9. CASE STUDIES

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9.1 Tugun Bypass

9.1.1 Location

The Tugun Bypass is a new seven kilometre long motorway between Currumbin in Queensland and Tweed Heads in New South Wales. Construction was undertaken by the PacificLink Alliance between April 2006 and June 2008 and involved the construction of a four-lane restricted access motorway with a central median to separate north and south traffic flows at a posted speed of 100 km/h. The median was designed to allow for future upgrading of the road to six lanes. The road corridor ranges in width from 60 metres to 90 metres with additional land required at interchanges. The design objective was to maintain the required safety standards and minimise impacts on environmentally sensitive areas.

The following environmental management principles were employed during the project in decreasing order of preference:

- Avoid
- Minimise
- Mitigate
- Compensate

For example, the project avoided a number of significant areas through corridor realignment designs. Impacts were also minimised on some species and communities.

Fauna management mitigation measures were incorporated and included regenerative corridors between 10 metres and 30 metres wide aimed at attracting wildlife to fauna structures. The provision of compensatory habitats included four frog ponds, 43 nest boxes, five underpasses and one at-grade overpass. Three of the underpasses were principally for planigales and frogs and one for fish.

Figure 9.1.1 Tugun Bypass project under construction.

9.1.2 Project Area Biota

The Tugun Bypass spans an area of south-eastern Queensland and north-eastern New South Wales recognised for its high environmental values. It comprises a biogeographical zone where temperate and sub-tropical regions meet and a large number of flora and fauna species are at the northern or southern limits of their geographical range. The area accommodates significant flora and fauna species and a high diversity of vegetation communities and important mammal, bird, amphibian and bat species. A total of 586 plant species were recorded in the study area together with 247 species of vertebrate fauna, consisting of

179 species of bird, 31 species of mammal, 20 reptile species and 17 amphibians. Notable values of the area include:

- The occurrence of a number of populations of threatened plants;
- Small isolated populations of common planigales and long-nosed potoroos and significant populations of the wallum sedge frog, wallum froglet and the eastern long-eared bat;
- A high diversity of vegetation communities;
- wallum heath/sedgeland;
- rainforest;
- swamp;
- woodland/forest;
- mangroves; and
- saltmarsh.
- A high diversity of bird, amphibian and bat species;
- The occurrence of habitat for a range of threatened and significant flora and fauna species and important habitat for use by a number of protected migratory bird species;
- A regional wildlife corridor and a sub-regional wildlife corridor; and
- Proximity to Cobaki Broadwater, an important breeding ground for commercially and recreationally important fish in the Tweed Estuary.

9.1.3 Species-specific information

a) Frogs

- The project's management plan required the capture and release of frogs within the project's footprint prior to construction (PacificLink Alliance 2006a).
- A number of frogs, including the *L. olongburensis* and *C. tinnula* were captured and relocated. This involved five ecologists and resulted in the capture of approximately one or two frogs per hour of effort.
- Monitoring:
  - Has been and will continue to be undertaken between 4pm and midnight (although exact times are dependent upon weather and season).
  - Monitoring of frog pond usage to occur between April and August for wallum froglets and between September and April for wallum sedge frogs (PacificLink Alliance 2006a).
  - Monitoring of the wallum froglet and wallum sedge frog for one day every month for the first year post-construction (PacificLink Alliance 2006a).

b) Birds

- Prior to construction the alignment was searched either side for 50-100 metres for any fauna, but the listed species, brahminy kite and eastern grass owl were particularly targeted during their breeding season (PacificLink Alliance 2006a).
- Call playback was utilised during searches for species including the eastern grass owl and brahminy kite.
- A bird specialist relocated nests that were found within the proposed road footprint (PacificLink Alliance 2006a).
- Birds were discouraged from the construction site by limiting food scraps through the provisions of bins.
- During construction sediment ponds were heavily landscaped to minimise the likelihood of them attracting foraging waterbirds.

- Monitoring:
  - o During clearing monitoring was undertaken three times a day
    - Monitoring commenced thirty minutes after first light; at midday; and concluded thirty minutes before dark (PacificLink Alliance 2006a).
    - This was aimed at minimising bird strikes associated with airport activities.
  - o Bird breeding areas within 100 metres of the construction zone were monitored during construction for any changes (PacificLink Alliance 2006a; PacificLink Alliance 2006c).
  - o During construction, contractors were employed to undertake daily monitoring of bird numbers, behaviour and activities. This information was used to reduce impacts on significant bird species and to identify the need for additional mitigation measures to reduce bird activity and attraction.
  - o If an area had particularly high bird numbers during construction, the reason was identified and mitigation actions undertaken (PacificLink Alliance 2006a). These included waving arms, sounding car horn and chasing away (Ecosure 2005).
  - o Monitoring was further reduced once treatment ponds and other water holding devices were either vegetated or decommissioned.
- Transparent noise walls included a rectangular pattern to minimise bird collisions (Figure 9.1.2).

Figure 9.1.2 Transparent noise walls with pattern to prevent bird collisions (Taylor 2008).

c) Mammals

- Common planigales
  - o Capture and release of common planigales occurred prior to construction and followed the project's management plans (PacificLink Alliance 2006a).
  - o After trapping common planigales were transferred out of the proposed construction zone (Queensland Department of Main Roads 2004).
  - o Mammals monitored annually using pitfall traps.
- Long-nosed potoroos
  - o Pre-clearing guidelines were followed.

- Visual delineation of road footprint occurred with no-go zones clearly marked.
- Potoroo warning signs were erected around known long-nosed potoroo habitat during construction.
- Potoroo-specific toolbox presentations were provided during construction to staff working near known potoroo habitat.
- Grass was slashed at intervals of 600mm to decrease the chance of wildfire in potoroo habitat.

- Microbats
  - Prior to construction, bark was stripped at dusk from paperbark trees earmarked for clearing to encourage microbat species, specifically *Nyctophilus bifax* (eastern long-eared bat), to roost elsewhere (PacificLink Alliance 2006b).
  - Lights less attractive to bats and insects were used in the tunnel (Tugun Bypass Alliance undated).
- Grey-headed flying-fox
  - Seasonal monitoring occurred during construction and post-construction using active searches and nocturnal surveys at known camp sites on the eastern shores of Cobaki and Hidden Valley.

9.1.4 Phase mitigation measures

- Pre-construction measures
  - Baseline data of all threatened species was compiled prior to clearing (PacificLink Alliance 2006a).
  - Management plans were created for the following species:
    - frogs;
    - long-nosed potoroos;
    - common planigales;
    - grey-headed flying foxes;
    - vegetation;
    - wetlands; and
    - Bird control (PacificLink Alliance 2006a).
  - The locations of hollow-bearing or habitat trees were recorded using a GPS and visibly marked to be checked prior to clearing.
  - No-go zones were delineated using signs and flagging tape and illustrated on "Sensitive Area Drawings". No-go zones were communicated to all staff through site induction and toolbox talks (PacificLink Alliance 2006a).
  - Significant fauna from within and immediately adjacent to the project footprint were relocated to alternative suitable habitat (PacificLink Alliance 2006a).
  - A "fauna rescue kit" was kept by spotter-catchers (and the project ecologist when acting in this capacity) and in the site office (PacificLink Alliance 2006a).
  - A pre-clearing integrated work method statement was also developed prior to commencement of clearing works.
- During Construction
  - The environment team communicated to all staff the importance of preserving environmental integrity.
  - A fauna specialist was present during vegetation clearing and tree relocation (PacificLink Alliance 2006a).
  - Clearing occurred in two stages. Smaller, younger trees were cleared first, followed by mature, hollow-bearing trees the following day.

- If threatened species were found during construction activities work in the immediate area was to be halted and the relevant authorities and Site Environmental Manager to be informed (PacificLink Alliance 2006a).
- Rescued animals were either immediately relocated or for nocturnal species kept in a designated area until dusk.
- During construction, "no-go" fences were monitored regularly (PacificLink Alliance 2006a).

- Post-construction
  - All maintenance staff and sub-contractors completed environmental training during site induction. Training included:
    - Location, identification and management of environmentally sensitive areas and threatened species;
    - Purpose and content of relevant standard operating procedures; and
    - Any information regarding environmental issues relevant to the staff's intended activity.
  - Fauna underpasses to be monitored for noise and vibration levels.
  - Environmental reporting on temporary and permanent structures quarterly. This includes recommendations for improvements to structures.
  - Weekly roadkill surveys to record observational road mortality data.

9.1.5 Mitigation measures: Underpasses

a) Potoroo culvert (Boyd Street)

Target Species

- Long-nosed potoroo.

Design:

- Figures 9.1.3 and 9.1.4.
- Box culvert.
- Dimensions:
  - Width: 2.4 metres.
  - Height: 1.8 metres.
  - Length: approximately 25 metres.
- Fauna exclusion fencing is used to guide fauna into the culvert.
- Base slab was constructed above the natural ground surface to ensure water does not pond.
- Entrances and exits to culvert were revegetated.
- Refuge pole design:
  - Height: 1.2 metres.
  - Diameter: 200 mm.
  - Placed to one side of the culvert.
  - Fork at the top.
- Logs were placed at entry and exit points to act as refuge for long-nosed potoroos.

Monitoring:

- Annual monitoring of bush hen nest sites at Boyd Street for one year.
- Infra-red still camera monitoring has now commenced in the Boyd Street culvert. A FaunaFocus FF120 remote camera is being utilised with two infra-red pre-illuminators (Figure 9.1.5). This system

has been attached to the roof of the culvert with a tree bracket from Faunatech. The camera has been placed mid-way through the structure.

- o The camera has recorded a number of rodents, snakes, lizards and butterflies, a swamp wallaby and an echidna.

Issues:

- Species scheduled to be planted at the culvert entrances were selected based on observed behaviours and use of plants by the long-nosed potoroo. Some of these species were difficult to procure from nurseries and a more generalised species mix was utilised.

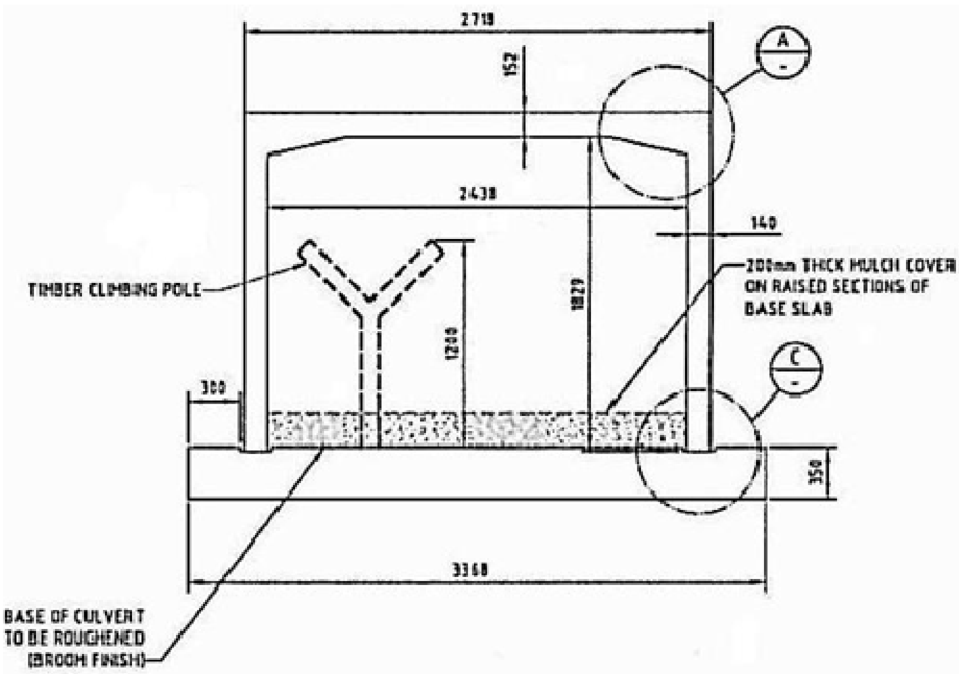


Figure 9.1.3 Cross section of fauna underpass, adapted from drawing 3003181-BYD-010-7306 (PacificLink Alliance 2006e).

