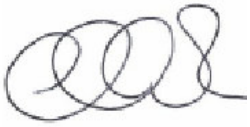
INTEGRATED PLAN OF MANAGEMENT FOR THE ENDANGERED LONG-NOSED POTOROO (*Potorous tridactylus tridactylus*) POPULATION AT COBAKI

JULY 2009

REPORT PREPARED FOR PACIFICLINK ALLIANCE BY:

LEWIS ECOLOGICAL SURVEYS

This ecological report has been prepared for PacificLink Alliance: Environment Manager Darren Brighton. This report relies upon data, surveys, measurements and results based on a series of short-term studies and review of relevant research material in a manner consistent with the brief provided by the client (PacificLink Alliance). Although conclusions have been based on the available data at the time, some professional judgement has been applied in reaching the conclusions. Every attempt has been made to ensure the accuracy and objectivity of the reports findings, conclusions and recommendations. *Lewis Ecological Surveys* does not accept responsibility for its use by other parties.



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EXECUTIVE SUMMARY

The Long-nosed Potoroo (*Potorous tridactylus tridactylus*) is a small cover dependant macropod known from a range of habitats including rainforest, sclerophyll forests and coastal heathlands distributed along the coast and hinterland areas of south eastern Australia. Despite its broad distribution and equally broad use of habitats, this species of potoroo is known from relatively few locations in northern NSW and southern Queensland, this being at least partly attributed to its specialist habits and vulnerability to exotic predators. As a result, it is currently listed as a 'vulnerable' species on state (NSW *Threatened Species Conservation* Act 1995; Queensland *Nature Conservation Wildlife* Regulation 2006) and commonwealth legislation (*Environment Protection and Biodiversity Conservation* Act 1999). The Cobaki potoroo population which is the focus of this document is currently afforded an 'endangered population' status pursuant to the *Threatened Species Conservation* Act 1995. This largely stems from a number of recent approvals for development in the Cobaki area including Cobaki Lakes, Boyd Street Overpass and Extension and the Tugun Bypass where concerns have been raised from regulatory bodies about the viability and potential impacts on this endangered population, and have sought the preparation and implementation of an integrated potoroo plan of management (PoM). This document seeks to address this requirement via a number of detailed management actions, monitoring techniques, performance measures and timing commitments as well as providing a framework for reporting and corrective actions.

Among the management options proposed in this plan are mechanisms designed to address threatening processes such as habitat fragmentation, wildfire, predation by exotic vertebrates, road and residential edge effects. They include fauna underpasses used in conjunction with fauna exclusion fencing to improve connectivity across Boyd Street, exotic predator control to alleviate current and possible future predatory pressures, fire management using prescribed mosaic burns to reduce the incidence of wildfire and promote evolutionary processes associated with burning cycles of 10-15 year intervals, revegetation and habitat augmentation strategies designed to ameliorate impacts from clearing, reduce edge effects and to enhance the suitability of fauna underpasses.

A detailed monitoring program has been proposed in order to collect data to determine the performance of the management actions implemented. Among the techniques are road kill surveys designed to assess the effectiveness of the fauna exclusion fencing, monitoring of the seven underpass culverts using sand trays, infra red camera systems and trapping in the immediate area to determine the status of potoroo and to ascertain movement data in recaptured individuals via the use of passive transponder tags (PIT tags). Habitat surveys of the remnant vegetation would facilitate in identifying the preferred microhabitat requirements for potoroo and allow a direct comparison to the regeneration areas as well as those areas subject to prescribed burning regimes. The exotic predator control surveys would focus initially on collecting baseline data on the activity levels of fox (*Vulpes vulpes*), dog (*Canis familiaris*) and cat (*Felis catus*) before implementing the first control surveys and the data compared between the baseline survey and the subsequent monitoring and control events.

In assessing the performance measures of the management actions, a number of questions have been proposed and would be driven through yearly monitoring reports providing an opportunity for recommendations and corrective actions to be adopted as necessary. Taking this approach over the life of the five year plan would provide a sound basis for the long term management and conservation of this important population.

1.0 INTRODUCTION

This document in intended to act as an integrated plan of management for the endangered Long-nosed Potoroo (*Potorous tridactylus tridactylus*, hereafter potoroo) population located at Cobaki in far north-east NSW with the aim of alleviating current and likely impacts arising from infrastructure and residential development. Whilst this plan is centred on potoroo it is by no means limited to a single species plan because species do not function in isolation but are components of ecological systems that inherently fall into the category of organised complexity (Allen & Star 1982; O'Neill *et al.* 1986 *cited in* Clevenger & Walton 1995). Included in the plan are a series of management actions along with monitoring techniques, which are designed to assess their performance for potoroo between monitoring events, and over the five year life of this plan. Following this period, a public review would be undertaken, and coordinated by the NSW Roads and Traffic Authority (RTA), and the QLD Department of Main Roads (DMR).

The following is some background information relevant to the project and potoroo.

1.1 BACKGROUND TO THE PROJECT

Potoroo were first formally recorded at Cobaki in the late 1980s and early 1990s as part of surveys for the Cobaki Lakes residential development and associated infrastructure (Warren 1992 & 1994; Mason 1993 & 1997). Around this time one of the previous Tugun Bypass options was located further to the west (i.e. Western Bypass) and would have resulted in both a substantial loss of potoroo habitat and created an east-west barrier to movement. The subsequent re-alignment and selection of the C4 option was located as far as possible to the east within the constraints set by the Tugun Landfill Depot, Gold Coast Airport and Pacific Beach residential estate and resulted in most of the potoroo habitat being avoided.

