimise the removal of dead wood, which has been listed on the TSC Act as a key threatening process. As a guide to the appropriate rates of distribution, the DECCW benchmarks for total length of fallen logs occurring within the equivalent vegetation class for each natural vegetation community recorded in the study area are given below:

Table 6-1 Fallen log benchmarks

Keith (2004) class	Equivalent vegetation community(ies)	Benchmark for total length of fallen logs (m per 1000 m^2)
Hunter-Macleay Dry Sclerophyll Forests	10	10
North Coast Wet Sclerophyll Forests	2, 8, 9	10
Subtropical Rainforest	1	0.5
Coastal Swamp Forests	3, 4, 5, 7	5
Coastal Floodplain Wetlands	6	0

- A nest box strategy would be developed for the Proposal as part of the construction environmental management plan. This strategy would include installing nest boxes or relocating salvaged tree hollows in nearby habitat areas to provide alternative roost sites.
- Prior to construction, native seed would be collected from construction sites for use in the revegetation of cleared and or disturbed areas.

Bat roosting habitat

Bats are known to move to new roost sites on a regular basis and therefore could be roosting at different locations to those recorded during this survey. Therefore, bridges and culverts would be inspected by a qualified ecologist for bats prior to any maintenance or demolition work in order to avoid the accidental deaths of bats that may be roosting in these structures. Inspections would involve the following actions:

- Prior to cleaning or flushing any of the scuppers, a visual inspection by a qualified ecologist for bats would be undertaken. This is particularly important during the breeding season of the southern myotis (October – March) as non-flying young could be present.
- Dark recesses within the bridge structure, including the scuppers, would be inspected by a qualified ecologist for the presence of bats immediately prior to the commencement of work.
- Any swallow/fairy martin nests to be removed would be carefully inspected by a qualified ecologist for roosting bats prior to removal.

The presence of bats during the above inspections would require a cease work in that section of the bridge until they are moved and relocated by a bat expert. Should a maternity roost be identified, mitigation measures would be developed in consultation with DECCW and an appropriately qualified ecologist.

Depending on the design of the replacement bridges /culverts, the provision of 'bolt on' bat roosts would be considered to increase the availability of roost sites. It is suggested that vertical concrete shafts and/or slot roosts be manufactured and bolted on to the headstocks of bridges or the ceiling of larger culverts.

Green-thighed frog

Targeted surveys for the threatened green-thighed frog would be undertaken prior to construction, particularly in the vicinity of the apparent breeding pool located in an ephemeral tributary of the Maria River in Maria River State Forest. This would provide more information regarding the importance of the breeding pool to the local population of the green-thighed frog and would allow minor refinements to the design, or appropriate mitigation measures to be applied. Surveys would be undertaken in late spring or summer following heavy rain in order to locate breeding aggregations of this species.

In areas where known habitat for the green-thighed frog would be disturbed, measures to mitigate impacts would be discussed and negotiated with DECCW. The results of any recent research regarding the breeding requirements of this species or the effectiveness of mitigative strategies implemented on other sections of the Pacific Highway Upgrade Program would be used to inform the design of mitigation measures for the Proposal.

Potential mitigation measures could include the creation of artificial habitat associated with the existing creek line during construction. The constructed habitat would be designed to mimic the natural situation where breeding occurs within areas of impeded drainage close to sites of intact native vegetation. The pond designs would include the following features as specified for those created for the Kempsey to Eungai Pacific Highway upgrade (PB 2008):

- Size: 20 metres diameter (core pond), but could be a series of potholes/ponds and larger flooded areas.
- Depth: variable depth to 1 metre.
- Shape: steep sides reducing evaporation and increasing water volumes.

- Length of time for inundation: of the order of 40 days for sunny site, 100 days for shaded site.
- Location: next to moist forest areas if possible.
- Vegetation: dense understorey vegetation or leaf litter.

An ecologist with specialist knowledge of the green-thighed frog would be engaged to implement an adaptive monitoring program to determine the effectiveness of mitigation measures and to recommend modifications where necessary.

Giant barred frog

During recent construction works on the Maria River Bridge, various mitigation measures were put in place to mitigate impacts on the giant barred frog. Such measures included frog fencing, water quality controls, silt fencing and spill booms. A monitoring program was also implemented at the site and site inspection and audits conducted by DECCW indicate that the measures have been successfully implemented and are functioning as required. Similar mitigation and management measures would be implemented for the construction of other bridges across major creeks (particularly Cooperabung, Barrys, Smiths and Pipers Creeks, and tributaries of Maria River through Maria River State Forest), in consultation with the relevant authorities. A threatened frog monitoring program targeting the giant barred frog (as well as the green-thighed frog – see above) would be implemented during and following construction, focusing on areas of known and potential habitat within the Proposal footprint including Maria River and associated tributaries, and Cooperabung, Barrys, Smiths and Pipers creeks to determine the species' persistence in the area and the success of the mitigation measures. Consideration would be given to constructing artificial breeding ponds to provide alternative habitat. The location, size and design of these ponds would be considered at the detailed design and construction stages.

Chytridiomycosis is known to affect the giant barred frog and other threatened frog species with potential to occur within the study area. Chytrid fungus is a water borne pathogen and could be spread through water or mud on vehicles, machinery, footwear and other equipment. In order to prevent the spread of the water-borne chytrid fungus, appropriate cleaning and disinfection protocols would need to be followed when moving between wet-area work sites representing giant barred frog habitat (including Maria River and associated tributaries, Cooperabung, Barrys, Smiths and Pipers Creek) as per *Hygiene protocol for the control of disease in frogs* (NPWS 2001).

Threatened flora species

No threatened flora species were recorded during field surveys however the proposal footprint may provide suitable habitat for seven threatened flora species. A protocol would be developed for managing unexpected finds of threatened plant species during construction. This would include the preparation of a management plan and mitigation measures in consultation with DECCW. Since two properties between Cairncross State Forest and the Wilson River could not be directly accessed during the field surveys, a supplementary survey of the Proposal footprint within these properties for threatened flora species would be conducted as soon as legal access is available prior to construction.

Additional fauna surveys

Two properties between Cairncross State Forest and the Wilson River were not surveyed during the terrestrial field surveys as property access was not available. One of the properties is well vegetated with swamp forest which provides potential habitat for the koala, squirrel glider, bats and possibly the wallum froglet (*Crinia tinnula*). During surveys from adjacent properties, it was noted that parts of the well vegetated property was covered in surface water and the presence of paperbark groves indicate potential habitat for the wallum froglet. This species was not recorded during the surveys but could occur in paperbark swamps on the coastal floodplain. Although predominantly a winter breeder, this species will call at any time of the year following heavy rainfall and therefore, if present, should have been heard calling during the summer survey. Although the fauna assemblage for this property can be predicted by an assessment of the habitat present from adjacent properties, further detailed survey would be carried out once access can be gained, prior to construction.

The other property not surveyed due to access restrictions is predominantly cleared for cattle grazing and is unlikely to support important fauna habitat. However, this property would also be surveyed prior to construction to confirm this conclusion.

Revegetation and rehabilitation

Areas disturbed during the construction process but not required for operation of the road would be rehabilitated progressively during and following construction. This is particularly important for cleared areas that are part of identified regional corridors and key habitat areas in order to maintain adequate links and habitat.

The restoration, regeneration and rehabilitation of areas cleared of native vegetation within the Proposal footprint would be carried out in such a way that it increases the visual amenity and habitat value of the areas and aims to minimise edge effects by complementing and protecting adjoining native vegetation where possible.