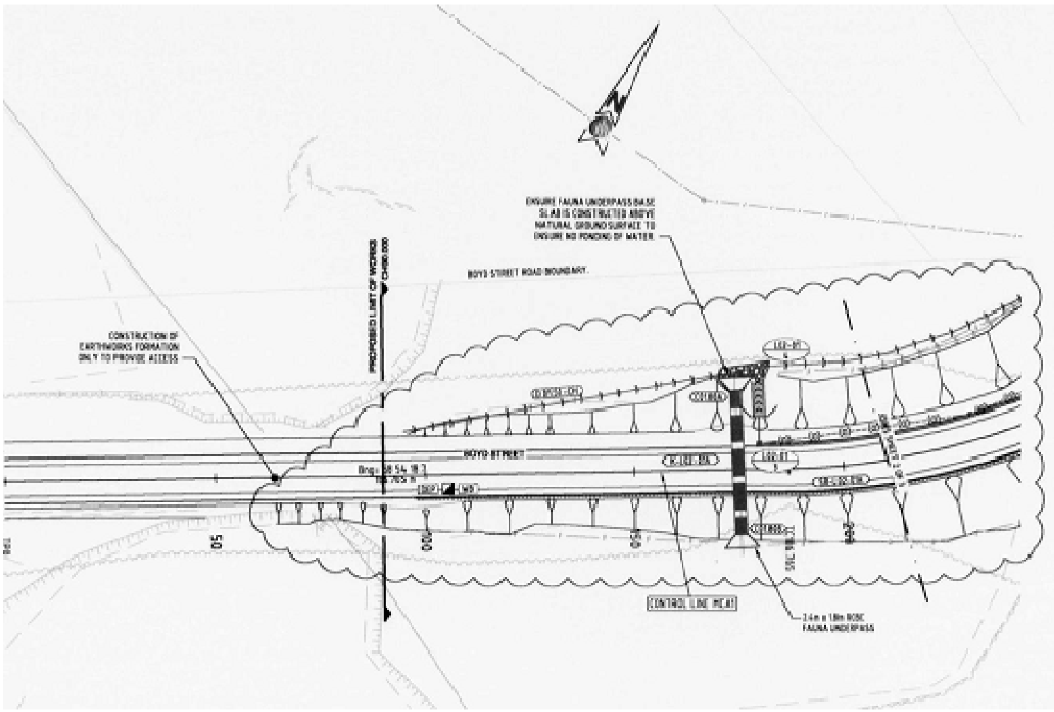


Figure 9.1.4 View of culvert alignment adapted from drawing 3003181-BYD-010-1001.

Figure 9.1.5 Infra-red still camera utilised in Boyd Street culvert

b) Frog culverts

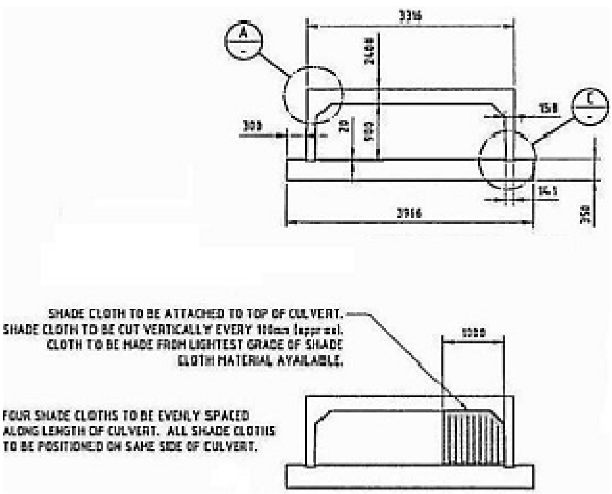
Fauna passage was needed to link areas identified as frog habitat and compensatory frog ponds.

Target Species

- Wallum sedge frog and wallum froglet.

Design:

- Three frog-specific box culverts have been installed (PacificLink Alliance 2006e).
- Precast box culvert.
- Dimensions:
  - o Width: 3 metres.
  - o Height: 900 mm.
  - o Length: 41 metres.
- Base was made up of 17 concrete blocks with 22 mm gaps.
- Base slab dimensions (per block):
  - o Width: 3 metres.
  - o Height: 900 mm.
  - o Length: 2.44 metres.
- 25 mm of mulch placed on culvert floor.
- Four strips of shade cloths were placed at regular intervals in underpass opening to provide refuge points (see Figure 9.1.6) (PacificLink Alliance 2007). Shade cloth is not usually utilised in fauna or frog culverts. This is an experimental design.
- Clearing was minimised near entrances.
- Culvert is protected from large fauna by exclusion fencing.
- Landscaping near entrances occurred as soon as possible after construction.
- Specific frog fencing is used to guide frogs towards the culvert entrances.



a)

b)

Figure 9.1.6 a) Cross sectional drawing of frog culvert adapted from drawing 3003181-DRN-020-3076 (PacificLink Alliance 2006c).
b) Frog culvert shade cloth treatment.

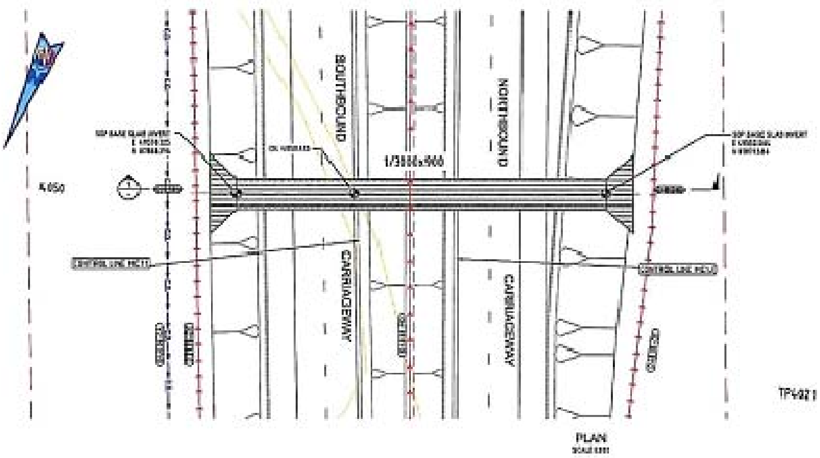


Figure 9.1.7 Drawing of frog culvert alignment adapted from drawing 3003181-DRN-020-3021 (PacificLink Alliance 2006c).

Issues:

- During rain periods the culvert will hold moisture and facilitate movement. However, during drier times culverts do not readily maintain a moist environment, which may affect the structure's success.
- Issues with monitoring techniques used have not been resolved. For more information see the Monitoring section below.

Monitoring:

- Monitoring has consisted of pitfall trapping at entrances to culverts.
- Pitfall trap monitoring is not effective as wallum sedge frogs are able to jump over the guiding barriers and out of buckets.
- Pitfall trapping outside the entrances to the culvert may only indicate presence of frogs adjacent to the structure and not actual use. To rectify this issue active searches within the culvert during or after significant rainfall events is being considered.
- Ink pads were used to monitor use of culverts. However, this method was seen as an undesirable monitoring method for frogs by the environmental approval agency.

c) Wet-dry culvert

A fauna crossing structure was needed in an area where frogs and common planigale were known to cross frequently, the wet-dry culvert was the solution (PacificLink Alliance 2007).

Target Species

- Common planigale, arboreal species and frogs.

Design:

- A wet-dry culvert was installed (Figure 9.1.8).
- The culvert consisted of two dry ledges running along the length (each side 850 mm wide) and a channel running down the centre (700 mm wide, 300 mm deep).
- Dimensions:
  - o Height: 0.9 metres.
  - o Width: 2.4 metres.
  - o Length: 3.7 metres.
- One fauna refuge pole was placed at each end of the culvert.
- Refuge pole design:
  - o Height: 1.2 metres.

- Diameter: 200 mm.
- Fork at top.
- Placed to one side of culvert.

- An unobstructed view of habitat is provided at either end.
- Minimal clearing was undertaken near the culvert.
- Culvert entrances have been revegetated with low, dense local plant species.

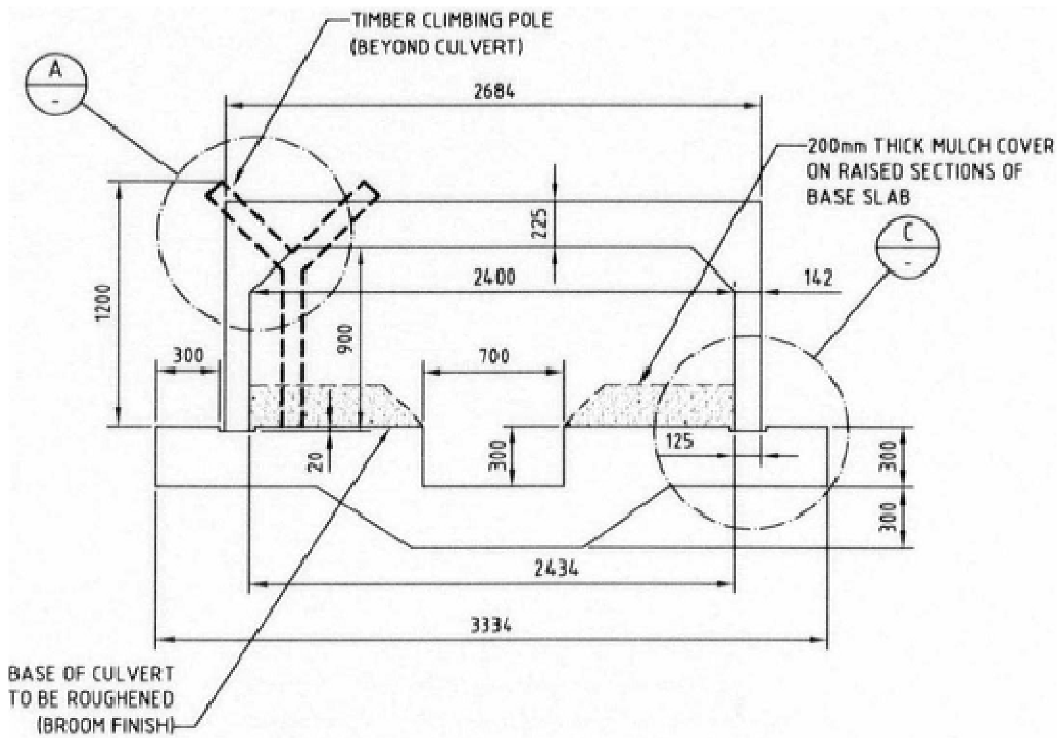


Figure 9.1.8 Cross section drawing of wet-dry culvert adapted from drawing 3003181-DNR-020-3096.

Design Proposal:

- A proposal to trial skylights and light wells was not approved due to concerns over their proposed locations (PacificLink Alliance 2007).

Issues:

- The low height and length of culvert may discourage use by common planigales.
- Mulch was supposed to be placed in the dry sections of the culvert but this has not occurred due to wetness of the culvert.
- Unexpected changes in drainage patterns have caused:
  - the culvert to convey more water then was originally anticipated;
  - water to pool around the culvert entrance;
  - postponement of planting vegetation required in designs.
- Construction of an access track on the western side of the culvert has resulted in an area of rock riprap that has been unable to be replanted.

Monitoring:

- After construction the culvert has been and will continue to be inspected monthly to ensure it does not become blocked with debris. Debris to be removed if it prevents fauna movement.
- Pit-fall monitoring was scheduled but this has not been possible due to the presence of water around culvert entrances.

d) Fish culvert

A drainage channel was constructed as a dedicated fish passageway (PacificLink Alliance 2007). This was a combined fauna and drainage channel but the structure's primary purpose was drainage.

Design:

- Two-celled box culvert design (Figure 9.1.10).
- Culvert has a one metre incline to accommodate drainage.
- Dimensions:
    - o Height: 1.5 metres.
    - o Width: 1.8 metres each.
    - o Length: 100 metres.
- Rocks were embedded in base slab to create back eddies or areas of reduced flow.
- 25 mm of sand was placed on top of the base slab to create a natural base.

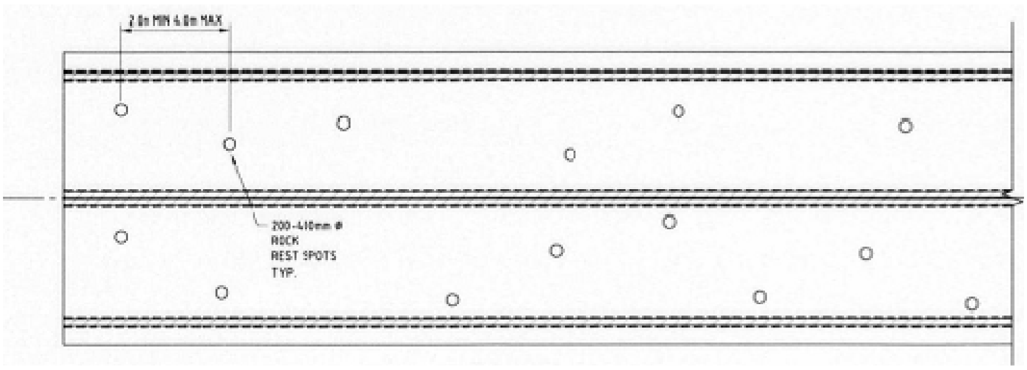


Figure 9.1.9 Rock arrangement for fish culvert base slab adapted from drawing 3003181-DNR-020-3116.