Since the late 1980s and 1990s several studies have been undertaken to determine the ecological status of the Cobaki Lakes potoroo population. Initially, two potoroo were recorded adjacent to the Boyd Street extension as part of a Fauna Impact Statement (FIS) for the construction of Boyd Street extension between the state border and the proposed residential development known as Cobaki Lakes (Warren 1992). At that time the area near the current construction footprint was not considered suitable potoroo habitat on the basis of a wildfire event in August 1991 which escaped from a control burn at Tugun Hill and burnt into the Cobaki heathland. Mason (1993) conducted surveys of this area approximately one year later and was able to detect the presence of potoroo using hair tubes, and by extrapolating from data collected from his nearby study site at Tyagarah (45 km south) he proposed the Cobaki population probably consisted of 10-20 individuals and that 25-50% of the Cobaki area provided suitable potoroo habitat owing to these recent fires.

As part of the Tugun Bypass EIS targeted surveys were undertaken over three time periods in 2000, 2001 (Hero *et al.* 2000 & 2001a) and 2003 (Bali *et al.* 2003). The initial two studies confirmed the continued presence of potoroo in the Cobaki area whilst the later study set about determining the real extent and size of the population. They found the population was distributed over at least 108 ha and comprised somewhere in the vicinity of 55-85 individuals. The radio telemetry study found individuals occupied overlapping home ranges of between 1.5-5.1 ha and combined with the mark recapture study there was no evidence to suggest potoroo would readily cross the Boyd Street extension construction footprint measured at 49 m but was capable of regularly traversing smaller vehicle fire trails < 6 m in width. These results suggest the population was probably comprised of two sub populations (north and south of Boyd Street extension) and management was required to bolster its current conservation status.

1.2 RELEVANT STAKEHOLDERS

Two types of stakeholders are relevant to this management plan and include regulatory bodies and landowners. Regulatory bodies include:

- Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA) previously known as and referred to in this document as Department of Environment and Water Resources (DEWR);
- NSW Department of Environment and Climate Change (DECC) (incorporating NSW National Parks and Wildlife Service (NPWS));
- QLD Environmental Protection Agency (EPA) (incorporating Queensland Park and Wildlife Service (QPWS));

- Tweed Shire Council (TSC);
- NSW Rural Lands Protection Board (RLPB);
- NSW Rural Fire Service (NSW RFS);
- QLD Department Primary Industry and Fisheries (DPI&F);
- QLD Rural Fire Service (QLD RFS).

Landowners include:

- NSW Department of Lands (DoL);
- NSW Roads and Traffic Authority (RTA);
- NSW Department of Primary Industries (DPI) (Quarantine);
- QLD Department of Main Roads (DMR);
- Tweed Shire Council (TSC);
- Tweed Byron Local Aboriginal Land Council (TBLALC);
- Leda Manorstead Pty Ltd (Leda); and
- Gold Coast Airport Pty Ltd (GCAPL).

1.3 CONDITIONS OF APPROVAL

Table 1. Compliance summary of all conditions of approval and statements of commitments

Source	Condition	Details of Compliance
Tugun Bypass (Approved 16/02/06)		
Commonwealth Department of Environment and Water Resources (DEWR) (From letter dated June 2006)	The management plan for the Long-nosed Potoroo … will be superseded by an integrated management plan … submitted within 12 months.	This integrated management plan has been developed to address this condition. The original conditions and commitments are detailed below, along with details of compliance with regards to this revised version of the management plan.
Commonwealth Department of Environment and Water Resources (DEWR) **CoA No. 2a**	The person taking the action must prepare and implement plans addressing the requirements outlined below for the conservation of the Long-nosed Potoroo. The plan must be submitted to the Minister for approval and construction may not occur until the Minister approves them. (a) Installation of animal proof fencing along the boundary of Potoroo habitat and the road proposal; (b) Installation and maintenance of a fox control program on NSW Crown land adjoining the identified Potoroo habitat; (c) Preparation and implementation of a fire management plan for the NSW Crown land taking into account the habitat requirements of the Potoroo by prescribing a mosaic of 'patch' burning and the prevention of catastrophic wildfires; (d) Implementation of a monitoring program to determine the effectiveness of the management plan and to monitor the status of the population with annual reporting to relevant government agencies; and (e) A requirement for a five year public review of the management plan.	The Tugun Bypass Long-nosed Potoroo Management Plan was developed, and later approved, to address this condition. This integrated management plan has subsequently been developed, and once approved, can be considered to supersede the original. Specifically; (a) The installation of animal proof fencing is included in Section 5.4 and Appendix 5. (b) Installation and maintenance of fox control program is included in Section 5.5, 6.5, 7.4 and Appendix 6 (c) Preparation and implementation of a fire management plan for the NSW Crown land in regards to mosaic patch burns are included in Section 5.6, 6.6, 7.5 and Appendix 7. (d) Implementation of a monitoring program is included in Section 6.0. (e) Implementation of a five year public review, to be coordinated by RTA and DMR and is detailed in Section 8.0 and 9.0.
Statement of Commitment (from Submission Report)	The aim of this commitment is to minimise impacts on the Cobaki Lake Population of Long-nosed Potoroo.	The Tugun Bypass Long-nosed Potoroo Management Plan was developed, and later approved, to address this condition. This