Revegetation works would include:

- Planting of locally occurring species, including plants representative of groundcover, understorey and canopy strata. DECCW would be consulted regarding the choice of species, particularly in areas adjacent to existing areas of endangered ecological communities.
- Planting of preferred food trees for native fauna, including appropriate eucalypt species for the koala and yellow-bellied glider and *Allocasuarina* species for the glossy black-cockatoo. The planting of winter flowering trees is also recommended to supplement seasonal foraging habitat for a wide range of birds and arboreal mammals.
- Placing logs and rocks removed from construction sites to provide refuge and foraging substrates for native fauna.
- Monitoring and maintenance of plantings.
- Managing and controlling weeds.

6.2 Managing edge effects and weeds

The measures designed to mitigate edge effects generally relate to measures that reduce impacts outside the footprint of the Proposal. The aim of these measures is to control the possible impacts at their source within the road corridor and soften the edge between the earthworks and the native vegetation. Some of the measures adopted include:

- Avoiding the stockpiling of materials adjacent to native vegetation wherever possible.
- Avoiding the disposal of waste and / or contaminated construction materials (for example, spoil material) in areas adjacent to native vegetation.
- Implementing soil erosion and sediment control measures.
- Progressive revegetation and rehabilitation.
- Implementing a weed management strategy within the road reserve.
- Using locally occurring plant species where possible for landscape plantings and revegetation.
- Developing protocols to prevent the introduction or spread of root rot *Phytophthora cinnamomi* and chytrid fungus prior to commencements of construction in consultation with DECCW.

Management and control of weeds is a crucial issue during both the construction and operation phases of the Proposal. Lantana in particular is a declared noxious weed and the invasion of this species together with exotic vines and scramblers (such as moth plant) are listed as key threatening processes to natural vegetation communities. A weed management strategy would be developed, prior to commencement of construction that aims to prevent the spread of noxious and environmental weeds beyond roadside reserves and reduce their abundance within these areas during construction. Protocols that currently exist in relation to weed management for roads managed by the RTA would be applied for the operational phase of the Proposal.

6.3 Fragmentation, terrestrial barrier effects and road mortality

The incorporation of fauna crossing infrastructure into road design has been shown to increase wildlife connectivity and combat the barrier effects caused by linear habitat fragmentation (AMBS 2001; Goosem et al. 2006; Bax 2006; Bond and Jones 2008; Mata et al. 2008). Monitoring studies on completed sections of the Pacific Highway Upgrade Program have shown use of fauna underpasses by a diverse range of native fauna, including rodents, bandicoots, dasyurids, macropods, goannas, frogs and bats (AMBS 2001-2002).

To reduce the potential for adverse impacts on native wildlife as a result of habitat fragmentation, barrier effects and road mortality resulting from the Proposal, dedicated fauna underpasses and combined drainage/fauna movement culverts (in conjunction with wildlife exclusion fencing) and aerial fauna crossings have been incorporated into the design. In addition to the fauna underpasses, bridges would be designed to provide opportunities for fauna movement along the banks of watercourses. These features aim to maintain linkages between vegetation communities and allow for the safe movement of fauna within the wildlife corridors identified in the study area.

A summary of proposed fauna crossings is presented in **Table 6-2** and indicative locations are shown on **Figure 12a** to **Figure 12c**.

Note that only structures greater than 1.2 metres in diameter and height are described, although smaller structures are likely to provide fauna passage for amphibians, small ground-dwelling mammals and reptiles. Existing structures such as the Maria River bridge are also not shown. The precise location, size and design of structures including provision of skylights would be further refined in consultation with DECCW during the detailed design phase.

The following points were considered when determining the location for the fauna crossing structures in the Proposal:

- Regional connectivity within the study area based on the key habitats and corridors produced by the Department of Environment and Climate Change (Scotts 2003).
- The size and location of vegetation patches on both sides of the Proposal and their suitability as fauna habitat.
- Terrestrial fauna species likely to occur and use the fauna crossing structures at particular locations based on known species occurrence and/or the presence of suitable habitat.
- The feasibility of constructing a fauna crossing structure at that location due to engineering and terrain constraints.
- The proximity of crossing locations to culvert / bridge structures required for creeks / rivers.

The types of fauna crossings incorporated into the Proposal are described below.

Table 6-2 Details of proposed fauna crossings

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
4	1020	Combined	Replace existing with single cell 3m x 3m box culvert. 0.5m flow height at max event. Therefore steps to account for terrestrial fauna together with enough flow to account for fish-friendly crossing can be accommodated by restricting the channel width to 1m.	Links mapped key habitat to the west and habitat to the east contiguous with vegetation in proximate subregional east-west corridor	Koala, general fauna
6	1590	Incidental	Four 1.8m x 1.2m box culverts	Links native vegetation east and west, located in a mapped subregional corridor	General fauna
6F	1620	Dedicated	Stand-alone fauna crossing. Sized at 2.4m x 3m. 50m length, would require a skylight. Entry-Exit re-grade works to prevent water entry into the fauna crossing.	Located within a mapped sub-regional corridor linking areas of key habitat to the east and west	Koala, general fauna
9	2605	Incidental	Four 1.8m x 1.8 m box culverts	Not part of a mapped regional corridor	General fauna

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
9F	2625	Dedicated	3m (w) x 2.7m (h) stand-alone fauna crossing	Not located within mapped regional or sub-regional corridor; mapped key habitat to the west and habitat to the east	Koala, general fauna
10	3585	Incidental	Four 1.5m x 1.2m box culverts	Links native vegetation east and west, not part of a mapped regional corridor	General fauna
10F	3605	Dedicated	Single cell 3m x 2.1m box culvert	Not located within a mapped regional or sub-regional corridor; mapped key habitat to the west and habitat to the east	Koala, general fauna
12	4231	Incidental	One 1.2m x 1.2m box culvert	Links native vegetation east and west, not part of a mapped regional corridor	General fauna
13	4456	Combined	Existing 3m(w) x 2.1m(h) box culvert. Extend to the west. Gap can be used for lighting, plus another skylight for the western carriageway.	Links native vegetation east and west, not part of a mapped regional corridor	General fauna
15	4600-4900	Bridge	Fernbank Creek Bridge 104m long, 6 spans	Not part of a mapped regional corridor; patchy vegetation connectivity within riparian corridor to the east and west of proposed crossing	General fauna
16	5180	Combined	3m x 2.1m box culvert x 4 cells	Not part of a regional corridor; floodplain	General fauna (no forest species) mainly waterbirds, grassland birds, macropods, frogs, reptiles depending on grazing levels and bridge design

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
19	5540 and 6020	Bridge	Hastings River Bridge 468m long, 17 spans	Not part of a mapped regional corridor; patchy vegetation connectivity within riparian corridor to the east and west of proposed crossing	General fauna
20	6283	Combined	3m x 3m single box culvert	Not part of a mapped regional corridor; floodplain	General fauna
21	6727	Combined	3m x 2.4m single box culvert	Links vegetation east and west. Not part of a mapped regional corridor.	General fauna - possibly koala, quoll
22	7272	Combined	3m x 2.4m single box culvert	Not part of a mapped regional corridor. Links vegetation to the east and west contiguous with State forest	General fauna - possibly koala, quoll
29	9209	Combined	Re-grade to allow for 3m x 3m fauna crossing. Look at dry crossings. No fish passage required.	Mapped regional corridor associated with key habitat in Rawdon Creek Nature Reserve to the west and key habitat in Cairncross State Forest to the east	Green-thighed frog, general fauna, koala, quoll
32	10680	Incidental	One 1.2m x 0.9m box culvert	Links native vegetation east and west within Cairncross State Forest, vegetation contiguous with mapped regional corridors located to the north and south	General fauna
32A	11151	Incidental	Proposed 3m(w) x 2.4m(h) fauna crossing	Links native vegetation east and west within Cairncross State Forest, vegetation contiguous with mapped regional corridors located to the north and south	Green-thighed frog, general fauna, koala, quoll
32B	11692	Incidental	3m x 2.4m single box culvert	Located within mapped regional corridor, links vegetation in Cairncross State Forest to the east and west	Green-thighed frog, general fauna, koala, quoll