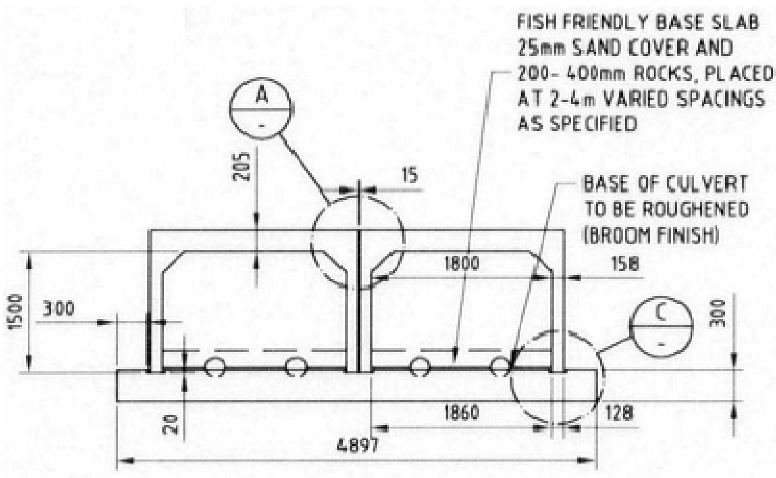


Figure 9.1.10 Cross sectional drawing of fish culverts adapted from drawing DNR-020-3116.

Issues:

- Construction of the culvert required a creek diversion.
- Mass fish relocation was required.

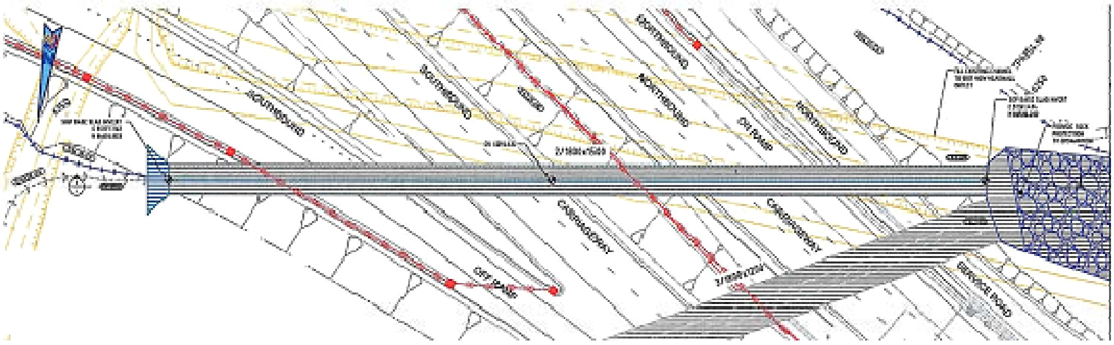


Figure 9.1.11 Fish passage alignment adapted from drawing 3003181-DRN-020-3111.

9.1.6 Mitigation measures: Barriers

a) Temporary frog exclusion fence

This fence was to prevent frogs escaping from the wetlands and entering the construction site and to assist in stabilising wetland habitat (Ecosure 2005; Australian Wetlands Pty Ltd 2006).

Target Species:

- Wallum sedge frog and wallum froglet.

Design:

- Installed around known wallum sedge frog and wallum froglet habitat (PacificLink Alliance 2007).
- Constructed from sediment fencing (Figure 9.1.12).
- Dimensions:
    - o Height: 400 mm (minimum).
- Once temporary frog fences were installed, ecologists searched known frog habitat and relocated frogs caught into the compensatory ponds enclosed by these temporary fences.
- Flexible lip to deter climbing frogs.

Monitoring

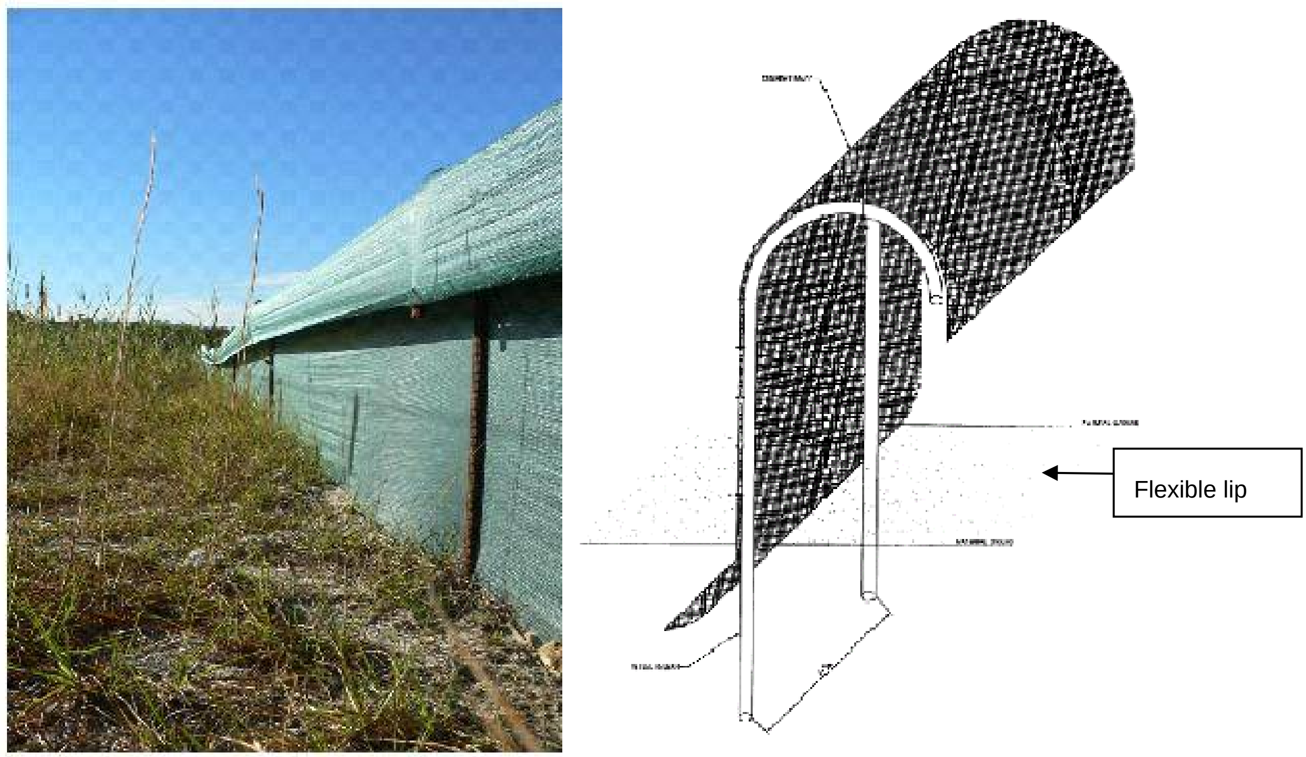
- Fence monitored monthly through active searches after rainfall events.

Issues:

- Sediment fence replacement became increasingly expensive as it deteriorated quickly and construction vehicles often ran over the fence.

Learnings:

- Fencing was relatively easy to install, and materials were easy to obtain.
- For long-term structures, UV resistant sediment fence material should be used to decrease fence maintenance costs.
- The innovation of having frog fencing that also performed the function of sediment fencing had the following benefits:
    - o Saved time and costs on installation.
    - o Less maintenance costs (as less structures).
    - o Reduced vegetation clearing needed.



a) b)

Figure 9.1.12 a) Temporary frog fence
b) Sketch of frog fence design

b) Floppy-top fence with ground mesh

This fence type channels fauna towards either the Hidden Valley viaduct or the closest fauna culvert (PacificLink Alliance 2007).

Target species:

- Range of species.

Design:

- Large trees and road design were considered when deciding on fence alignment.
- Dimensions:
  - o Height: 1.8 metres.
  - o Metal angle length: 400 mm (Figure 9.1.13).
  - o Mesh overhang (fauna side): 500 mm past end of metal frame.
- The fence was designed to have internal angles no less than 135^{o} to ensure that the fence does not create predator trap (PacificLink Alliance 2007).
- Does not cross through waterways.
- Maintenance gates were constructed so that fauna cannot pass through when closed but access to the road corridor has been maintained.

Monitoring:

- Fauna fence inspected monthly and any maintenance issues are noted (PacificLink Alliance 2007) and repaired within one month. (PacificLink Alliance 2008).

Issues:

- A small drainage culvert (typically dry) passed beneath the exclusion fencing. This was identified as potentially allowing fauna onto the carriageway. The culvert was retrofitted with vertical bars to prevent use by fauna.
- At the Tweed interchange the fence was installed within three metres of retained vegetation. Vegetation was retained rather than cleared as it was deemed unlikely that arboreal species were in the area.
- The length of the ground mesh pins made them unsuitable for sandy soils so they were lengthened.

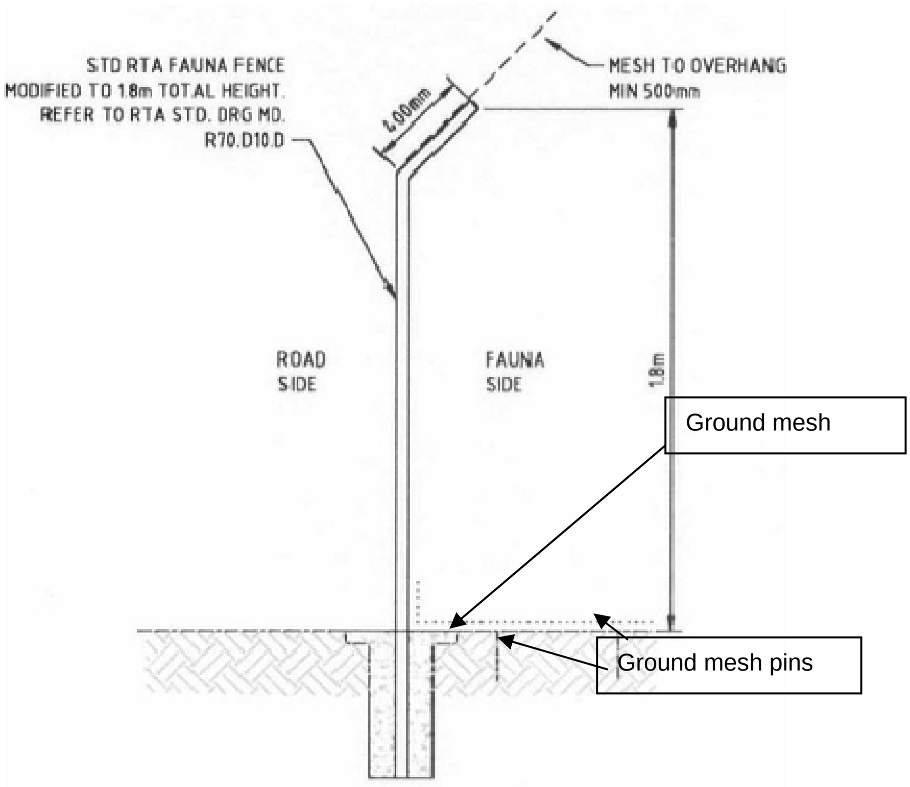


Figure 9.1.13 Floppy top fencing (adapted from drawing 3003181-BFF-020-6003).

c) Fauna fence with ground mesh

Installed in known potoroo habitat to direct fauna to the Boyd Street underpass.

Target Species:

- Used to exclude ground dwelling species with the potential to dig.

Design:

- The fauna fences are joined in some sections and two distinct fences in others.
- The fence is designed to have internal angles no less than 135^{o} to ensure that the fence does not create a predator trap (PacificLink Alliance 2007).
- Does not cross through waterways.
- Maintenance gates were constructed so that fauna cannot pass through when closed but access to the road corridor has been maintained.

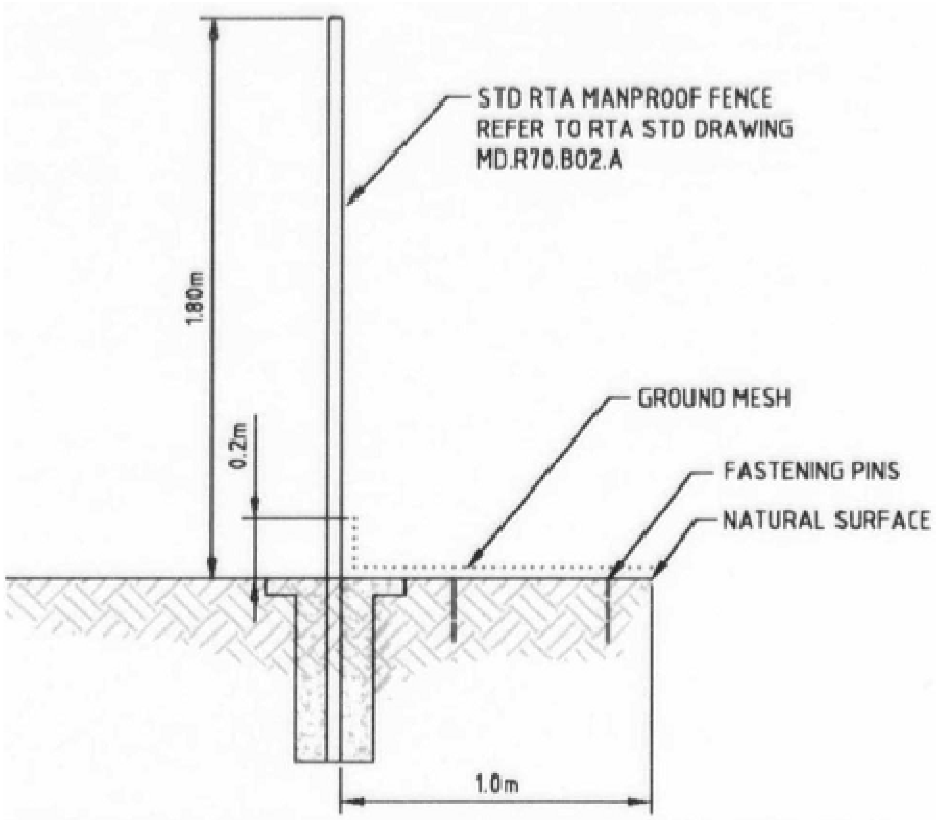


Figure 9.1.14 Fauna exclusion fencing with frog fencing attached (adapted from PacificLink Alliance 2006 Drawing 3003181-BFF-020-6003) (Pacific Alliance 2006c).