Source	Condition	Details of Compliance
SoC No. 12 Long-nosed Potoroo	**Pre-construction -** The Proponent would ensure that measures to minimise impacts on the Long-nosed Potoroo is detailed within the Threatened Species Management Plan. The plan would be developed in consultation with land owners and the Environmental Review Group described in Section 35 of the SIS. The plan would also incorporate measures described within *Tugun Bypass, Stewart Road to Kennedy Drive – Compensatory Habitat* (QDMR 2005). Development of the plan would commence prior to construction and would include construction and post-construction management measures. **During construction -** The construction management measures described in the plan would be implemented throughout the various stages of construction and would include, but not be limited to the following: a) Initiation of fox control measures within Long-nosed Potoroo habitat on the area of NSW Crown land, to the west of Tugun Bypass. b) Provision of fauna exclusion fencing along the Bypass corridor to deter domestic dogs and cats from residential areas to the east from accessing Long-nosed Potoroo habitat. Fencing would be chain mesh and extend from Chainage 2400-3600 metres and be constructed the minimum distance from constructed infrastructure. Priority however shall be given to safety and maintenance considerations in the first instance. Vertical grates at the headwalls of culverts would also be used. c) Preparation of a fire management strategy for NSW Crown land (Boyd Street area) in consultation with the NSW Rural Fire Service that would account for the habitat requirements of the Long-nosed Potoroo. This would include the prescription of mosaic patch burns as to prevent catastrophic wildfires and would be implemented as soon as practical. **Post-construction -** The post-construction management measures described in the plan would be implemented after the completion of various stages of construction and would include, but not be limited to the following: d) A monitoring program to measure the effectiveness of the management measures for the Long-nosed Potoroo and to monitor the status of the local population. The monitoring program would be developed in consultation with the Queensland Environmental Protection Agency, NSW Department of Environment and Conservation, Commonwealth Department of Environment and Heritage and/or Commonwealth Department of Transport and Regional Services depending on jurisdiction.	integrated management plan has subsequently been developed, and once approved, can be considered to supersede the original. Specifically; (a) Initiation of fox control measures is included in Section 5.5, 6.5, 7.4 and Appendix 6. (b) Provision of fauna exclusion fencing is included in Section 5.4, 6.3, 6.4, 7.3 and Appendix 5. The provision for vertical grates at the headwalls of culverts are included in Section 5.3. (c) Implementation of a fire management strategy is included in Section 5.6, 6.6, 7.5 and Appendix 7. (d) Details of the monitoring program are included in Section 6.0.

Source	Condition	Details of Compliance
	Monitoring would commence once the management measures within the plan have been commissioned and would be conducted on an annual basis over a period of at least five years.	
NSW Minister for Planning	The proponents must provide compensatory offset measures summarised in Table 1 (relevant extract below) and as described in *Tugun Bypass Stewart Road to Kennedy Drive – Compensatory Habitat* (Appendix H of the Submissions Report) and Statement of Commitment No. 17, prior to the Project opening to traffic, unless otherwise agreed by the Director-General following consultation with the DECC. **Extract from Table 1.** Management Measure; Mosaic patch burns in accordance with Potoroo Management Plan.	Implementation of offset measures in regards to mosaic patch burns are included in Sections 5.6, 6.7, 7.4 and Appendix 7.
Boyd Street Overpass (Approved 13/02/07)		
Tweed Shire Council CoA 10	A Fauna Management Plan prepared by a qualified person and submitted and approved by Council's Environmental Scientist prior to commencement of work. The plan must describe measures to mitigate fauna mortality pre, during, and post construction and include: a) measures outlined within the Roads and Traffic Authority of NSW policies and guidelines to prevent fauna mortality during road construction and management; b) measures contained within the Tugun Bypass Construction Environmental Management Plans including pre clearing protocols for fauna; c) Provision of a dedicated fauna underpass under the western section of the proposed overpass in accordance with the Long-nosed Potoroo Integrated Plan of Management that will facilitate the movement of the Long-nosed Potoroo; d) construction and operational stage fauna exclusion … linking to fauna underpass structures where required and consistent with designs employed in the Tugun Bypass project; and e) ongoing maintenance regimes during construction.	The Tugun Bypass Long-nosed Potoroo Management Plan addresses this condition, however this integrated management plan provides further detail regarding the long term management of this population. Specifically; a) Construction protocols relating to prevention of fauna mortality are detailed in Section 5 b) Pre-clearing protocols from the Tugun Bypass CEMP are detailed in Section 5.1. c) Provisions for a dedicated fauna underpass are included in Section 5.3. d) Design and installation of fauna exclusion fencing is included in Section 5.4, 6.3, 6.4, 7.3 and Appendix 5. e) Ongoing maintenance is detailed in Section 5.0, 6.0 and 8.0.
Tweed Shire Council CoA 11	A draft Long-nosed Potoroo Integrated Plan of Management prepared in consultation with relevant stakeholders and a qualified wildlife biologist, and submitted to Council's Environmental Scientist prior to commencement of work. This plan must describe, but is not limited to: a) fauna crossings and fauna exclusion fencing, predator control programs, fire management, and revegetation;	A draft version of this integrated management plan was submitted to Tweed Shire Council to address this condition. This plan addresses the following items; a) Fauna crossings, fauna exclusion fencing, predator control, fire management and revegetation are included as Sections 5.0, 6.0, and 7.0.