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
34	12410	Incidental	Single cell 1.8m x 0.60 box culvert	Not part of a mapped regional corridor	General fauna (no forest species) mainly grassland birds, frogs, reptiles
40	16050	Bridge	Wilson River Bridge 559.7m long, 15 spans	Not part of a mapped regional corridor; narrow band of generally continuous vegetation within riparian corridor to the east and west of proposed crossing	General fauna
44	17175	Bridge	36m long, 3 spans	Not part of a mapped regional corridor	General fauna
50	17158	Combined	3m x 3m single cell box culvert	Not part of a mapped regional corridor	General fauna
51	17708	Multiuse crossing (livestock, vehicles, fauna)	Approx 4.5m (w) x 4.5m (w) to account for farm equipment	Not part of a mapped regional corridor network; fragmented vegetation to the east and west	General fauna
52	18623	Incidental	One 3m x 0.9m box culvert	Links fragmented vegetation east and west, not part of a mapped regional corridor	General fauna
53	18743	Incidental	Replace existing with 3m (w) x 2.1m (h) box culvert	Not part of a mapped regional corridor	General fauna
57	19660-19710	Bridge	Cooperabung Creek Bridge 32m long, 4 spans	Not part of a mapped regional corridor; riparian vegetation continuous within riparian corridor to the east and west of proposed crossing	General fauna
58S	20050	Incidental	One 1.2m x 1.2m box culvert	Not part of a mapped regional corridor	General fauna
59	20260	Incidental	Replace existing 2.1m RCP with 3m (w) x 2.4m (h) box culvert	Links native vegetation east and west adjacent to Cooperabung Nature Reserve, not part of a mapped regional corridor	General fauna

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
60F	20528	Dedicated	Single cell 3m (w) x 3m (h) box culvert.	Not part of a regional corridor. Links vegetation to the east and west that is contiguous with a mapped regional corridor in Cooperabung Nature Reserve and Ballengarra State Forest	Koala, quoll, general fauna
63F	21255	Dedicated	Single cell 3m (w) x 3m (h) box culvert	Located in a mapped regional corridor linking mapped key habitat in Cooperabung Nature Reserve and Ballengarra State Forest	Koala, quoll, general fauna
64	21531	Combined	3m x 3m fauna crossing. Median is wide and therefore would need an opening for light. Look at step. Existing 1200 mm RCP to be replaced	Located in a mapped regional corridor linking areas of key habitat to the east and west	Koala, quoll, general fauna
65	21791	Combined	Replace existing with 3m (w) x 3m (h) box culvert to be installed. Look at open median with treatment to stop fauna jumping on to carriageways	Located in a mapped regional corridor linking areas of key habitat to the east and west	Koala, quoll, general fauna
66	22179	Combined	Existing 2 x 2.7m dia steel pipes to be replaced with single 3.6m (h) x 3.6m (h) box culvert	Located in a mapped regional corridor linking areas of key habitat to the east and west	Koala, quoll, general fauna
67F	23325	Dedicated	Single cell 3m (w) x 3m (h) box culvert	Located in a mapped regional corridor linking areas of key habitat to the east and west; vegetation contiguous with mapped climate change corridor to the east	Koala, quoll, general fauna
71	23140	Incidental	Single 900mm dia RCP. To be replaced with 3m (w) x 2.1m (h)	Located in a mapped regional corridor linking areas of key habitat to the east and west; vegetation contiguous with mapped climate change corridor to the east	Koala, quoll, general fauna

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
73	23967	Combined	5 x 3m x 3m box culvert to be extended to the east. Median opening/skylights required	Located in a mapped regional corridor linking areas of key habitat to the east and west; vegetation contiguous with mapped climate change corridor to the east	Koala, quoll, general fauna
74	24441	Incidental	Replace existing 1500mm dia RCP with single 3m (w) x 1.8m (h) box culvert	Located in a mapped regional corridor linking areas of key habitat to the east and west; vegetation contiguous with mapped climate change corridor to the east	Koala, quoll, general fauna
75	24732	Incidental	Replace existing with single 3m (w) x 2.4m (h) box culvert	Located in a mapped regional corridor linking areas of key habitat to the east and west; vegetation contiguous with mapped climate change corridor to the east	Koala, quoll, general fauna
76	25105	Incidental	Extend existing 1500mm dia RCP	Located in a mapped regional corridor linking areas of key habitat to the east and west; vegetation contiguous with mapped climate change corridor to the east	Koala, quoll, general fauna
78	25427	Incidental	Replace existing 1500mm dia RCP with 3m (w) x 1.5m (h) box culvert	Located on northern edge of mapped regional corridor; links vegetation to the east and west	Koala, quoll, general fauna
80	25706	Combined	Replace existing 1800mm with single cell 3m x 2.7 box culvert	Not part of a mapped regional corridor; links vegetation to the east and west	Koala, quoll, general fauna
83	26383	Incidental	Existing 1800mm RCP to be replaced with 1500mm culvert	Not part of a mapped regional corridor; links vegetation to the east and west	General fauna
83F	26400	Dedicated	Single cell 3m (w) x 3m (h) box culvert	Not part of a mapped regional corridor; links vegetated habitat east and west	Koala, quoll, general fauna

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
84	26785	Combined	Existing 1200 mm dia RCP to be replaced with 3m (w) x 3m (w) box culvert	Not part of mapped regional corridor network; limited connectivity to the west	Koala, quoll, general fauna
86	27510	Combined	Replace existing 1200 mm dia RCP with 3m x 3m box culvert	Located within sub-regional corridor linking extensive areas of mapped key habitat within state forests to the east and west	Koala, quoll, general fauna
88	28225-28270	Bridge	Smiths Creek Bridge 30m long, 3 spans	Located on edge of subregional corridor; riparian vegetation continuous within riparian corridor to the east and west of proposed crossing	General fauna
88a	28295	Dedicated	Two 3m x 3m box culverts	Located on the edge of a mapped sub-regional corridor linking extensive areas of key habitat within state forests to the east and west	General fauna
89	28673	Combined	Three 2.4m x 2.4m box culverts	Not part of mapped regional corridor; Links fragmented vegetation to the east and west	General fauna
90	29608	Incidental	Four 1.5m x 1.5m box culverts	Not part of mapped regional corridor; Links fragmented vegetation to the east and west	General fauna
91	30077	Incidental	One 3m x 2.7m box culvert	Not part of mapped regional corridor; Links fragmented vegetation to the east and west	General fauna
92	30660	Bridge	Pipers Creek Bridge 31m long, 3 spans	Not part of a mapped regional corridor; riparian vegetation continuous within riparian corridor to the east and west of proposed crossing	General fauna

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
93	30957	Combined	One 3m x 1.5m box culvert	Located near a mapped regional corridor to the north; Links fragmented vegetation to the east and west	General fauna
94	31107	Combined	One 3m x 1.8m box culvert	Located near a mapped regional corridor to the north; Links fragmented vegetation to the east and west	General fauna
96	31887	Combined	Existing 1050mm dia RCP to be replaced by 3m x 3m box culvert	Located within a mapped regional corridor linking extensive areas key habitat in Maria River and Ballengarra state forests	General fauna
97	32357	Combined	Existing 1050mm dia RCP to be replaced by 3m x 3m box culvert	Located within mapped regional corridor linking extensive areas key habitat in Maria River and Ballengarra state forests	General fauna
98	32662	Combined	Existing 1350mm dia RCP to be replaced by 3m x 3m box culvert	Located within a mapped regional corridor linking extensive areas key habitat in Maria River and Ballengarra state forests	Koala, quoll, general fauna
99	33103	Combined	3m x 3m box culvert	Located within a mapped regional corridor linking extensive areas key habitat in Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, general fauna
100F	33390	Dedicated	3m x 3m single cell box culvert on new carriageways	Located within a mapped regional corridor linking extensive areas of key habitat within Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, general fauna