Issues:

- Complete installation of fences could not occur until the end of the construction phase due to ongoing access requirements.
- Mesh pinning did not work satisfactorily in sandy soils and the mesh rolled upwards. Rocks have held down the fencing, but to avoid this issue would require longer and more numerous pins to be installed. Grass is now starting to assist in pinning down the mesh.

Monitoring:

- Fauna fence is inspected monthly and any maintenance issues are noted (PacificLink Alliance 2007) and repaired within one month (PacificLink Alliance 2008).
- Fence monitoring is currently being undertaken to:
  - identify gaps, particularly at drains, gates and other areas;
  - ensure mesh is intact;
  - clear vegetation within three metres of the fence that is likely to allow fauna to climb the fence.

d) Stand-alone frog fencing

Target Species

- Frogs.

Options:

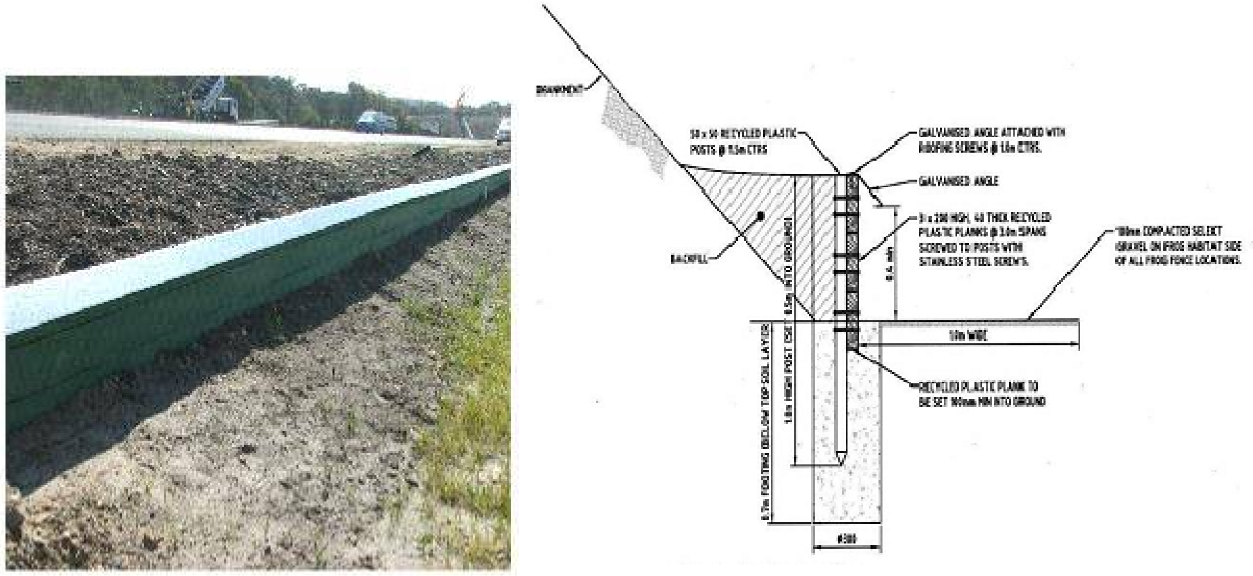
- No existing frog fence designs were considered suitable for the species and location (PacificLink Alliance 2007).
- Eight options for a free-standing fence were designed and trialled.

Trials:

- Undertaken prior to construction (PacificLink Alliance 2006b).
- An initial trial looked at a number of options based on recommendations from Dr Glen Ingram (PhD Bsc).
- Fence efficacy was determined by giving each design a weighted score from 1 = low, 3 = high for the following categories:
    - Durability.
    - Ease of construction.
    - Price.
    - Ability to blend with surrounds.
    - Recycled components.
- Trial designs undertaken by PacificLink Alliance for free-standing frog exclusion fence based on constructability were:
    - Recycled polyethylene sheeting and galvanised star pickets.
    - Recycled polyethylene sheeting and plastic SHS posts.
    - Galvanised roof purlin and galvanised SHS posts.
    - 8 mm compressed fibre cement sheeting and galvanised SHS posts.
    - 18 mm compressed fibre cement sheeting and galvanised star pickets.
    - Hebel blocks and galvanised universal column.
    - Recycled plastic planks and recycled plastic posts.
    - 18 mm compressed fibre cement sheeting and galvanised SHS posts (PacificLink Alliance 2007).
- Based on research and trials a design was chosen for the project.

Design:

- Installed recycled plastic planks and recycled plastic posts (Figure 9.1.15).
- The roof and lip were made of pre-fabricated galvanised sheet and attached to the top of the planks (Chambers and Ingram 2005).
- Dimensions:
    - Height: 400 mm.
    - 150 mm long sloped (Ecosure 2005; Hay 2007).
- The lip material, lip length and angle of lip toe seemed to be important factors in fence success.
- Sub soil drainage pipes were installed.
- Rock riprap and geofabric were installed to counteract erosion and reduce vegetation maintenance requirements.
- Vegetation was cleared one metre either side of the fence (Hay 2007; McPherson and Metzger 2007).
- The fence was installed as close as possible to the bypass zone to allow for the greatest habitat retention (PacificLink Alliance 2007).



a) b)

Figure 9.1.15 a) Stand-alone frog fencing.
b) Detailed drawing of freestanding frog fence adapted from PacificLink Alliance Drawing 3003181-BFF-020-6003.

Issues:

- Issues have arisen due to lack of vegetation maintenance around frog fencing
- Difficult to undertake the cost-benefit analysis between price and durability for the different options (Hay 2007; Marix-Evans 2007).
- The fence was not designed as a retaining wall. However, the area behind the fence was backfilled resulting in difficulties with drainage and change in vegetation behind fence (Figure 9.1.16).
- There were issues with the fence alignment where it crossed access tracks. A special frog fence for access tracks was designed and installed to correct this issue (Figure 9.1.17).
- Fence installation led to some erosion issues below the fence line.

Figure 9.1.16 Specially designed frog gate across access track. Note the geofabric at the base of the frog fence.

Figure 9.1.17 Backfilling behind frog fences has caused drainage problems.

Learnings:

- Minor changes to the fence design were needed because batters directed concentrated water flows through the fence.
- Due to the height of the fence, it required very little vegetation adjacent to it before frogs had the potential to jump or climb over the fence.

Figure 9.1.18 Concrete batter chute channelling water through the frog fence. Rubber flaps were installed to minimise frog access.

e) Frog fencing attached to chain-wire fence

Target Species

- Frogs and other fauna.

Options:

- No existing frog fence designs were suitable for attaching to a chain-wire fence so another design was needed (PacificLink Alliance 2007).
- Three options of frog fences to be attached to existing fences were designed (PacificLink Alliance 2007).

Design:

- 5 mm insertion rubber clamped to a galvanised backing plate then attached to a chain-wire fence (Figures 9.1.19 – 9.1.21).
- Dimensions:
  - o Height: 400 mm.
  - o 150 mm long sloped roof (Ecosure 2005; Hay 2007).
- Vegetation was cleared one metre either side of fence (Hay 2007; McPherson and Metzger 2007).
- The fence was installed as close as possible to bypass zone to allow for the greatest habitat retention (PacificLink Alliance 2007).

Issues:

- Difficult to undertake the cost-benefit analysis between price and durability for different options (Hay 2007; Marix-Evans 2007).
- Difficulties with drainage occurred.
- Minor issues with installation occurred. The design required that the rubber flap be dug into the ground. In some areas this was overlooked.
- Vegetation around the fence has required active maintenance to maintain clear zones.

Figure 9.1.19 a) Frog fence attached to floppy top fencing.

Figure 9.1.19 b) Permanent frog fence design to be attached to the existing airport security fence (PacificLink Alliance 2007).

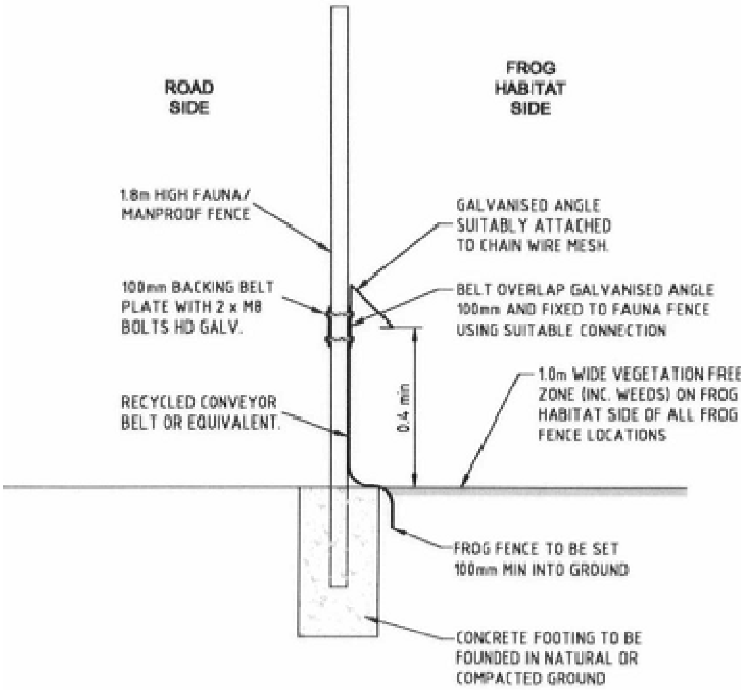


Figure 9.1.20 Frog fencing attached to chain-wire adapted from Drawing BFF-020-6003.

Figure 9.1.21 Security fence with frog fencing attached.

f) Fauna escape ramps

Target species

- Variety of species including swamp wallaby and echidna.

Design

- Ramp enables fauna to escape from the roadside to the habitat.
- Constructed as part of the fauna exclusion or site fencing.
- For details on structure design see Figures 9.1.22 and 9.1.23.

Issues

- The escape ramp was not high enough to prevent swamp wallabies using the ramp as an access point onto the carriageway. A retrofit occurred to correct this problem.

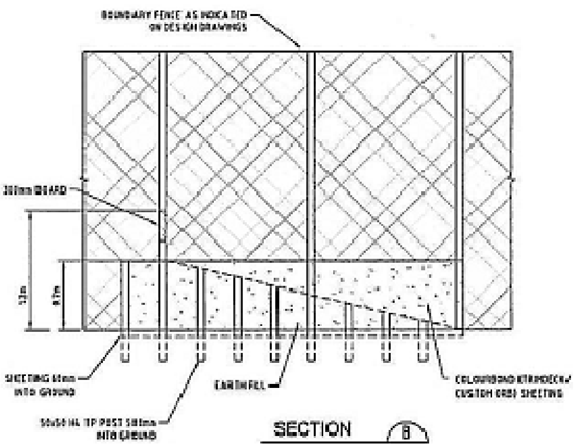


Figure 9.1.22 Retrofit design drawings of fauna escape ramp adapted from Drawing SK-1001.

a) Fauna escape opening.

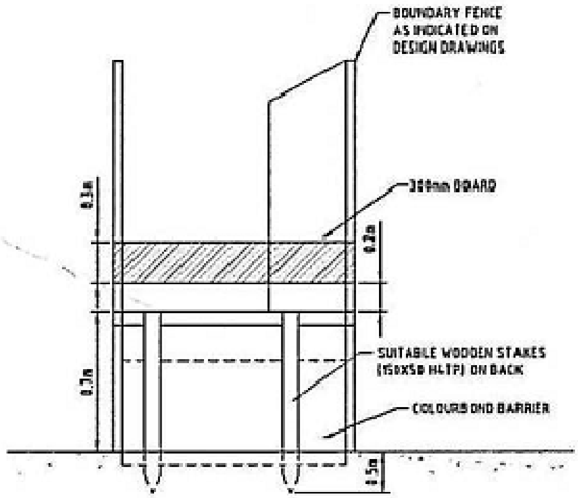


Figure 9.1.22 b) Fauna escape mechanism front elevation.

Figure 9.1.23 Retrofit fauna escape ramp.

g) Fence monitoring

- Preliminary monitoring results show a decline in roadkill in the area. This indicates effectiveness of the retrofitted barrier structures.
- Slight adjustments to fences, particularly at access points and drainage crossings, may continue to decrease incidence of roadkill.

9.1.7 Habitat enhancement

a) Frog ponds

- The design was needed to allow frog movement without allowing fish migration into the frog ponds (Ingram and Caneris 2005).
- Ponds were constructed as stepping stones between existing wetlands areas and within existing vegetative corridors (PacificLink Alliance 2006c).