Source	Condition	Details of Compliance
	b) time lines and performance indicators for all management measures;	b) Timelines and performance indicators are included in Section 7.0 and 8.0.
	c) defined roles and responsibilities;	c) Roles and responsibilities are detailed in Section 8.0.
	d) reporting and review mechanisms, with specific provision for a 5 year public review;	d) Reporting and reviewing mechanisms are detailed in Section 9.0.
	e) design options for the construction of the future road incorporating management for the Long Nosed Potoroo; and	e) This plan includes management for the future Boyd Street Extension throughout the document.
	f) the plan is to be finalised in accordance with the Tugun Bypass conditions of approval.	f) This plan is being finalised in line with the Tugun Bypass Conditions of Approval (as specified above).
Boyd Street Extension (Approved January 1993 with subsequent amendments)		
Tweed Shire Council DA 18	The applicant shall prepare a plan of management specifically for the long-nosed potoroo – utilising the service of the CSIRO and a qualified fauna consultant. This management plan shall:	The Cobaki Lakes Environmental Management Plan, Section C, was developed to address this condition. This integrated management plan takes into consideration the Cobaki Lakes EMP and adds further detail with the view to long term management of this threatened population. This plan addresses the following items;
	a) demonstrate the protection of the long-nosed potoroo's long-term viability;	a) Protection of the viability of the potoroo population is included in Section 1.4;
	b) be submitted to Council with final plans of engineering design for the road;	b) This plan will be submitted to Tweed Shire Council;
	c) be implemented within 12 months of completion of the finalised road works granted by this consent – or earlier if recommended by the CSIRO scientists and/or qualified fauna consultant engaged by the applicant.	c) This plan has been developed in consideration of the Cobaki Lakes EMP, and as such take into consideration the impact assessment undertaken by Catling (1992). A schedule for management implementation is included as Section 5.10.

1.4 AIMS AND OBJECTIVES OF THE PLAN

The aim of the Integrated Long-nosed Potoroo Plan of Management is to ensure the viability of the population for at least the short to medium term (5-50 yrs) via addressing current and likely impacts arising from, but not limited to infrastructure, residential development and vertebrate pests. This would be undertaken using a range of management actions including, but not limited to, fauna underpasses, fauna exclusion fencing, exotic predator control, revegetation and habitat augmentation combined with design review/and a well designed monitoring program capable of gauging the performance of each component. In the case of under performing management actions corrective actions would be undertaken via annual reporting (i.e. adaptive management).

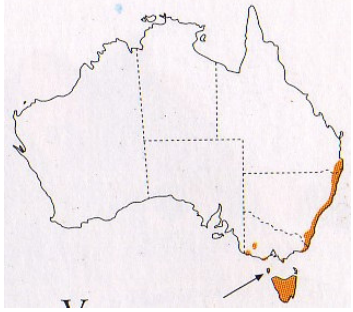
2.0 BIOLOGY OF THE LONG-NOSED POTOROO

2.1 DESCRIPTION

Potoroo may attain weights of up to 1.75 kg (740 - 1750 grams) in males and a few hundred grams lighter in females (Menkhorst & Knight 2001; Bali *et al*. 2003). There appears to be some clinal variation with lighter animals in southern parts of its range in Tasmania and Southern Victoria (i.e. Long 2001 versus Bali *et al.* 2003). Head and body length is generally about 360 mm with a tail length of between 200-260 mm. Fur colour is greyish-brown above and light grey below. It is easily distinguished from the Long-footed Potoroo (*Potorous longipes*) by its shorter tail (less than 250 mm long) and smaller hind-foot (shorter than its head) and the lack of a leathery pad on the sole of its foot.

2.2 DISTRIBUTION AND STATUS

Potoroo are restricted to south-eastern Australia except for a disjunct population in south-western Western Australia (Johnston 1995; *see* Figure 1). In eastern Australia its distribution is disjunct extending from near Gladstone in mid coastal Queensland to south western Victoria (Seebeck *et al.* 1989). In NSW and Queensland, it is generally restricted to coastal heaths and forests east of the Great Dividing Range, with an annual rainfall exceeding 760 mm (NPWS 2003).



Although ~400 records presently occur on the Department of Environment and Climate Change (DECC) Wildlife Atlas for NSW, they are generally restricted to specific areas including far southern NSW, the Shoalhaven district and hinterlands of the north coast bioregion[1]. In the north coast bioregion, potoroo records occur in the Tweed, Brunswick, Richmond, Clarence, Bellingen, Nambucca, Macleay, Hastings, Manning and Hunter Valleys; however, few of these locations occur on the coastal sandplain (NPWS 2003). Coastal localities are limited to Cobaki, Cudgen-Cabarita, Brunswick Heads, Tyagarah, Lennox Head, Wardell, Wooli, Old Bar, near Bulahdelah and Coolongolook (NPWS 2003; B. Lewis unpublished data.). Only the Tyagarah population is found within a coastal conservation reserve whilst the other populations occur on crown, state forest, and indigenous or private land.

Figure 1. Distribution of Long-nosed Potoroo (*Potorous tridactylus*). Source Menkhorst & Knight (2001)

Potoroo distribution in the Tweed Local Government Area (LGA) is restricted to 11 records (DECC 2007). Two records occur to the west and south-west of Tyalgum and the remaining ones occur near Cabarita (20 km south) or on the northern shores of Cobaki Broadwater (i.e. this population)[2]. The nearest known records in Queensland occur at Green Mountain about 45 km to the west (Capararo & Lundie-Jenkins 1998). Recent potoroo surveys at 10 historic locations in south-eastern Queensland recorded potoroo at just four of these sites (Capararo & Lundie-Jenkins 1998).