Culvert no.	Station	Crossing type	Description	Regional connectivity	Species that may use the crossing
102	34086	Combined	3m (w) x 1.8m (h) box culvert cut in at western side. Min 1.8m (h) required	Located within a mapped regional corridor linking extensive areas key habitat in Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, general fauna
103	34714	Combined	3m x 2.4m single cell box culvert	Located within a mapped regional corridor linking extensive areas key habitat in Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, general fauna
106	35727	Combined	3m x 3m single cell box culvert	Located within a mapped regional corridor linking extensive areas key habitat in Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, general fauna
109	36356	Combined	3m x 3m single cell box culvert	Located within a mapped regional corridor linking extensive areas key habitat in Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, giant barred frog (possible), general fauna
-	37730-37790	Bridge	Stumpy Creek bridge 36m long, 3 spans	Located within a mapped regional corridor linking extensive areas key habitat in Maria River State Forest to the east and west	Koala, quoll, green-thighed frog, giant barred frog (possible), general fauna

Note: These values / dimensions are subject to refinement during detailed design.

6.3.1 Fauna underpasses and bridges

The proposed fauna underpasses fall within three categories:

1. Dedicated fauna underpasses.
2. Combined fauna and drainage structures.
3. Incidental crossings.

Dedicated fauna underpasses

Dedicated fauna underpasses have been strategically located to align with identified wildlife corridors (Scotts 2003) where possible (**Figure 12a** to **Figure 12c)**. These dedicated underpasses would generally be of larger dimensions so as to encourage and facilitate use by a broad range of fauna species, including the koala and larger fauna such as macropods (**Table 6-2**). Permanent floppy top fencing would be installed to direct fauna into dedicated underpasses.

Combined fauna crossing and drainage structures

The culverts required at watercourse crossings would be primarily for hydraulic purposes but would be designed to act as dual-purpose drainage and fauna movement structures. The combined structures aim to supplement the dedicated underpasses and provide further opportunities for fauna movement through the study area and wider locality (**Table 6-2** and **Figure 12a** to **Figure 12c**). The structures comprise box culverts rather than pipes which have been shown to be less attractive to larger fauna in underpass monitoring surveys along the Pacific Highway (AMBS 2001-2002).

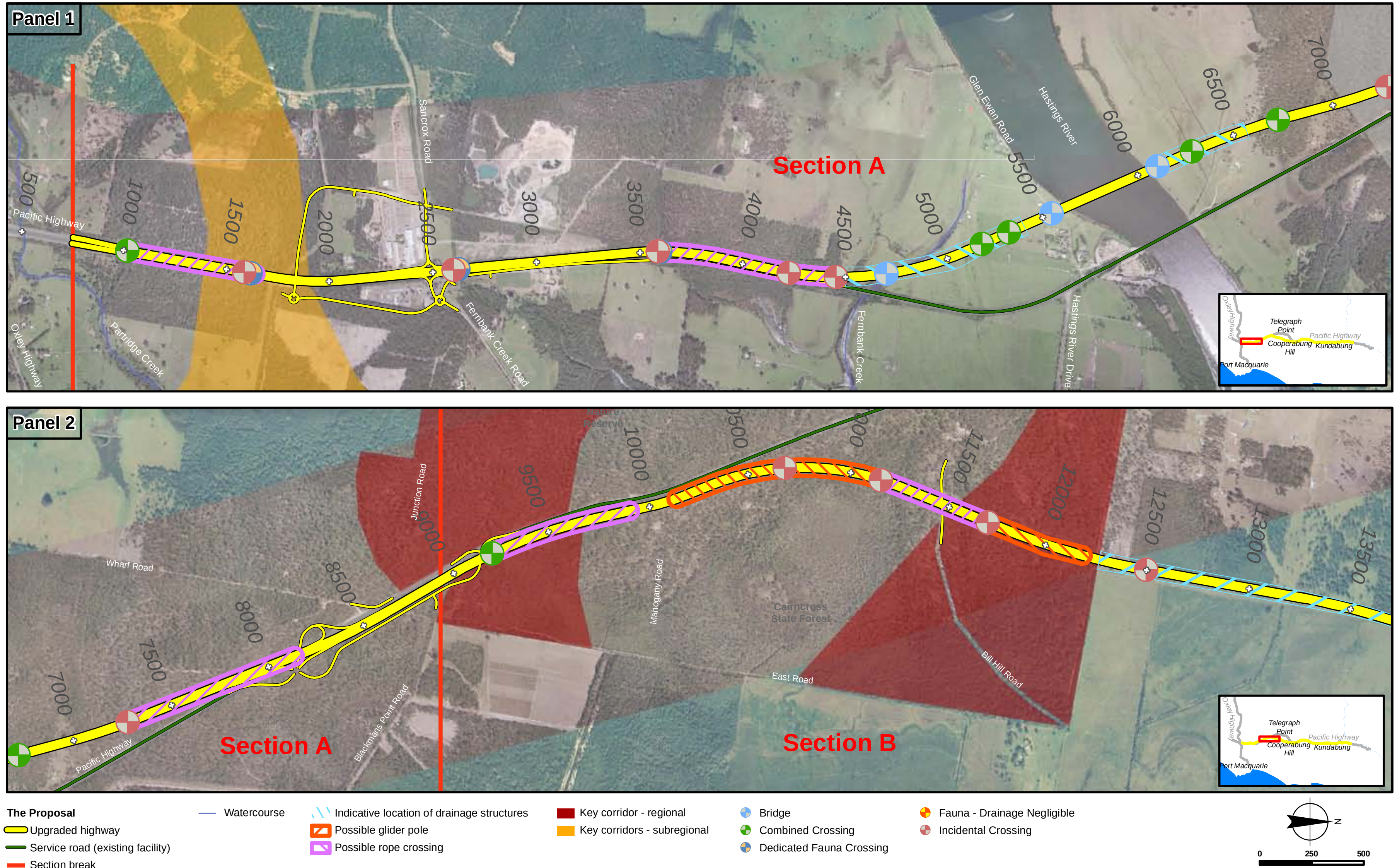
The combined culverts would comply with the RTA requirements for the installation of fauna underpasses and associated structures, including consideration of the requirement to provide dry passage, sky lights, appropriate refuge for native fauna and fauna fencing at the detailed design phase. Fencing would most likely be installed in the vicinity of combined crossings where the Proposal traverses areas of key habitat (for example, state forests and nature reserves) and regional corridors. Frog fences and turfed dish drains (or similar) would be established in areas where threatened frogs are known or likely to occur to assist in directing frogs away from the highway and through culverts along creeks or drainage lines. Measures to facilitate fish and amphibian crossings would be incorporated into the detailed design in accordance with the *Policy and Guidelines for Fish Friendly Waterway Crossings* (DPI 2003).

Scour protection devises such as rock armouring would be incorporated into the culvert design to provide a gradual transitional level between the ground level and the level of the culvert so that terrestrial fauna can reach and utilise the drainage culverts as fauna underpasses.