Design:

- Four frog ponds were installed.
- Dimensions:
    - Depth: 1.5 metres.
    - Slope leading into water: 300 mm (Australian Wetlands Pty Ltd 2006; PacificLink Alliance 2006c).
    - Two ponds approximately 10 metres x 20 metres (Australian Wetlands Pty Ltd 2006).
    - One pond approximately 15 metres x 30 metres.
    - One pond of 15 metres x 15 metres (Australian Wetlands Pty Ltd 2006).
- Water heights in ponds are controlled using a water control device (see Figure 9.1.24).
    - Water controlled using a uPVC twister, in a precast pit.
    - The twister height can be set to enable adjustment of water levels, or complete draining of the pond.
    - Twister can be capped to prevent loss of water from pond when required.
    - The twister joins a drainage pipe running through the pond embankment and discharging into the nearest watercourse.
- An impermeable layer of bentonite was used in two of the ponds to help hold water in ponds to prevent drying out (Figure 9.1.25).
- Vegetation and soil from the surrounding area were used to construct ponds (Australian Wetlands Pty Ltd 2006).
- Hydro periods were established so ponds periodically dried out, preventing *Gambusia* infestations from lasting for more than one season.
- Revegetation of surrounds aimed to replicate frog habitat with locally sourced native species to reduce edge effect and invisibility of pond ecosystems (PacificLink Alliance 2008; PacificLink Alliance 2006c).
- Reeds were planted to limit bird access to ponds (PacificLink Alliance 2008).
- Constructed frog ponds were fenced with sediment and frog protection fencing during construction.
- Ponds were protected from soil build-up and erosion via sediment fences (PacificLink Alliance 2007).

Figure 9.1.24 uPVC twister used to control water level in ponds.

Figure 9.1.25 Frog pond construction process.

a) Laying of impermeable layer necessary to prevent the pond from drying out.

Figure 9.1.25 b) Slabbing method used to transfer wetland vegetation.

Figure 9.1.25 c) Established revegetated frog pond.

Issues:

- Suspected leaking seals affected hydro-periods.
- It was hard to prevent weed outbreak.
- One test pond for relocated frogs was unsuccessful, potentially due to inappropriate location (Tugun Bypass Alliance undated).
- Personnel with knowledge of pond design principles were required to be present on site at all times to ensure that any deviations from drawings still fulfilled design requirements. This was very time consuming.
- Leaking pipe outlets required replacement.
- Manual weed removal (as required) is resource intensive.

Learnings:

- Time and money was saved by ensuring non-weed contaminated soil was utilised and transferred.
- Time and money can be saved by ensuring only high-quality seeds are utilised for revegetation.
- The slabbing method used to transfer wetland vegetation was very successful as it reduced the need for direct planting of tube stock.
- It took time for the water to reduce in pH (to the required level) whilst ponds matured.

Monitoring:

- Monitoring will continue for five years (Australian Wetlands Pty Ltd 2006).
- Ponds are monitored quarterly for the identification and removal of weeds (PacificLink Alliance 2008).
- Monitoring has involved quarterly active searches at night, preferably after or during a significant rainfall event.
- Call playback has also been used.
- Physical parameters of the frog ponds have also been collected as they have been identified as a measure of success. Parameters collected included:
  - pH;
  - Water level; and
  - Electricity conductivity.
- Preliminary results are inconclusive. However, maturing of vegetation and active maintenance may improve effectiveness.

- Frog monitoring needs to account for different habitat requirements at different stages of life cycle.

b) Nest boxes

Target species

- Nest boxes have been installed for a variety of species:
  - common brushtail possum;
  - sugar glider;
  - squirrel glider;
  - large bats;
  - boobook owl;
  - barn owl;
  - owlet nightjar;
  - medium-sized microbat;
  - mountain brushtail possum.

Considerations:

- Data was collected on density and dispersion of original hollows before removal (PacificLink Alliance 2007).
- Site ecologist completed a hollow inspection checklist every time a hollow was disturbed.
- If a hollow-bearing tree was cleared, the tree species, positioning and dimensions of hollow were noted so that an appropriate nest box could be provided.
- Tree hollows that could not be relocated were replaced by nest boxes at a ratio of 1:1 (PacificLink Alliance 2007).
- 43 nest boxes were installed. For target species please see Table 9.1.1 (PacificLink Alliance 2006a).

Table 9.1.1 Nest boxes installed at Tugun Bypass (PacificLink Alliance 2008).

Target Species	Number of boxes
common brushtail possum	10
sugar glider	9
squirrel glider	10
large bats	5
boobook owl	1
barn owl	1
owlet nightjar	3
medium-sized microbat	2
mountain brushtail possum	2

- Medium hollows were replaced with medium nest boxes and large hollows with large nest boxes (PacificLink Alliance 2007).
- New boxes and hollows were installed before clearing of original habitat, where possible.

Design:

- Nest box openings were designed to allow minimal rainfall and sunlight to enter (PacificLink Alliance 2007; PacificLink Alliance 2006c).

- Nest boxes were installed away from human pathways and approximately 4-8 metres above ground by a flexible metal strap to allow for tree growth (PacificLink Alliance 2007; PacificLink Alliance 2006c).
- Replacement hollow logs were sourced from other construction sites to provide a more natural habitat.

Issues:

- Although details regarding tree species, positioning and dimensions of hollow were noted, it was found that land tenure, access issues and limited area were the main limiting factors on box location.

Monitoring:

- Nest boxes were installed to facilitate monitoring.
- Placement of nest boxes took into account future land-use and land tenure issues to ensure that nest boxes could be accessed till the end of the monitoring period.
- Monitoring will occur for two to three years.
- If nest boxes are being used by pests or insects then modifications and/or movement of the nest boxes are made in consultation with a qualified ecologist (PacificLink Alliance 2008).
- After initial monitoring, any unused boxes were moved and/or modified (PacificLink Alliance 2008).
- The following are being monitored:
  - Effectiveness of nest boxes;
  - Appropriateness of nest box location;
  - Whether the nest box is inhabited or vacant;
  - What species is using the box; and
  - If maintenance is required.
- Preliminary monitoring indicates a 75% rate of occupation.

Figure 9.1.26 Nest box used to compensate for hollows lost from Tugun Bypass construction (Environment and Heritage presentation 2007).

9.1.8 General environmental project information

a) Anthropogenic measures

- Site environmental officers encouraged communication between workers to enhance fauna and flora mitigation measures. These methods included:
    - Educating staff to ensure they understood how to mitigate impacts to fauna (PacificLink Alliance 2006a).
    - Communicating the importance and location of ‘no-go’ zones.
    - Forming relationships with site staff encouraging them to contact environmental officers with any problems.
    - Maintaining a strong site presence by environmentally qualified staff by having at least two environmental officers and one ecologist on site for the majority of the project.
- Site environmental officers developed and delivered toolbox talks to raise environmental awareness to all site staff (PacificLink Alliance 2008).
- Toolbox talks included:
    - Bird flocking – understanding the importance of controlling waste and ponded water to reduce attractiveness of work areas to birds and focused on those staff working around the Gold Coast Airport and tunnel.
    - Long-nosed potoroo – showed staff what a long-nosed potoroo looked like and explained their lifestyle habits. Undertaken for those staff working in the vicinity of known potoroo populations.
    - Frogs – explained the importance of taking care when working in known frog habitat, and explained the importance of minimal impacts, staying out of these areas, not polluting water, including the correct management of acid sulphate soils.
    - General environmental issues included pollution of waterways, waste management and importance of no-go zones.
- All employees and sub-contractors received inductions in:
    - Location of sensitive areas according to sensitive area drawings.
    - Vegetation protection areas (PacificLink Alliance 2006a).
    - Habitat trees.
    - Basic fauna rescue procedures.
    - Threatened species habitat areas.
    - Weed identification and control (PacificLink Alliance 2006a).
- Employees and sub-contractors particularly involved with flora and fauna received additional training in:
    - Clearing.
    - Topsoil management.
    - Culvert installation requirements.
    - Waterway realignment.
    - Species identification.
    - Bridge construction.
    - Crossing installation.
    - Habitat restoration.
    - Mitigation measures.
    - Fauna injury response (PacificLink Alliance 2006a).
- Site meetings addressed complaints, monitoring outcomes and other issues (PacificLink Alliance 2006a).

b) General issues

- Although monitoring results were supposed to be used to evaluate management plans, there were minimal changes due to extended process of gaining approval for changes made (PacificLink Alliance 2006a).
- Excavating soil needed to minimise release of acid sulphate soil (ASS). Had to ensure that ASS did not leach into frog wetlands (Australian Wetlands Pty Ltd 2006).
- Government agencies and contractors often had personal values and ideas about the environment which impacted upon management plans and day-to-day operations.

c) General learnings

- Roads and Traffic Authority developed specific fauna rescue framework with New South Wales Department of Environment and Conservation (Tugun Bypass Alliance undated).
- Introduced role of independent project verifier who guaranteed quality of design and also negotiated any changes proved successful (Los and Stein 2007).
- Having representatives from RTA and TMR with the ability to make decisions and amendments available on site decreased and simplified the review process (Tugun Bypass Project Learnings Workshop 2007).

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9.2 Compton Road - Brisbane City Council

9.2.1 Background

Compton Road is located on Brisbane's south-side. A 1.3 kilometre section of Compton Road was upgraded from two lanes to four lanes with a centre median (Goosem 2005; Jones 2006). The upgrade included measures to link Kuraby Bushlands with the nationally significant Karawatha Forest via eight glider-poles; three rope ladders; two box culverts, two wet culverts; fauna exclusion fencing; escape poles; and a fauna land bridge (Brisbane City Council 2005) (Figure 9.2.1). This collection of fauna mitigation structures is the highest diversity of fauna structures in one location anywhere in the world (Veage and Jones 2007). The upgrade was finalised in 2005.

9.2.2 Target species

Arboreal species

- feathertail glider (*Acrobates pygmaeus*).
- sugar glider (*Petaurus breviceps).*
- squirrel glider *(Petaurus norfolcensis*).
- greater glider (*Petauroides volans*).

Birds

- grey goshawk (Accipiter novaehollandiae).
- brown goshawk (Accipiter fasciatus).
- powerful owl (Ninox strenua).
- varied sittella (Daphoenositta chrysoptera).
- black-faced monarch (*Monarcha melanopsis*).
- spectacled monarch (*Monarcha trivirgatus*).
- satin flycatcher (*Myiagra cyanoleuca*).
- white-throated treecreeper (*Cormobates leucophaeus*).

Reptiles

- fire-tailed skink (Morethia taeniopleura).
- lace monitor (Varanus varius).

Monotremes, rodents and marsupials

- eastern grey kangaroo (*Macropus giganteus*).
- short-beaked echidna (*Tachyglossus aculeatus*).
- koala (*Phascolarctos cinereus*).
- common dunnart (S*minthopsis murina*).
- common planigale (*Planigale maculate*).
- yellow-footed antechinus (*Antechinus flavipes*).
- bush rat *(Rattus fuscipes*).

- swamp rat (*Rattus lutreolus*).

Figure 9.2.1 Location of Compton Road and fauna mitigation measures (Veage and Jones 2007).

9.2.3 Mitigation measures

a) Overpass: Land bridge

Considerations:

- The final measurements of the land bridge were based on budgetary constraints, topography and engineering ability.

Design:

- Figures 9.2.2 and 9.2.3.
- Arched and hourglass.
- Dimensions:
    - o Length: 70 metres, base width: 20 metres, mid-width: 10 metres.
    - o Height is eight metres above the road.
    - o Each vehicle tunnel is 5.4 metres high.
    - o Slope of the batters on either side is 1:3.
- Roadside fauna exclusion fence is continuous along both sides of the road for the entire length of the upgraded road and keys into the land bridge.
- The land bridge vegetation consists of local shrub, tree and grass species. However, vegetation at either end of land bridge was not replanted. This has caused a gap between the land bridge and forest vegetation until natural regrowth establishes.
- Vegetation growth on the land bridge was aided by a drip irrigation system and between two and three metres of mulch during the early stages of plant establishment.

Figure 9.2.2 Land bridge at Compton Road (Robinson-Wolrath 2008).