2.3 CONSERVATION STATUS

NSW – Only the Cobaki population is currently listed as Endangered under part two of the *NSW Threatened Species Conservation* Act 1995. Elsewhere the species is currently listed as Vulnerable.

Queensland - Vulnerable under the *Nature Conservation* Act 1992

Commonwealth – Vulnerable under the *Environment Protection and Biodiversity Conservation* Act 1999

[1] The validity of these records remain unconfirmed; there is a risk of confusing bandicoots as potoroos during brief field observations (Menkhorst & Knight 2001; Ben Lewis *pers. obs.*).

[2] An additional record from this area, which is not listed on the DECC Wildlife Atlas, is an unconfirmed hair tube record obtained from approximately 300 m from known distributional limits (Parker 2006). The record remains unconfirmed on the basis that Rufous Bettong (*Aepyprymnus rufescens*) had also apparently been recorded as a definite hair tube record and this species does not occur in the Cobaki area.

2.4 HABITAT

Potoroo is known to inhabit a range of vegetation types from sub tropical and warm temperate rainforest through open eucalypt forests and coastal woodlands with a dense understorey and may also occur in dense coastal heaths (Johnston 1995; Menkhorst & Knight 2001). A principal habitat requirement appears to be a dense groundcover which is used for sheltering (squats) with nearby open areas used for foraging. Typically the dense shrub layer and ground stratum comprises Grass Trees (*Xanthorrhoea spp*), sedges, ferns, tea trees or Melaleuca's in coastal areas. Soft friable soils are a common feature enabling this species to easily dig for food items.

2.5 DIET AND FORAGING HABITS

Potoroo forage on underground roots and hypogeal fungi (underground fruiting) using long, slightly curved claws on their front feet (Claridge *et al.* 1993). They are also known to consume fruits, flowers, seeds, insects and their larvae (Claridge *et al.* 1993; Johnston 1995). Two dietary studies undertaken in Victoria suggest hypogeal fungi is an important foraging resource to potoroo with at least 50 fungal species consumed in western Victoria and 60 fungal species in eastern Victoria with seasonal variation that is best explained by the changing abundance of fungal sporocarps (Bennett & Baxter 1989; Claridge *et al.* 1993). In a short term study in eastern Victoria, Claridge *et al.* (1992) found spores of 33 fungal species collected during a single month. It is thought fire and the extent of rainfall cause a shift in foraging patterns on fungi as some species become more prolific than others (Claridge *et al.* 1993). For example, *Mesophellia spp* generally increase after fire.

The majority of the fungal species consumed in these Victorian studies were of hypogeal habits and are thought to form mycorrhizal (symbiotic) associations with the roots of a variety of trees and shrubs. As such it is quite likely that potoroo play an important role as a disseminator of spores in faeces (Claridge *et al.* 1992), and they may be capable of facilitating regeneration. No quantitative data is available for potoroo diet in northern NSW or Queensland, however, similar principals could be applied given the sites in southern NSW are also acidic and nutrient poor.

2.6 LIFE HISTORY AND ECOLOGY

Potoroo is mainly a solitary animal occupying a non-territorial home range of approximating 2-5 ha (Long 2001; Bali *et al*. 2003). It is mainly nocturnal sheltering by day in dense low vegetation where individuals form shallow depressions known as squats. Typically this vegetation is comprised of Midgen Berry (*Austromyrtus dulcis*) and clumps of Flat-leaved Lepidosperma (*Lepidosperma laterale*) at Cobaki but it may also use *Restio spp*. and *Lomandra spp*. Potoroo is known to have crepuscular habits at a number of sites where it has been studied (i.e. Long 2001) including Cobaki but the extent of this behaviour is likely to be influenced by site specific predatory pressure.

Breeding typically occurs in late winter to early summer and a single young is born per litter. Adults are capable of two reproductive bouts per annum. This trait is supported in the Cobaki population with various sized pouch young and sub adult animals recorded during the baseline study in autumn 2003 (Bali *et al.* 2003).

2.7 THREATENING PROCESSES

Potoroo is subject to a number of threatening processes including:

- Habitat loss and fragmentation as a result of land clearing for residential, infrastructure and agricultural development;
- Predation from exotic fauna including red fox, feral and domestic dogs and cats;
- Frequent fire regimes and/or livestock grazing that reduces the density and floristic diversity of the shrub and ground layer; and
- Logging regimes or other similar disturbances that reduce the availability and abundance of food resources such as hypogeous fungi and dense ground covers.