Incidental fauna crossings

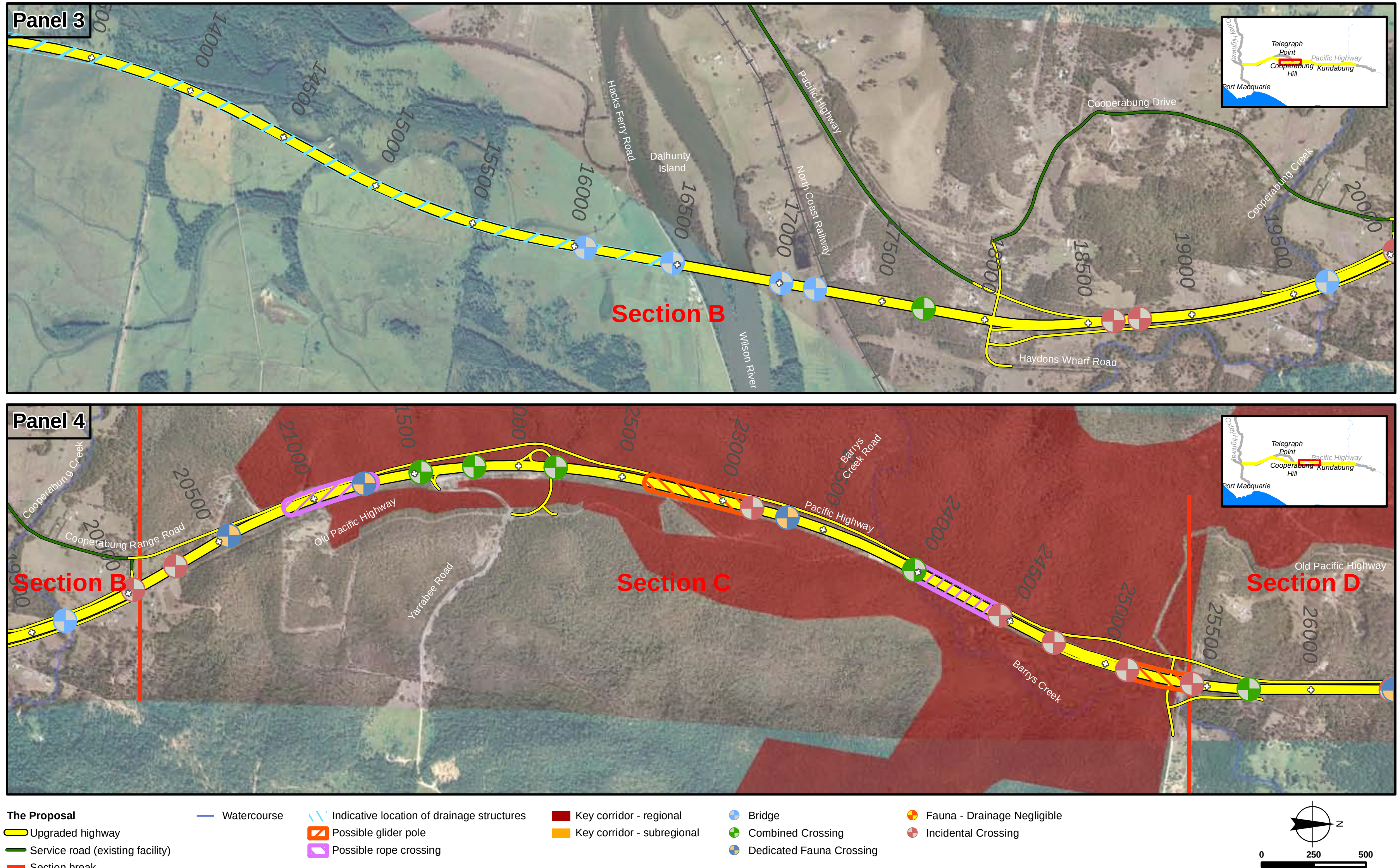
Incidental crossings comprise pipes and culverts designed for drainage purposes only but that may be used by fauna on occasion. The structures are of smaller dimensions than the dedicated underpasses and combined use culverts and use in many cases would consequently be limited to smaller fauna (for example, small terrestrial mammals, reptiles and frogs) when and if conditions were suitable (for example, when dry for mammals). These structures would not be designed specifically to facilitate fauna movements.

Figure 12a Fauna crossings



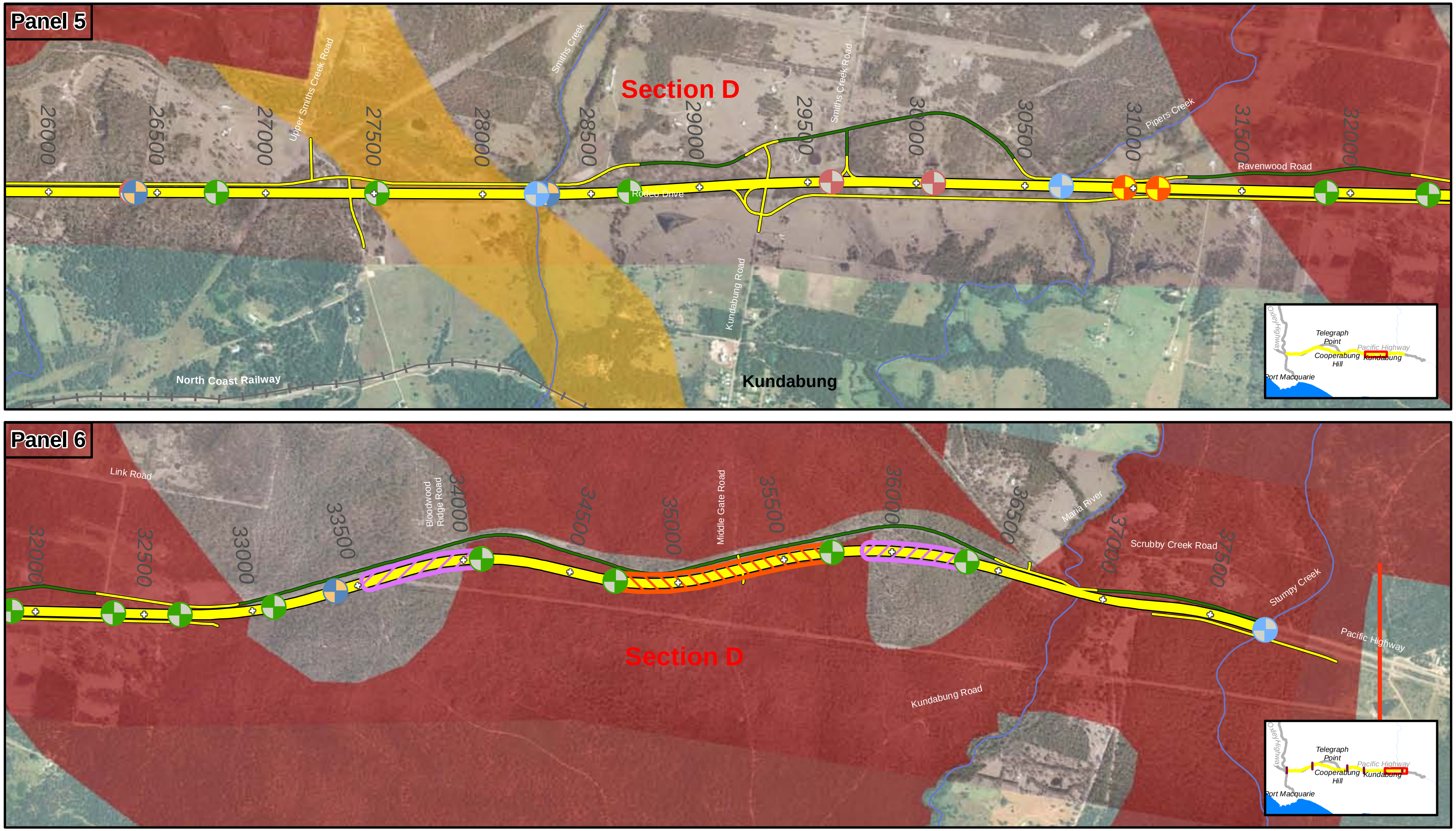
Note: Locations and features are subject to refinement during detailed design; 2004 Aerial photography.