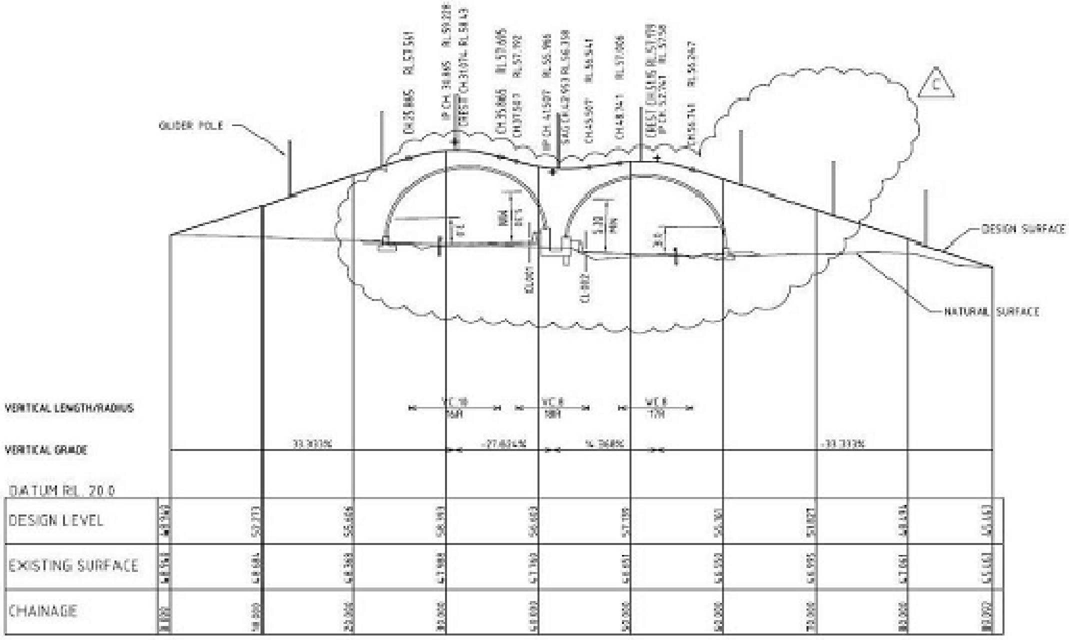

Figure 9.2.3 Longitudinal section of the land bridge adapted from drawing LB-02 (Chambers and Ingram 2005).

Monitoring:

- Scat collection and identification was the primary method of monitoring.
- Pitfall trapping was utilised (Veage and Jones 2007).
- Two Faunatech Digicam 120 infra-red triggered cameras were installed on the land bridges in 2006 (Figure 9.2.4). Cameras utilised dual sensor modification for passive infra-red sensors and active infra-red beam sensors.
    - Due to a series of technical issues cameras were unavailable to collect data on a regular basis.
    - Cameras were raised on poles on either side of the land bridge, against the fauna exclusion fencing.
    - Each camera was powered by a 12V sealed lead-acid battery which was changed fortnightly.
- Results from monitoring cameras:
    - Due to serious technical and logistical problems camera monitoring capabilities were compromised. Despite camera problems, monitoring methods detected the following species: brown hare, red-necked wallaby, swamp wallaby, Australian magpie, torresian crow and lace monitor.
- Results from monitoring:
    - Over the summer of 2006 the introduced brown hare dominated, with a report of utilisation by short-beaked echidna (*Tachyglossus aculeatus*) (Veage and Jones 2007).
    - Species which have become resident on the land bridge include lace monitor (*Varanus varius*), yellow-faced whip snake (*Demansia psammophis*) and ornate-burrowing frog (*Limnodynastes ornatus*) (Veage and Jones 2007).
    - There are fewer snakes utilising the land bridge than expected. The reason for this is unclear (Wilson 2007).

a)

b)

Figure 9.2.4 a) Faunatech Digicam used to monitor use of land bridge (Veage and Jones 2007). b) Active infra-red beam sensors (Veage and Jones 2007).

Issues:

- The slope leading into Karawatha Forest is particularly steep to avoid excessive clearing of vegetation.
- The presence of a gully on the Karawatha Forest side of the land bridge also contributed to the slope's steepness.
- There were concerns that such a gradient would deter some fauna from utilising the land bridge. However, monitoring outcomes to date have shown this has not been a factor.

- A break in the vegetation growth at the base of the land bridge for access purposes has resulted in a loss of the habitat continuum.

Learnings:

- Vegetating the land bridge with grass seeds instigated immediate usage by macropods.
- Due to the success of establishing vegetation and relocating logs on to the land bridge, it has become home to numerous species rather than just acting as a movement corridor.

b) Barrier structure: Fauna exclusion fence

Design:

- Aim of the structure is to guide fauna towards safe fauna crossing structures.
- The fauna exclusion fence is continuous along both sides of the road for the length of the upgraded road.
- Dimensions:
  - o 2.48 metres high.
  - o Extends five centimetres into the ground (Figure 9.2.5).
- The fence is constructed of rubberised metal mesh.
- A UV stabilised root barrier 3 mm thick and 480 mm high runs along the bottom of the fence and extends 300 mm into the ground. The sheet is attached to the forest side of the fence.
- A rolled metal sheet, 590 mm wide and 1.38 metres above the ground, is attached on the forest side of the fence to discourage climbing animals.
- Timber escape poles are located every 50 metres on the roadside of the fence.

Figure 9.2.5 Fauna exclusion fencing at Compton Road (Robinson-Wolrath 2008).

Monitoring:

- Success of fauna structures was determined by monitoring roadkill pre- and post-construction.
- Pre-construction monitoring:
  - o 1.3 kilometres of road were surveyed by walking along the road (both sides) and recording fauna roadkill numbers.

  - o Surveys were undertaken over 16 weeks between February and June 2004, twice weekly over consecutive days.
  - o Surveys were conducted between the hours of 8.30 am – 11.00 am.
  - o Numbering of each individual roadkill and recording locations prevented duplication.
- Post-construction monitoring:
  - o Weekly roadkill surveys commenced in February 2005 immediately following construction. Surveys continued through until June 2007.
  - o Post-construction monitoring consisted of travelling both sides of the survey section in a car at 70 km/h.
  - o The change in survey method from pre- to post-construction was due to work health and safety concerns.
- Results:
  - o Monitoring of the fauna exclusion fence revealed a 77% reduction in mammal roadkill and a 66% reduction in bird fatalities (Brisbane City Council 2005).

Issues:

- Landholder negotiations were required as the fauna exclusion fence was required to cross a private driveway and a section of their property.
  - o The fence design in front of this property was amended to have clear sheeting (instead of rolled sheet metal) and a sliding door across the driveway.

Learnings:

- Compton Road has shown the necessity for and effectiveness of fauna exclusion fencing. During the four months pre-construction thirteen individuals (fauna species) were killed on Compton Road whilst in the two years post-construction this was reduced to five individuals, two of which were attributed to human-caused fence breaches (Veage and Jones 2007).

c) Underpasses: Culverts

Considerations:

- Existing drainage lines, ‘natural’ water movement and target species.
- Details, such as size, entrance pole gradient and furniture were based on budgetary capability, engineering possibility and cooperation between project managers, engineers and ecologists.

Design:

- Two fauna-specific concrete culverts were installed (Figures 9.2.6 and 9.2.7).
- Dimensions:
  - o 2.4 metres high;
  - o 2.5 metres wide;
  - o 48 metres long.
- Contains three levels:
  - o A lower cement level (0.9 metres wide) for water flow.
  - o A raised cement level with rocks, leaf litter, sand and gravel as furniture:
    - This level is 1.6 metres wide and 400 mm above the ground, leaving a height of two metres from this level.
    - Although rocks were embedded into the concrete, natural processes are required to deposit sand, gravel and leaf litter.
  - o Two shelves are provided along the entire length of the underpass to provide dry passage and safety from predators:

- A small wooden shelf (250 mm wide) attached to the wall of the underpass aims to facilitate the passage of smaller species without requiring them to move along the relatively open area of the underpass floor; and
- A raised half-log railing one metre from the bottom of the culvert. Entrance poles on the end of this railing are installed.

- The substratum is cement which allows for water flow if required.
- One of the culverts has a gully in the median that acts as a skylight and is connected to an artificial pond.

Figure 9.2.6 An underpass at Compton Road. Note the raised cement level with rock 'furniture', wooden shelf and log railing (Bond and Jones 2006).

Figure 9.2.7 Kuraby Bushland entrance to an underpass and the wet culverts opening into an artificial pond. The fauna exclusion fence is also visible above the culverts (Bond and Jones 2006).

Monitoring:

- Post-construction monitoring consisted of sand plots, scat collection and infra-red cameras with sensors.
- Sand plots:
  - o Sand strips inside both ends of the culverts, approximately one to two metres from the end to minimise disturbance from rain or wind. The strips were approximately 10-20 mm thick, one metre wide and covered the entire width of the raised section of the underpasses.
  - o Smaller sand strips were also set up on the shelves (5 mm thick and 500 mm wide).
- Results from sand plot monitoring:
  - o A successful crossing was claimed if prints belonging to the same species were found at either end of the culvert and at the same time. Between 15% and 28% of detected tracks by animals made complete crossings (Veage and Jones 2007).
  - o The highest rate of use recorded for one day has been 42 tracks in February 2006, one year after construction (Veage and Jones 2007).
  - o Small mammal, ‘rodents’, specifically *Rattus* species, both native and introduced species have dominated the structures.
  - o The next most frequent users have been lizards, snakes and birds.
  - o Sand tracking revealed there were strong seasonal movements by the northern brown bandicoot (*Isoodon macrourus*).
- Infra-red cameras:
  - o Four Faunatech Digicam 120 cameras were operational in the underpass in 2007.
  - o Cameras were passive infra-red and microwave sensors triggered by treadles on the raised shelf.
  - o Cameras were encased in weatherproof and vandal deterrent housing.
  - o Cameras were positioned within two to three metres of each culvert entrance mounted with stainless-steel brackets that sit perpendicular to the culvert ceiling, secured via two U-shaped padlocks.
  - o Each camera was powered by a battery pack of 10 rechargeable nickel-metal hydride AA batteries, which lasted for four nights.
  - o Microwave sensors enabled detection of smaller species using the underpass.
  - o Passive sensors detected changes in ambient background temperature.
- Results from infra-red cameras:
  - o Initial mounting of cameras directly into the culvert ceiling was ineffective in terms of field of vision and life of batteries.
  - o Due to serious technical and logistical problems camera monitoring capabilities were compromised. Despite camera problems the house mouse, rodent and skink were all recorded using the underpass.

Issues:

- One culvert has a drainage pipe passing close to the roof of the culvert resulting in the clearance between the wooden fauna ledge and the pipe to be only 300 mm (approximately). However, a ramp was recently installed to allow for fauna movement over the pipe.
- Existing water levels in some areas prohibited the design of dry fauna culverts due to the high probability of constant flooding.
- The process of establishing details such as the dimensions of culverts, shelving, height of shelving, other furniture and gradient of entrance poles generally had a very limited scientific basis.

Nevertheless, monitoring has revealed that most design features have been successful at providing a safe crossing.

- A potential ongoing issue is that the culverts have large concrete aprons with limited vegetation around the entrance. Some species are known to avoid the concrete bases.

d) Glider poles

Design:

- Eight glider poles made of bare treated timber were installed spanning the entire length of the land bridge (Taylor and Goldingay 2007a).
- Each pole is eight metres high with crossbeams located between six and seven metres above the ground (Figure 9.2.8). The cross beams serve as possible landing pads and launch opportunities for gliders moving across the land bridge.

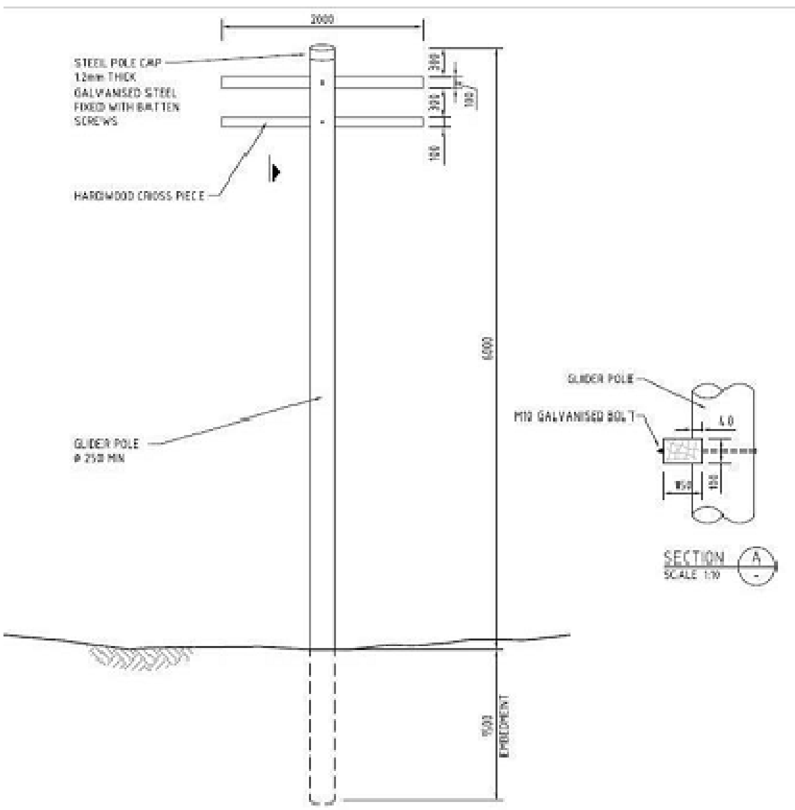

Figure 9.2.8 Glider pole drawing adapted from drawing LB-02 (Chambers and Ingram 2005).

a) b)

Figure 9.2.9 a) Glider pole on the land bridge.
b) Hair tube mounted on glider pole.