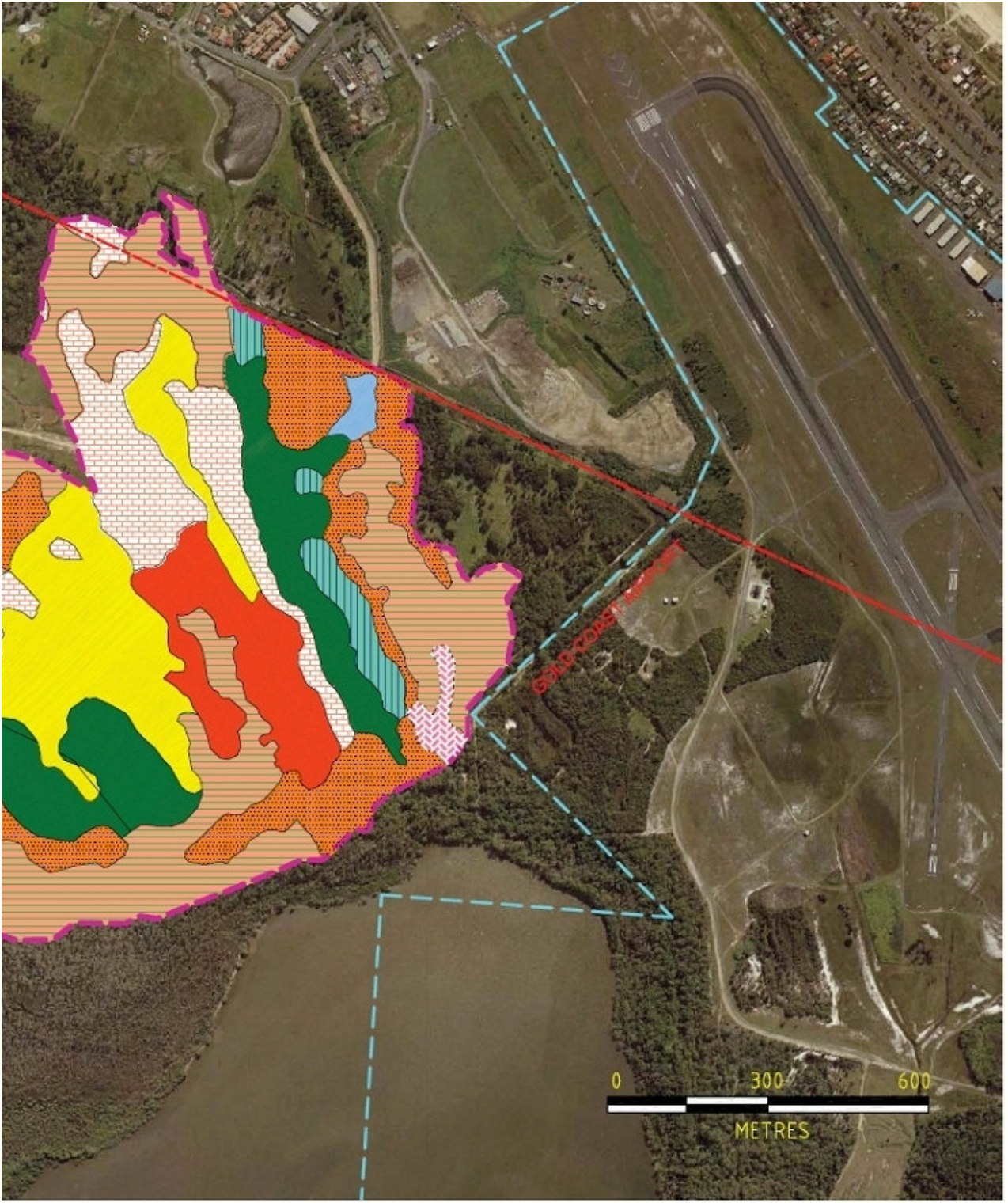
The threatening processes outlined above are difficult to assess alone and often show multiple effects such as fire resulting in a reduction of ground and shrub cover which leads to increased predation levels. For example, the incidence of potoroo remains in Dingo scats increased by 8-10 times in the first year after wildfire but fell dramatically as revegetation took place (Newsome *et al.* 1983).

3.0 STUDY AREA OF MANAGEMENT

The potoroo population considered in this management plan occurs in the Tweed LGA, north-eastern NSW and extends into Gold Coast LGA of far south east Queensland. It covers an area of ~108 ha of predominantly NSW Crown Land between the northern shore of Cobaki Broadwater extending north and east to Gold Coast Airport land and just beyond the Queensland state border, and west to Cobaki Lakes residential development (Mason 1993, Bali *et al.* 2003). The area occupied by this population is defined by the localities of Cobaki Lakes and Tweed Heads West (Geographical Names Board of NSW 2004).

Nine vegetation communities occur within known potoroo habitat (Figure 2). They include:

- Forest Red Gum Forest;
- Scribbly Gum Mallee Heathland;
- Paper Bark Forest;
- Swamp Mahogany/Paper Bark Forest;
- Scribbly Gum Forest;
- Tree Broom Heathland;
- Swamp Mahogany Forest;
- Swamp Mahogany Scribbly Gum; and
- Black She-oak Heathland.



FOREST RED GUM FOREST

BLACK SHEOAK HEATHLAND

SCRIBBLY GUM MALLEE HEATHLAND

TREE BROOM HEATHLAND

SWAMP MAHOGANY PAPERBARK FOREST

SCRIBBLY GUM FOREST

PAPER BARK FOREST

SWAMP MAHOGANY FOREST

GOLD COAST AIRPORT

LONG-NOSED POTOROO HABITAT BOUNDARY

NOT FOR CONSTRUCTION

REVISION	DATE	AMENDMENT / REVISION DESCRIPTION
01	04.06.2007	ORIGINAL ISSUE

SKETCH

The sketch shown on this document may have been compiled from varied sources and has NOT been checked for its correctness or

PacificLink

PROJECT TITLE: TUGUN BYPASS

FIGURE 2. KNOWN DISTRIBUTION OF LONG-NOSED POTOROO AT SOBAKI &

4.0 THREATS TO THE COBAKI POTOROO POPULATION

Threats associated with the Cobaki potoroo population have been discussed according to those which currently exist and those likely to eventuate in the future.