Figure 12b Fauna crossings



Note: Locations and features are subject to refinement during detailed design; 2004 Aerial photography.

Figure 12c Fauna crossings



The Proposal

- Upgraded highway
- Service road (existing facility)
- Section break
- Watercourse
- Possible glider pole
- Possible rope crossing
- Key corridor - regional
- Key corridor - subregional
- Bridge
- Combined Crossing
- Dedicated Fauna Crossing
- Fauna - Drainage Negligible
- Incidental Crossing

N

0 250 500
Metres

Note: Locations and features are subject to refinement during detailed design; 2004 Aerial photography.

Fauna exclusion fencing

Exclusion fences used in conjunction with wildlife crossings have been found to significantly reduce roadkill mortality (Falk et al. 1978; Singer and Doherty 1985; Foster and Humphrey, 1995) and increase rates of underpass use (Yanes et al. 1995; AMBS 1997; Port Stephens Council 2002). Fences are typically only effective if erected on both sides of the road. In areas where fencing is erected on only one-side of the road, the potential for roadkill is increased, as wildlife could enter and potentially become trapped on the roadway. With regard to koalas, fences need to be regularly maintained to be effective as vegetation must be removed on either side of the fence so that there is no touching canopy. Therefore the fence should be erected in areas that allow the access of a tractor and slasher.

Permanent floppy top fencing (**Figure 13**) would be installed in appropriate locations to direct fauna to dedicated underpasses and combined culverts where they could cross the road in safety. Fencing would be installed in the vicinity of dedicated crossings and in areas where the road traverses areas of key habitat (for example, state forests) and regional corridors. The location and extent of fauna fencing would be determined at the detailed design phase in consultation with DECCW.

Figure 13 Example of floppy-top fencing

Crossing design principles

The following generic design guidelines would be used to inform the detailed design of fauna underpass crossings:

- *Location and design of wildlife crossings*: Careful consideration of the location and design of fauna underpasses to ensure fauna are not directed onto nearby service roads.

- *Provision of dry passage*: Inclusion of raised ledges/runways (at least 60 centimetres wide) in box culverts to ensure dry passage even during periods of stream flow. In general, bridge abutments should be as far from creek banks as possible, to maximise the area of dry ground available to accommodate terrestrial fauna.
- *Substrate type*: A natural substrate should be used on the floor of underpasses and culverts where possible to encourage use by native fauna. In areas targeting the green-thighed frog, the placement of rocks and other ground-level 'furniture' would assist in attracting use of the culvert. Logs should also be incorporated to mimic natural travelling habitats of small-medium sized mammals such as the spotted-tailed quoll and bandicoots. Flat wooden substrates could be used to line shelving provided to allow dry passage during high-stream flow.
- *Incorporation of vegetation*: Where possible maintain or incorporate vegetative cover under bridges and in underpasses to facilitate movement for fauna that require protective cover (for example, spotted-tailed quolls, red-necked wallabies and small mammals).
- *Protection from predators*: Ensuring adequate cover of vegetation at culvert entrances to encourage use by small mammals and assist in protection of predators. Where possible maintain or incorporate vegetative cover under bridges and in underpasses. Installation of koala refuge poles at underpasses starting at least 3 metres from each culvert entrance.
- *Natural lighting*: Careful consideration of the structure and composition of vegetation leading to the entrance of wildlife crossings so as to not block the entrance of natural light to encourage the growth of natural vegetation within the underpass. Consideration of the requirement or otherwise for skylights dependent on underpass length and engineering constraints.
- *Directing fauna toward underpasses*: In conjunction with fauna fencing (see below) the use of strategically placed incentives such as the planting of suitable feed and nesting trees and providing favourable habitat structures (for example, rocks, logs and fallen timber) to direct wildlife movement toward a desired crossing location. A strip of sheet metal (50 centimetres high and dug in to the ground 20 centimetres deep) may assist in directing small animals toward culvert crossings and is likely to be particularly important for threatened frogs at crossings in the vicinity of Maria River State Forest (giant barred frog and green-thighed frog) and Rawdon Creek Nature Reserve / Cairncross State Forest (green-thighed frog).
- *Fauna fencing*: Careful consideration of fauna fencing placement and ends to avoid the potential for increased fauna road mortality at these locations. Maintenance of fence lines to ensure trees do not occur close to the fence to prevent fauna access onto the road corridor.

Bridge design principles

Bridge construction techniques such as minimising the clearance footprint on embankments, and maintaining clear passage of the stream channels would assist in mitigating the impact of construction on the various rivers and creeks within the study area. The retention and possible enhancement of creek banks beneath the bridges would allow the channels to be maintained as crossing points for terrestrial fauna. Bridge designs have been developed to avoid placing bridge abutments in the channels and low-flow channel banks. This would assist to maintain the clear passage opportunities on the stream channels and serve to mitigate barrier impacts associated with the Proposal.

6.3.2 Aerial fauna crossings

Whilst fauna underpasses are known to provide passage for a range of fauna species including koalas, rodents, wallabies, bandicoots and reptiles (AMBS 2001-2002; Bond and Jones 2008; Goosem et al. 2006), their value is limited for arboreal species that rarely travel along the ground, such as gliders (Ball and Goldingay 2008). As a result, purpose built aerial fauna crossings are becoming increasingly more common in road design throughout Australia (Goosem et al. 2006; Ball and Goldingay, 2008; Bond and Jones, 2008).

A combination of the following types of crossings for arboreal fauna which do not utilise underpasses is proposed:

- Rope ladders: principally catering for arboreal wildlife, such as possums and gliders.
- Glider poles: designed specifically for glider species.

Rope ladders

Rope ladders consist of a single rope, ladder or rope tunnel that spans the entire road. Rope tunnels were originally designed to protect arboreal mammals from aerial predators, however it has since been recognised that the ladder design is preferred over both tunnel and single rope designs (Goosem et al. 2006; Bax, 2006).

Rope ladders have been used in a range of environments and range from 7 metres to 70 metres in length (Goosem et al. 2006; Bax 2006; Bond and Jones 2008). While initial habituation periods have been observed, rope ladders have been shown to effectively provide passage for a range of ringtail possum species, the common brushtail possum (*Trichosurus vulpecula*), fawn-footed melomys (*Melomys cervinipes*) and the sugar glider (*Petaurus breviceps*). Rope ladders 25 to 50 centimetres wide provide sufficient stability to allow for the safe crossing of most arboreal species (Goosem et al. 2006) and short ropes leading from the ends of the rope ladder to nearby trees could encourage ladder use (Goosem et al. 2006).

Indicative ranges where the location of rope ladders would be considered are:

- Station 1000 to 1500.
- Station 3500 to 4500.
- Station 7250 to 8250.
- Station 9250 to 10000.
- Station 11150 to 11750.
- Station 20750 to 21250.
- Station 24000 to 24500.
- Station 33500 to 34000.
- Station 35800 to 36400.

These are shown in **Figure 12a** to **Figure 12c**. The location and design of rope ladders would be determined at the detailed design phase in consultation with DECCW.

The following generic design guidelines would be used to inform the detailed design of rope ladders:

- Rope ladders should consist of a length of rope netting suspended across the road between two upright poles.
- The horizontal netting surface should be approximately 400 millimetres wide and consist of four longitudinal ropes.
- To maintain the ladders' shape, the outer sides of the longitudinal ropes could be connected to two 4 millimetre galvanised cables strung between the outer uprights.
- Lateral interconnecting ropes (rungs) should be spaced 10 to 20 millimetres apart.
- Marine grade 'silver rope' (14 millimetre diameter) is recommended for the lateral and longitudinal ropes.