Monitoring:

- PVC hair tubes 100 mm x 40 mm with double sided tape on the inside were installed approximately four metres off the ground (Figure 9.2.9b).
- Analysis of hair tubes has revealed the presence and use of gliders but not their abundance.
- Trapped gliders have been radio tagged, determining whether gliders have crossed the road (Taylor and Goldingay 2007a).
- Some radio tagged gliders were caught, translocated to the opposite side of the road and then monitored to ascertain whether they returned to their original side, either simply through gliding or use of the fauna structures (Veage and Jones 2007).
- Squirrel glider tissue samples have also been collected and genetically tested to ascertain whether crossings are necessary for the survival of the population (Veage and Jones 2007).

Learnings:

- The height of the poles is too low to provide sufficient height for gliding from pole to pole. The recommendation is that glider poles should be 12 metres tall.
- The monitoring revealed that some gliders avoided glider poles and used the vegetation between poles instead. The reason for this is uncertain but it is believed that glider poles may be too open, unsheltered and low for many gliders (Taylor and Goldingay 2007b).

e) Rope ladders

Design:

- Three rope ladders were installed, each with a centre pole in the median strip (Brisbane City Council 2005).
- The rope ladders are constructed with durable sailing rope and resemble a ladder with three vertical supports.
- The rope bridges are linked to the adjoining canopy via several ropes leading from the top of the poles adjacent to the forest.

Figure 9.2.10 Canopy bridge used by arboreal species to the road (Scott 2007).

Monitoring:

- Hair tubes were set up on six poles and 24 trees connected to rope bridges (Taylor and Goldingay 2007a).
  - Hairs from squirrel gliders, sugar gliders, common brushtail possums and common ringtail possums were detected in the hair tubes attached to trees (Veage and Jones 2007).
- Two Faunatech Digicam 120 cameras with active infra-red beams were mounted atop support poles of two canopy bridges.
  - 12V battery and USB port for downloading data were located close to the ground (small ladder required) in a security box.
  - Due to technical reasons, no images have been collected by cameras to date.
- Results from hair tubes:
  - Hair tubes detected gliders (squirrel glider and sugar glider) and possums (brushtail and ringtail) on the trees connected via rope leading to the canopy bridge.

Issues:

- Cameras were shut down for at least a month as a result of movement of the rope constantly triggering the sensors.
- Researchers were unable to modify the sensors, as Brisbane City Council policy only allows staff to do so. Thus, researchers lost valuable time and information waiting for Brisbane City Council staff to modify the sensors.

9.2.4 General information

a) Monitoring

- Roadkill monitoring:
  - Carried out four months pre- and post-construction (Bond and Jones 2007).
  - Pre-construction survey found 13 terrestrial vertebrates of ten species, whilst immediate post-construction survey (four months after completion) found a wallaby and a wood duck (Bond and Jones 2007).

- Up to July 2007 only three vertebrate individuals have been found (Bond and Jones 2007).

- Monitoring by researchers for Brisbane City Council commenced four months pre-construction and finalised in 2009.
  - The aim, however, is for monitoring to be extended until 2011.
  - This extensive monitoring period will allow for comprehensive data analysis.

b) Maintenance

- Brisbane City Council only undertakes maintenance as requested by the public or researchers.

c) Anthropogenic measures

- Local community groups undertook data collection and informed Brisbane City Council about impacts of construction before mitigation actions were undertaken.
- Results from an ecological assessment conducted through the cooperation of Brisbane City Council and the Karawatha Forest Protection Society provided the primary justification for implementing the fauna structures. The report indicated animals regularly crossed into habitat on either side of the road.
- Ecologists, architects and engineers cooperated and compromised to install fauna crossing structures which were favoured by all.
- Engineers did not make changes to design or location of structures without consultation with other parties.
- Brisbane City Council created a Memorandum of Understanding (MoU) with researchers. The MoU allows researchers to undertake necessary research whilst Brisbane City Council provided in-kind support, maintenance and necessary equipment. Researchers provide Brisbane City Council with annual effectiveness reports.
- The ongoing relationship between researchers and Brisbane City Council has been positive for all parties. There have, however, been some issues:
  - Poor communication between researchers and Brisbane City Council maintenance crews;
  - Inability for researchers to access some equipment (such as cameras) without Brisbane City Council personnel present (due to workplace health and safety concerns).
  - These issues have extended both time and labour costs.

d) General issues

- Street lighting infiltration into nearby habitat may cause stress or behavioural changes to nearby fauna (Caneris and Ingram 2003).
- Maintenance occurs only on an "as-need" basis.
- Monitoring has been unable to provide estimations of abundance of individuals by scat collection and analysis, as site-specific information is required and is unavailable for the Compton Road area (Veage and Jones 2007).
- A cat and fox eradication program was undertaken during construction due to fears they would prey on wildlife attempting to utilise fauna structures.

e) General learnings

- Use of the underpasses has fluctuated with seasons. Winter has lower usage rates; most use was recorded in summer (Bond and Jones 2007; Veage and Jones 2007).
- Despite findings from other research, all sizes of mammals habituated to structures faster than expected. Arboreal species took the longest time to habituate (Veage and Jones 2007).
- Glider pole use may be increased by increasing vegetation around poles (Taylor and Goldingay 2007b).

9.2.5 References

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9.3 The East Evelyn Range Upgrade

9.3.1 Background

The East Evelyn Range Road Upgrade was a 13 million dollar project between the townships of Ravenshoe on the Evelyn Tableland and Millaa Millaa on the Atherton Tableland in northeast Queensland (Goosem *et al.* 2001). This winding single lane section of road at high altitude (1,100 metres) was replaced with a straighter, two lane road (Goosem *et al.* 2005). The 3.2 kilometre section of road separates the Mount Fischer and Hypipamee Wet Tropics World Heritage Areas. The Department of Transport and Main Roads worked closely with the Wet Tropics Management Authority, the Department of Environment and Resource Management, James Cook University, Tree-Kangaroo and Mammal Group and Trees for the Evelyn and Atherton Tablelands (TREAT) on this project (Interface Magazine 2002). Road construction commenced in August 2000 (Goosem *et .al.* 2001) and the new road was opened in December 2001 (Goosem 2004). Fauna mitigation consisted of three fauna underpasses, a revegetated corridor and revegetation to reduce previous fragmentation.

Habitat present adjacent to the road corridor:

- Rainforest interior (dominated by pioneer species and gullies);
- Rainforest edges;
- Closed lantana shrub land; and

- Grassland (mainly consisting of dense pasture grasses).

9.3.2 Target species

Birds

- southern cassowary (Casuarius casuarius johnsoni)

Mammals

- Lumholtz tree-kangaroo (*Dendrolagus lumholtzi*)
- lemuroid ringtail possum (*Hemibelideus lemuroides*)
- Herbert River ringtail possum (*Pseudochirulus herbertensis*)
- green ringtail possum (*Pseudochirops archeri)*

9.3.3 Mitigation measures

- Preconstruction measures
  - o An environmental survey was completed, confirming the presence of southern cassowaries in the area (previously thought not to occur in the area) (Goosem *et al.* 2005).
  - o Underpasses were designed through extensive consultation with stakeholders and experts.
  - o All lantana located in the road verge was removed prior to construction commencing (Goosem *et al.* 2001)
- Post-construction measures
  - o TREAT assisted in an awareness education program for local schools and community groups.
  - o Roadkill will be monitored for five years post-construction (Goosem *et al.* 2005).

a) Underpasses

Considerations:

- Needed to be large enough to allow target fauna to pass through.
- Alignment and size needed to be adequate to allow fauna to have a direct line of sight to the forest on the other side (Goosem *et al.* 2005).

Design:

- Three fauna underpasses were installed (Figure 9.3.1).
- Underpasses were galvanised steel arches with a wide concrete base (Gibson 2001).
- Dimensions:
  - o 3.4 metres high;
  - o 3.7 metres wide;
  - o 38 metres long.
- Placed (where possible) in existing gullies and where thicker vegetation already provided good cover for local animals minimising revegetation costs (Gibson 2001).
- Rock piles and logs were installed to provide shelter from predators for animals such as goannas, frogs, rats and echidnas (Gibson 2001).
- A thin pathway through underpass was left clear for movement by larger species (Goosem *et al.* 2005).
- Ground cover consisted of logs, rocks, leaf litter and soil to replicate a natural environment (Gibson 2001).
- Thick trawler ropes were hung from the roof of culverts and extended to neighbouring trees for use by obligate arboreal species (for example, tree-kangaroos) (Gibson 2001) (Figures 9.3.1 and 9.3.2).

- Footings for underpass furniture allow logs to be raised off the underpass floor (Figure 9.3.3). This prevents rotting and extends log life.
- Escape poles were installed to accommodate arboreal species (Goosem *et al.* 2001; Goosem 2004).
- Infra-red monitoring cameras were placed in cages to reduce the likelihood of theft (Figure 9.3.4).

Figure 9.3.1 Fauna underpass at East Evelyn Range (Scott 2008).

Figure 9.3.2 Fauna furniture in underpass (Scott 2008).

Figure 9.3.3. Footings for underpass furniture (Scott 2008).

Monitoring:

- Infra-red cameras and sand plots were used to monitor the effectiveness of the underpasses.
- Sand plots were installed as a one metre wide strip of fine sand 5 cm deep in centre of underpasses (Goosem *et al*. 2005).
- Monitoring of sand plots commenced in January 2002 and were monitored weekly (Goosem *et al.* 2005).
- Roadkill monitoring commenced in July 1999 and concluded in 2004 (Goosem 2004).
- Two section of the upgrade in the vicinity of the Millaa Millaa lookout were monitored for roadkill each week (Goosem 2004).
- Two sections of the Kennedy Highway near Longland's Gap were monitored as a 'control' to compare roadkill counts (Goosem 2004).
- During post construction surveys roadkill observed when checking the sand plots were noted (Goosem 2004).
- Results of monitoring:
  - Underpasses were used by rainforest generalist species.
  - Terrestrial and small mammal species have been found using the underpasses including two confirmed sightings of the Lumholtz tree-kangaroo (Goosem *et al.* 2005).
  - Underpasses were found to be ineffective for target possum species (Goosem *et .al*. 2005).
  - The presence of feral species did not inhibit use of the underpass by native species (Goosem 2004).
  - A decline or absence of roadkill for rainforest species was observed post-construction (Goosem 2004; Goosem 2008).
  - Birds were noted to fly through the underpasses (Goosem *et al.* 2005).

- o Observational sightings included crimson rosella and red-backed wren flying through underpasses, buff-banded rail foraging within the underpasses and boobook owl roosting on ropes and branches in the underpasses.

Figure 9.3.4 Infra-red monitoring cameras were caged to prevent theft (Scott 2008).

Issues:

- High rainfall in the area has washed away sand in sand plots and human interference limited data during monitoring periods (Goosem 2004).
- At the underpass entrances low bushes were planted to encourage passage by fauna. However, due to bad weather plants were unable to establish themselves in the shallow soil (Goosem 2004).
- Weeds have started to grow at the entrance of some underpasses due to sub-standard weed matting (Goosem 2004).
- Deep drainage channels along entrances and pooling of water in underpasses has decreased the attractiveness of these structures to animals.
- Cattle escaped from a neighbouring property (with inadequate fencing) and severely damaged furniture in an underpass (Goosem 2004). There has been no funding available to repair furniture.
- The cassowary has not been recorded using the underpasses. It is hypothesised that underpasses are too small to attract movement by the cassowary (Goosem *et al.* 2005).
- Due to extensive media coverage there has been a large amount of human use of fauna underpasses and some vandalism of furniture has occurred.

Learnings:

- Treatment for weeds immediately following construction would have aided underpass effectiveness (Goosem 2004).

b) Revegetation corridor

Considerations:

- The upgrade provided an opportunity to rehabilitate areas previously disturbed by the road and land use.

Design:

- Revegetation around underpass entrances was designed to channel species into these structures.

- Trawler rope connected to hooks inside the underpass extended into vegetative corridor (Figure 9.3.5).
- A funnel shape corridor measuring nine metres wide at the entrances to the underpasses and 50 metres wide near rainforest remnants was revegetated (Goosem *et al.* 2005).
- Monitoring of corridor did not occur.

Figure 9.3.5 Trawler rope connecting the surrounding vegetation to hooks inside the underpass (Scott 2008).

c) Revegetation

Design:

- Previously disturbed habitat connectivity was re-established.
- 15 hectares was revegetated with a variety of local plants (Queensland Department of Main Roads 2001).
- Plants were chosen based on initial ecological studies.
- The local tree community group, TREAT, coordinated volunteers who collected, propagated and planted 40,000 trees in the area (Interface Magazine 2002).
- To prevent roadkill in the area, non palatable food plants were planted near roads (Goosem *et al.* 2001).
- Steep embankments around the underpass openings were used to discourage fauna from reaching the road (Goosem *et al.* 2001).
- The closed canopy design was aimed at protecting smaller species and attracting larger species to the underpasses (Goosem *et al.* 2001).