4.1 EXISTING THREATS

Potoroo along with other fauna known to occur in the area face threats from:

- The loss of habitat totalling ~3 ha. This comprises 0.5 ha in order to accommodate the Tugun Bypass, 0.43 ha for the Boyd Street overpass and 1.8 ha for the Boyd Street Extension (Catling 1993; Tugun Bypass Alliance 2004a,b);
- Fragmentation arising from the widening of the Boyd Street construction track to ~50 m;
- Exotic predators including fox, dog and cat as well as domestic pets;
- Wildfire threat from unmanaged lands;
- Edge effects including but not limited to noise, light, hydrological processes, erosion and sedimentation; and
- Altered hydrological processes, particularly the Tree Broom heathland on the northern side of Boyd Street extension. Following heavy rainfall[3] surface ponding occurs for extended periods of time (>6 weeks) and is likely to alter this community resulting in an area of reduced foraging and refuge habitat for potoroo (B. Lewis *pers. obs*).

4.2 FUTURE THREATS

During the construction phase of both the Tugun Bypass and Boyd Street Overpass/Extension potoroo and other fauna would face threats from:

- Increased fragmentation arising from further road widening;
- Further increases to edge effects (possibly 10's of metres) on remaining habitat as a result of increased traffic noise and vibrations, lighting, altered hydrological processes and habitat pollution from hydrocarbon runoff and construction spills;
- Further changes in hydrological processes from improved drainage and increased runoff;
- Further predatory pressures from exotic species such as fox, dog and cat;
- Further increased risk of wildfire arising from habitation and associated increased traffic at nearby Cobaki Lakes and developments such as Pacific Beach Exchange east of the Tugun Bypass;
- Human disturbance as a result of increased visitation;
- Increased visitation for land management, monitoring purposes and unauthorised access from pedestrians and trail bike riders; and
- The current bikeway alignment would contribute further to these impacts, increasing the clearing width, edge effects, fragmentation, wildfire threats, human disturbance and reduce and jeopardise the effectiveness of the proposed management actions outlined in this plan.

[3] >50 mm in 24 hrs.

5.0 MANAGEMENT ACTIONS

A series of management actions have been proposed with regard to the Tugun Bypass, Boyd Street Overpass and its extension to Cobaki Lakes Residential Estate. Essentially they revolve around the design and implementation of this current document that includes input from PacificLink Alliance (PLA), Leda, Tweed Shire Council, Tweed Byron Local Aboriginal Land Council, Department of Environment and Climate Change, QLD Environment Protection Agency, Rural Lands Protection Board, NSW Rural Fire Service and Gold Coast Airport Pty Ltd. Where necessary land owner permission would be sought prior to undertaking relevant control works, with further details on licensing and approvals included in Table 7.

In order to improve the long term conservation value of the Cobaki potoroo population the plan proposes the design and implementation of a number of management actions including:

- General mitigation measures such as clearing guidelines and threatened species inductions;
- Revegetation and habitat augmentation plan;
- Fauna underpasses;
- Fauna exclusion fencing;
- An exotic predator control program;
- A fire management plan promoting a regime of mosaic burns;
- Potoroo population monitoring; and
- A review of the detailed design.

The details of each are provided below.

5.1 GENERAL MITIGATION

The construction of the Tugun Bypass Project and the Boyd Street Overpass (which have been completed), adopted the best management practices (BMPs) as outlined in the Tugun Bypass Construction Environmental Management Plan (CEMP). Similarly, it is recommended that the construction of the Boyd Street Extension adopts those same practices. Some of the more relevant practices include;

- Delineation of any vegetation to be cleared prior to works, using coloured flagging tape or 'parawebbing';
- Clearing works to be supervised by a suitably qualified ecologist or environmental specialist;
- Retention and stockpiling of large woody debris for use in the habitat augmentation program (*see* Section 5.2 and Appendix 3);
- Undertaking of a site specific threatened species induction for all site staff prior to commencing work. This ensures to educate the staff about their environmental responsibilities and to foster a general awareness which encourages correct work practices;
- Induction would cover issues relating to threatened species, designated and restricted areas of access and waste disposal;
- Ongoing education of site staff through 'toolbox talks', ensuring important information relating to the protection of potoroo are reiterated regularly. To be signed off by all attendees; and
- Installation of signage at both extents of the work site to notify staff, particularly plant operators, to the possible occurrence of potoroo.

On completion of the construction works, signs identifying the presence of a 'Significant Environmental Area' would be attached to the fauna exclusion fence at 100 m intervals (*see* Section 5.4 and Appendix 1).

5.2 REVEGETATION-HABITAT AUGMENTATION WORKS

The revegetation component of this plan is drawn from schedules for both the Tugun Bypass Project Landscaping Plans and the EMP for Boyd Street Extension Construction Activities prepared for Cobaki Lakes by Master Planning Services (1993). Its objective is to reduce edge associated impacts, provide more amicable habitat in order to increase the likelihood of potoroo using the fauna underpasses and ameliorate for the loss of potoroo habitat during the construction works. It is predicted that potoroo would commence using these revegetated areas within several years as observations elsewhere suggest this pattern of habitat use. For example, potoroo have been recorded at sites previously cleared and allowed to regenerate over periods of 7-13 years in Tasmania (Heinsohm 1968) and northern NSW (B. Lewis *pers. obs*; P. Parker *pers.*

comm.). Potoroo have also shown a similar response to habitat affected by fire with numbers returning to pre-fire densities over a 10 year period in Victoria (Claridge *et al.* 1993; Catling *et al.* 2001).