The poles need to be of sufficient size to carry the weight of the rope ladder. Upright poles should be braced by 16 millimetre diameter galvanised stay ropes set at a 45 degree angle.

It is critical that the outer ends of rope ladders should start within existing vegetation and stand within reach of the canopy vegetation to ensure possums and gliders could easily walk from vegetation to the rope ladder.

Glider poles

Glider poles aim to assist gliding species to traverse open areas between habitat patches and have the potential to be used as a rapid technique to reconnect severed habitat (Ball and Goldingay 2008). While gliding mammals are dependent upon tree cover to traverse habitats, their gliding ability allows these species to move through relative open habitat providing that tree spacing does not exceed gliding capability (Selonen and Hanski 2003; van der Ree et al. 2003). Glider poles could provide a crossing solution in areas where trees are absent or of insufficient height (Ball and Goldingay 2008).

Investigation into the effectiveness of glider poles is limited. A recent study near Walkerston in Queensland has demonstrated that glider poles positioned across a 70 metre gap allowed for effective cross road movement of squirrel gliders (*Petaurus norfolcensis*). Gliders were observed to easily ascend, launch, glide and land on the wooden poles (Ball and Goldingay 2008). The spacing and height of gliding poles is critical to crossing success with glide distance directly proportional to launch height (glide ratio of 2.5:1 (horizontal distance: vertical drop)) (Jackson 1999).

To encourage the use of glider pole crossings in fragmented habitats, a number of crossing options may be required within the area. Launching points consisting of a horizontal crossbar positioned near the top of the poles are also preferred by gliders (Ball and Goldingay 2008).

Indicative ranges where the location of glider poles would be considered are:

- Station 10100 to 11150.
- Station 11700 to 12225.
- Station 22600 to 23200.
- Station 25075 to 25425.
- Station 34700 to 35775.

These are shown in **Figure 12a** to **Figure 12c**.

The number, location and design of glider poles would be determined at the detailed design phase in consultation with DECCW. The precise positioning of glider poles would be decided by an ecologist after vegetation clearing has been completed and would vary between crossings depending on the number and position of trees retained (to complement the natural connectivity of the landscape).

The following generic design guidelines would be used to inform the detailed design of glider poles:

- Poles should be as tall as possible (at least 10 metres in height) to maximise the drop distance available to gliders.
- Poles should be positioned to ensure a continual and consistent line of poles linking vegetation on one side of the road to the other.
- In circumstances where the road surface is lower than the landscape on either side, the central poles (within the median strip) would need to be taller to ensure gliders could glide to the nearest roadside pole.
- If reflective shields are placed around the base of glider poles, a gap should be retained to allow gliders the ability to climb back from the ground.
- Glider poles should be as natural as possible (avoid using treated pine) and could be constructed using local mature trees that are cleared for the Proposal.
- The location of aerial crossings in relation to overhead powerlines needs to be carefully assessed as the latter could pose a serious hazard to the effectiveness of the crossing.
- Because of the known risk to fauna, and gliders in particular, of entanglement, no barbed wire should be used in any boundary fencing erected as part of the Proposal.

6.4 Minimising impacts on aquatic ecology

Little aquatic disturbance within the study area is anticipated once construction of watercourse crossings is completed. Damage to any aquatic habitat and riparian vegetation during construction would be minimised. Areas of riparian vegetation likely to be damaged or removed during construction would be replanted on completion of the works. In addition, appropriate erosion sediment control measures would be put in place around all proposed watercourse crossings prior to construction to minimise water quality impacts on the watercourses due to run-off from the construction site.

The study area was extended to include Stumpy Creek after the aquatic assessments were completed. A further aquatic ecology assessment would be undertaken prior to construction.

6.4.1 Fish passage

Maintenance of fish passage needs to be an important consideration when designing stream crossings for the Proposal. Three species identified during the aquatic survey (striped gudgeon (*Gobiomorphus australis*), short-finned eel (*Anguilla australis*) and long-finned eel (*Anguilla reinhardtii*)) require unregulated longitudinal movement to facilitate and complete successful life cycles so that future generations could continue. The interruption of this could have a serious detrimental effect on the population dynamics of instream fauna.

It is widely acknowledged that fish have velocity requirements that influence their ability to move through regulator structures. The characteristics of fish passage that encourage movement through a foreign structure include suitable depth, space and light for the target species (**Table 6-3**).

The water velocity flowing in and out through any type of structure needs to be in balance with the hydraulic requirements of aquatic plants in the littoral zone, as the velocity would influence the rise and fall of water level stream. Little is known of the exact requirements regarding water level rise and fall for aquatic plants, though it is likely these levels would vary between species.

To facilitate longitudinal fish movement, water would be required to flow 'naturally' under a bridge or culvert as fish are extremely sensitive to sudden changes in velocity, especially when structures choke the natural flow of water, thus increasing the velocity (Koehn and Nicol, 1998).

Table 6-3 Guidelines for providing fish passage in culverts, fishways and regulators

Characteristic	Criteria
Fish size	**Maximum water velocity**
Fish < 80 mm	0.15 m/sec
Fish > 100 mm	0.30 m/sec
Fish > 150 mm	0.45 m/sec
Fish > 250 mm	0.75 m/sec
Fish type	**Minimum water depth**
Small native fish & carp	< 0.3 m
Small & medium sized fish. May exclude some adult fish.	0.4 m
Would pass most native fish except eastern cod	0.7 m
Would pass all native fish	1 m
Fish type	**Width of structure**
Would pass almost all native fish	1.5 m
Adult eastern cod may need a width of 2 m	2.0 m
Fish type	**Light**
Important for bony bream	As much light as possible

Source: Adapted from Mallen-Cooper (2000)

It is recommended that any bridge or culvert structures be designed to:

- Minimise changes to the channel's natural flow, width, roughness and base-flow water depth through the culvert's wet cells. Wet cells should have a minimum water depth of 0.2 to 0.5 metres to encourage fish passage (Fairfull and Witheridge 2003).
- Facilitate flow equal to the natural or existing flow area of the channel below the deck/crest level of the structure (Fairfull and Witheridge 2003).
- The structure should be designed to maximise the geometric similarities of the natural channel profile from the bed of the culvert up to a flow depth of 0.5 metres (Fairfull and Witheridge 2003).
- For passage during bankfull flows, consideration should be given to the placement of artificial sidewall roughness units along the cell wall immediately adjacent to the channel banks (Fairfull and Witheridge 2003).

- Where conditions allow, construct pools at both the inlet and outlet of the structure to assist in the dissipation of flow energy and to act as resting areas for migrating fish (Fairfull and Witheridge 2003).
- To avoid the formation of a perched structure and damage to the stream's bed and banks, erosion at the outlet should be controlled with the use of rock protection and/or the formation of a stabilised energy dissipation pool (Fairfull and Witheridge 2003).
- Maximise light penetration within the wet cells by maximising the height or diameter of the structure, and possibly by introducing a skylight (Fairfull and Witheridge 2003).

Maintaining aquatic fauna passage

Measures to facilitate fish and amphibian crossings would be incorporated into the detailed design in accordance with the requirements contained in the DPI publications *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003) and *Policy and Guidelines for Fish Friendly Waterway Crossings* (DPI 2003).

Bridges proposed for the creek crossings would be designed to minimise changes to the channel's natural flow, width, roughness and base-flow water depth to maintain fish passage.

Woody snags would be treated in accordance with the requirements of NSW Fisheries, with removal of the snag being the last option. NSW Fisheries would be notified of any proposed works in relation to snags.