Monitoring:

- The success of food tree placement and the effectiveness of the steep embankments adjacent to the underpasses were monitored by proxy through roadkill monitoring and sightings of target species on road surfaces.
- Results:
  - o After three years the trees planted in the rainforest corridor had grown to a height of between three and six metres and were starting to create a closed canopy attracting bird species (Goosem 2008).

Issues:

- Food tree placement and steep embankments has not been sufficient to prevent roadkill (Queensland Government 2001).
- It has been recommended that fauna exclusion fences be installed, however funding for this work has yet to be obtained.

Learnings:

- One roadkill tree-kangaroo occurred during the monitoring phase. It appeared that the tree-kangaroo became trapped on the road (after crossing) between two steep embankments with no means of escape (Goosem 2004).
- Ongoing roadkill indicates that unpalatable trees and steep embankments were not sufficient to prevent roadkill.

9.3.4 General information

- Rope bridges are proposed to be installed when trees in the road corridor have grown tall enough and if funding is available (Goosem *et al.* 2001).
- The local community has been responsible for the translocation of flora displaced by road construction and rainforest restoration works (Goosem *et al.* 2001).

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9.4 Mount Higginbotham, Victoria

9.4.1 Background

A population of endangered mountain pygmy-possums occurs between Mount Higginbotham and Mount Loch in Victoria, Australia (Mansergh and Scotts 1989) (Figure 9.4.1). The mountain pygmy-possum is the only mammal restricted to the alpine regions with an altitude of greater than 1430 metres. The mountain pygmy-possum occurs in the peri-glacial rock screes and boulder fields (Mansergh and Scotts 1989). The species is one of the most threatened mammals in Australia (Mansergh and Scotts 1989).

The Victorian population has sexual segregation during non-breeding seasons (Mansergh and Scotts 1989). Road and resort development have bisected mountain pygmy-possum habitat on the eastern slopes of Mount Higginbotham (Mansergh and Scotts 1989). This has led to problems as the juvenile males are ‘choosing’ not to disperse from their natal grounds. This has caused increased competition for resources and resulted in an increased level of female deaths over winter (Mansergh and Scotts 1989).

Due to the impact caused by the road, retro-fit mitigation measures were proposed. These are discussed below.

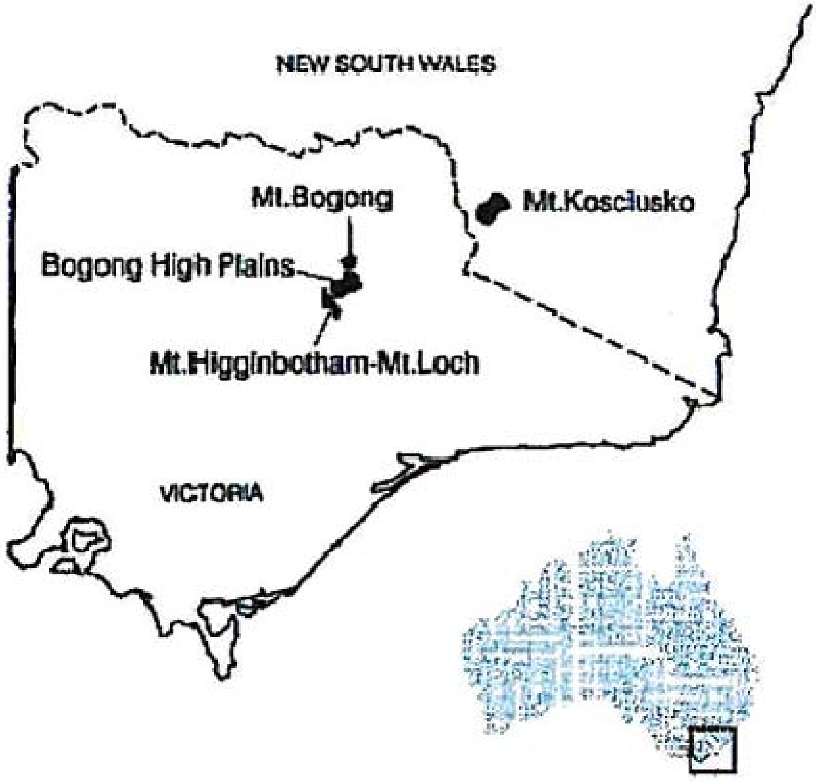

Figure 9.4.1 Locations of mountain pygmy-possum populations (Mansergh and Scotts 1989)

The habitat in the Mount Higginbotham area is:

- mountain plum-pine (*Podocarpus lawrenceii*) heathland.
- This community is long-lived, fire sensitive and introduced species are rare or absent (Mansergh and Scotts 1989).

9.4.2 Mitigation measures

- Post-construction
  - A basalt filled funnel shaped corridor of rock was constructed.
  - Two connecting box culverts were constructed to pass beneath the road.

Considerations:

- Species only travels through rocky substrate and avoids open spaces.

Design:

- A funnel shaped corridor of basalt rocks was constructed on the disturbed eastern slope between the largest remaining patches of habitat (Figures 9.4.2 - 9.4.4).
- Rocks were obtained from building excavations.
- Two culverts were installed and filled entirely with rock. Rocks used to fill the culverts were greater than 300 mm on their longest axis.
- Box culverts measured 900 mm x 1.2 metres.

- Wire mesh grills at the culvert entrances and rock depth of more than one metre ensured that animals using the structure had no higher than normal risk of predation by feral species.
- Rocks were removed from a small area of one culvert and two drift fences were erected to direct animals through a 0.5-1 metre rock free area.

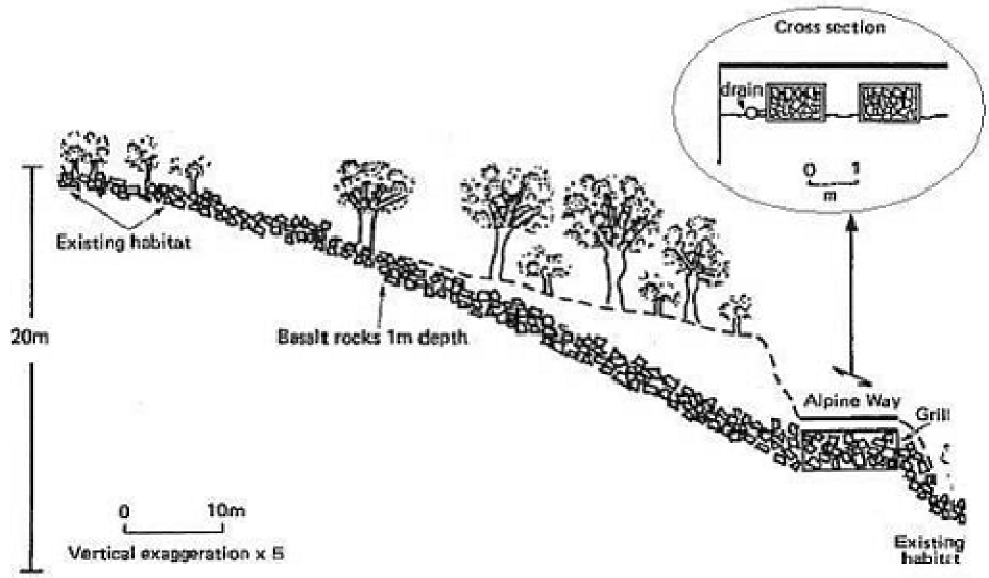

Figure 9.4.2 Cross-section of corridor and tunnel construction (Mansergh and Scotts 1989).

Figure 9.4.3 Entrance to the rock underpass (ABC 2009).

Monitoring:

- 1983 Study
  - Culvert use was monitored using a remote sensing camera (Canon T70) with light beam sensors.
  - Elliott traps were also used to sample the populations.
  - Areas of special interest were also monitored through Elliott trapping.
  - A capture-mark-release program was conducted over a series of trapping grids (van der Ree *et al.* 2009).
  - Biological information was obtained from captured animals and ear-tags were fitted (van der Ree *et al.* 2009).
- 2007 Study
  - The effectiveness of the installed fauna structures was analysed using population viability analysis (PVA).
  - A subset of the census data set was used to complete analysis of the PVA.
  - Two populations were compared: one population was divided by the road, the second population remained unaffected by the road.
- Results
  - Female survival rates increased over winter from 21% (pre-construction) to 42% (post-construction).
  - The female survival rate post-construction is similar to those found in undisturbed sites (44%) (Mansergh and Scotts 1989).
  - There were only two recorded roadkill pygmy possums during post-construction monitoring.
  - Although the mitigation structures reduced the impact of the road, the overall number of females was still 15% lower than in undisturbed sites.
  - Results showed fauna structures mitigated the barrier effect of roads but did not completely restore population levels (van der Ree *et al.* 2009).

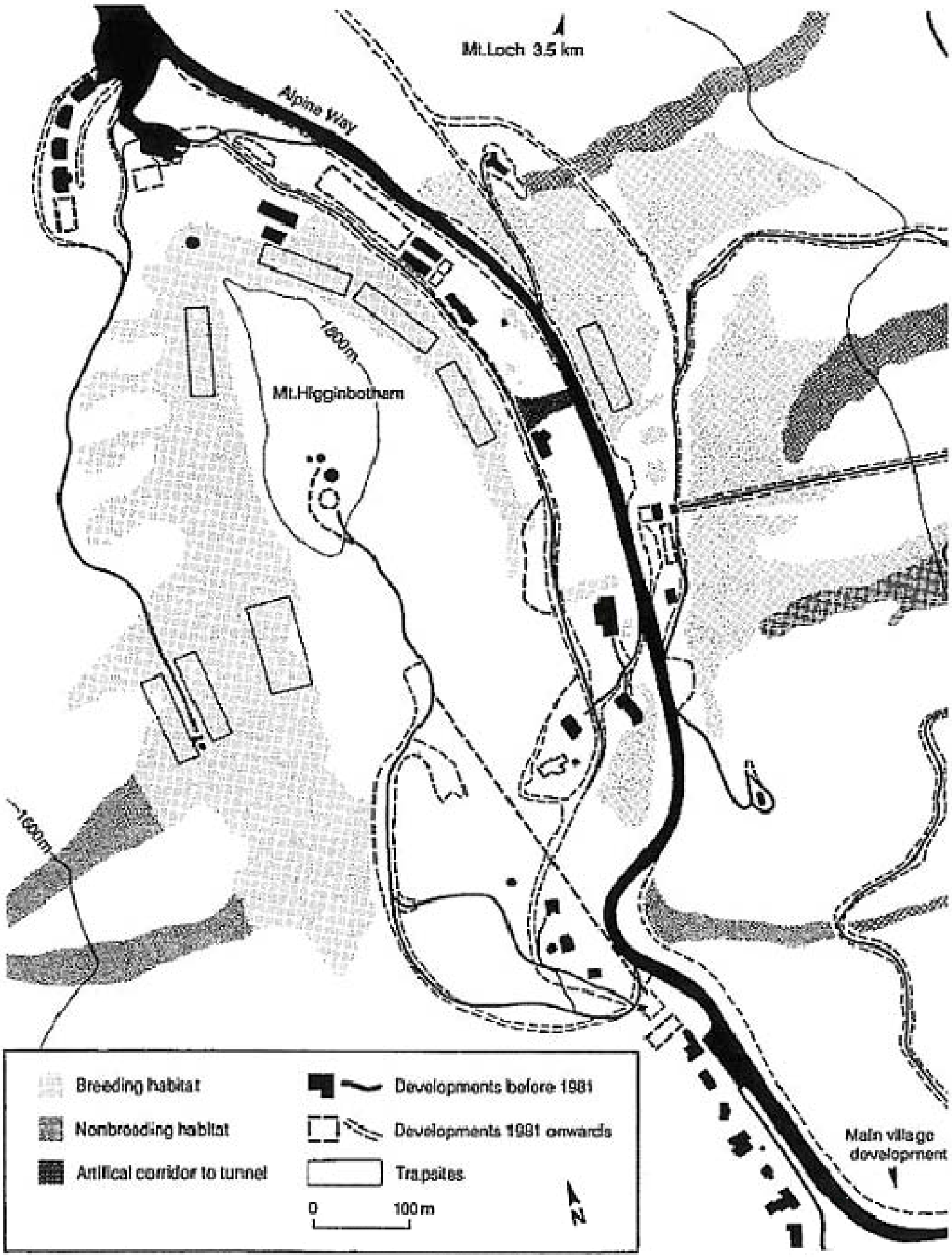

Figure 9.4.4 Extent of breeding habitat (past and present) and trap sites, the corridor, and the tunnels on Mount Hogginbotham, Victoria, Australia (Mansergh and Scotts 1989).

Issues:

- Juveniles take a long time to disperse when using the culverts. This may be because they could not find the culvert and will not cross the open road corridor.
- The population has not returned to post-construction numbers. This may have been due to insufficient numbers of culverts, the impact of road mortality and/or natural variation (van der Ree et al. 2009).

Learnings:

- Because the species is restricted to travel in rock habitats fauna exclusion fencing was not needed.
- Studies of the structure's effectiveness for the pygmy-possum revealed the actual use of the structures does not mean that the impact of the road is entirely eliminated.

- The rapid use of tunnels can probably be attributed to the unique habitat requirements and the social organisation of the species.

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