6.4.2 Proposed management and mitigation measures for bridge construction

Prior to constructing crossing structures in a streambed, a work method statement would be prepared that identifies the site constraints and appropriate environmental management measures for each construction location. The work method statement would include a progressive erosion and sediment control plan which details the appropriate erosion and sedimentation control measures that would be installed around the working site. The progressive plan may include such measures as temporary diversions, silt curtains, rock barriers or other control measures as necessary and appropriate for the location. The work method statement would be implemented for the construction.

To minimise the local impact of sediment mobilisation, the river flow could be temporarily diverted around the works, by either pumping or channelling the flow. If this is not an option, then all works would be undertaken during periods of minimal flow.

Care would also be taken to minimise the potential impacts of construction to protect the hydrology and habitat values of the watercourses. Actions to achieve this include:

- The prevention of instream barriers that impede future flows or obstruct fish passage.
- The prevention of hazardous wastes from construction equipment entering the watercourse.
- The immediate notification of appropriate authorities should any pollution incident occur.

6.4.3 Managing changes to water quality in aquatic habitats

Measures that would be implemented to manage and mitigate the potential impacts on water quality are discussed in Chapter 13 of the *Oxley Highway to Kempsey Upgrading the Pacific Highway Environmental Assessment* (GHD 2010), and include erosion and sedimentation control during construction and operation and progressive rehabilitation.

6.4.4 Minimising impacts on protected aquatic vegetation and State listed wetlands

The exact area of mangroves and seagrasses to be directly impacted by the Proposal would be determined at the detailed design stage when the precise dimensions of bridge structures and related overshadowing impacts can be determined.

Impacts on protected aquatic vegetation, including seagrasses, mangroves, saltmarsh and wetlands listed under *State Environmental Planning Policy No. 14 – Coastal Wetlands* at the Hastings River and Wilson River crossings would be minimised through the following measures:

- Bridge pilings and support structures would be constructed with the aim to avoid mangrove forests and seagrass beds where possible. Where it is not possible to avoid impacts on mangroves and seagrass beds, the Proposal footprint would be minimised as much as possible. A buffer zone would be maintained around mangroves for construction activities.
- Bridge design would limit the location of structures such as piers and piles within the channel bed of the watercourses where possible to reduce the potential for impacts as a result of increased flow velocities. Piers would be designed and orientated to avoid the generation of turbulence and subsequent bed and bank erosion. Where increased velocities have the potential to cause scour and cannot be minimised by changes to the design, appropriate scour protection would be provided (see Chapter 12 of the *Oxley Highway to Kempsey Upgrading the Pacific Highway Environmental Assessment* (GHD 2010)). Design of scour protection measures and other measures to mitigate potential impacts on geomorphology would be undertaken during the detailed design phase.
- The current design has been developed with consideration to light penetration to marine vegetation underneath the bridges. Factors including height, orientation, slenderness, piers, deck separation and potential use of construction materials with a higher degree of transparency where the Proposal crosses seagrass beds on the banks of the Hastings River would be considered;
    - Bridge pilings and support structures would be constructed with the aim to avoid impact on State-listed wetlands where possible. Given the identified discrepancies between the mapped boundaries and the extent of the wetalnds identified during field investigations, a more accurate boundary would be established prior to construction through quantitative observations and surveying of the mapped boundary.
- Pilings and support structures would be avoided on Dalhunty Island where possible.

Compensatory measures to offset unavoidable residual impacts on protected aquatic vegetation as outlined under Sections 6.4 and 6.5 of the *Policy and Guidelines for Aquatic Habitat Management and Fish Conservation* (DPI 1999) would be discussed and agreed with DII at the detailed design phase. Compensatory measures may include replacement of protected aquatic vegetation at a ratio as agreed with DII; transplanting of mangroves smaller than 1 metre and seagrasses to adjacent areas in accordance with DII guidelines; and stabilisation of the Hastings River banks in areas of high erosion potential to protect marine vegetation from sedimentation.

Measures that would be incorporated into the road design and implemented to manage and mitigate the potential impacts on water quality and downstream vegetation and habitats, including protected aquatic vegetation, are discussed in Chapter 13 of the *Oxley Highway to Kempsey Upgrading the Pacific Highway Environmental Assessment* (GHD 2010), and include erosion and sedimentation control during construction and operation and progressive rehabilitation.

6.4.5 Managing impacts on groundwater-dependent ecological communities

Proposal is not likely to result in significant drawdown of groundwater, groundwater impedance or changes to the groundwater quality such that groundwater dependent ecosystems would be detrimentally impacted. Measures to minimise impacts on groundwater are discussed in the Chapter 14 of the *Oxley Highway to Kempsey Upgrading the Pacific Highway Environmental Assessment* (GHD 2010).

Either existing groundwater bores or purpose-installed groundwater bores near groundwater dependent ecological communities would be monitored throughout construction for groundwater level and quality. The groundwater quality could be largely limited to pH and salinity, although occasional measurements of hydrocarbons in some key bores would also be appropriate.

6.4.6 Monitoring

A comprehensive adaptive monitoring program would be developed at the detailed design phase in consultation with DECCW. The monitoring program would focus on assessing rehabilitated areas and the effectiveness of measures to mitigate impacts on native fauna and their habitats.

6.5 Offsets

There is the potential for a number of direct and indirect impacts to occur on biodiversity values as a consequence of the Proposal. While most of these impacts have either been avoided or minimised through design decisions or could be adequately mitigated or managed, there are some impacts that could not be adequately mitigated. The following residual impacts are likely:

- Loss and degradation of native vegetation including communities that comprise endangered ecological communities as listed under the TSC Act. The Proposal would affect approximately 203.1 hectares of native vegetation of which approximately 36.3 hectares qualify as endangered ecological communities.
- Loss of habitat for a variety of native species.

The RTA would develop an offset strategy in consultation with DECCW and DII to address the residual impacts of the Proposal. The implementation of this offset strategy would contribute to the long term conservation of biodiversity. An offset is one or more appropriate actions that are put in place to counterbalance specific impacts on biodiversity. Appropriate actions are long-term management activities to improve biodiversity conservation.

The strategy would be developed to offset the residual impacts and could include a combination of measures, some of which could include:

- Management by DECCW or DII:
  - Purchase freehold property and transfer into NSW National Parks Estate.
  - Purchase freehold property and transfer into Forests NSW Estate, with a management zoning of Zone 1 (Special Protection).
  - Negotiation with Forests NSW for extension of existing portions of Zone 1.
- Management by RTA:
  - Negotiation with Forests NSW to transfer land currently identified as Zone 4 (General Management) and preserve in a ‘road reserve’ under RTA management.

- Management by non-government conservation organisations or by private landholders:
  - Secure additional native vegetation protected through an appropriate legal instrument that ensures the land is managed for conservation transfer ownership to non-government conservation organisations.
  - Negotiation of a conservation agreement under the *National Parks and Wildlife Act 1974* or *Nature Conservation Trust Act 2001* with private landowners.

It is envisaged the quantum of the offsets would be based on a set-ratio approach to offset impacts to endangered ecological communities and broad vegetation types on a like for like basis.

In addition to providing land offsets, the RTA could also consider, in consultation with DECCW, including additional revegetation in strategic locations and/or investment in management research related to the rehabilitation and protection of relevant threatened species.

The offset strategy would involve consideration of the total impact of a number of projects within a given section of the Pacific Highway and agreement on an appropriate offset area on a regional basis. It would aim to ensure greater regional biodiversity conservation outcomes by providing larger areas of land of greatest interest to the relevant land management agencies and potentially better links to existing conserved lands. It is considered that greater regional biodiversity benefits could be achieved by adopting this approach in preference to a piecemeal project by project approach.

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