Approximately 3 ha of land has been identified for revegetation and habitat augmentation works (*see* Figure 3). It includes the area surrounding Boyd Street Overpass and continues west for ~640 m to the boundary of Cobaki Lakes and Tweed Byron Indigenous Land, making allowances for plantings to within 2.5 m of the road verge and up to the entrance of the fauna underpasses (*see* Appendix 2). The area shaded green and orange in Figure 3 represent the areas outlined within the EMP for Cobaki Lakes. The blue shading represents the areas of Boyd Street Overpass revegetated as part of the Tugun Bypass Landscaping Plan, which is further detailed in Appendix 2.

During habitat augmentation of the Boyd Street Overpass, the site would be prepared using mulch from the clearing works (heathland, scribbly gum forest), with additional mulch taken from other Tugun Bypass stockpiles. Prior to landscaping the large woody material retained from clearing works (*see* Appendix 3) would be placed in a strategic nature among the plantings as a means of providing refuge habitat at an early stage of the regeneration works. This may benefit potoroo in several ways including promoting refuge habitat, providing a range of microhabitats to stimulate mycorrhizal fungi and ultimately encourage the use of fauna underpasses. It would also aim to reduce unauthorised access to these areas by trail bike riders.

Weed management for the Tugun Bypass and Boyd Street Overpass would be undertaken during the construction phase as per the Tugun Bypass CEMP, and where necessary would involve weed control before and after landscaping.

Habitat augmentation and management along the Boyd Street Extension would follow the same procedure as used for the Boyd Street Overpass (i.e. using mulch produced on site, weed control before and after landscaping and the use of woody debris to provide habitat features).

The proposed species list for landscaping is shown in Table 2, and follows the Tugun Bypass Landscaping Plan, essentially expanding upon the planting schedule of Old Man Banksia (*Banksia aemula*) and Scribbly Gum (*Eucalyptus racemosa*) forest identified in the Cobaki Lakes EMP (Master Planning Services 1993). Included in this schedule are plant species which are known to provide both refuge and foraging habitat for potoroo with the later probably ranking as the more important because the plan ultimately seeks to provide connectivity between the northern and southern populations. For example, potoroo were regularly flushed from thickets of Flat-leaved Lepidosperma (*Lepidosperma laterale*) and Midgen Berry (*Austromyrtus dulcis*) during the 2003 study. During this study, many of the radio transmitters were recovered from these areas and this probably reflects preferred refuge locations (i.e. squats). Plant densities would replicate the surrounding vegetation, with groundcovers being at higher densities immediately adjacent to the road or fence to reduce the likelihood of weed incursion.

Responsibility for ongoing maintenance of landscaping and revegetation is detailed in Section 8.

Table 2. Species list for revegetation of Scribbly Gum and Swamp Forest communities.

SCRIBBLY GUM FOREST	SWAMP SCLEROPHYLL FOREST
TREES/ SHRUBS	**SHRUBS**
Acacia fimbriata	*Acacia fimbriata*
Aotus ericoides	*Acacia obtusifolia*
Austromyrtus dulcis	*Banksia oblongifolia*
*Banksia aemula**	*Banksia robur*
Banksia oblongifolia	*Callistemon salignus*
Banksia robur	*Elaeocarpus reticulatus*
Callistemon pachyphyllus	*Leptospermum polygalifolium*
Dillwynia retorta	*Leptospermum whitei*
Dodonaea triquetra	
Elaeocarpus reticulatus	
*Eucalyptus racemosa**	
Hibbertia scandens	
Hovea acutifolia	
Leptospermum juniperinum	
Leptospermum liversidgei	
Leucopogon leptospermoides	
Melaleuca nodosa	
GROUNDCOVERS	**GROUNDCOVERS**
Baloskion tetraphyllum	*Aristida spp. schizachryium*
Caustis recurvata	*Gahnia clarkei*
Dianella caerulea	*Gahnia sieberana*
Lepidosperma laterale	*Eriachne glabrata*
Xanthorrhoea johnsonii	*Melaleuca thymefolia*
Xanthorrhoea macronema	*Xanthorrhoea johnsonii*
Zieria laevigata	

Note: (*) Species would not be planted within 5 m of fence line to reduce management issues arising from tree branch falls and fence breaches.

5.3 FAUNA UNDERPASSES - CULVERTS

Culverts have been used as wildlife crossings both extensively and effectively elsewhere around the world including Canada (Clevenger & Waltho 1995), United States (Brudin 2003) and Europe (Mata *et al.* 2003). Their use in Australia as a mitigation device has become increasingly common for linear developments which bisect forested landscapes and they now appear among best management practises for at least road projects in NSW (RTA), Queensland (DMR) and Victoria (VicRoads) and have also been used on rail projects in NSW (Hunt *et al.* 1997). Several of these studies have tested the factors which influence their use by small and medium sized terrestrial vertebrates and have found that culvert dimensions themselves play an important role in the effectiveness of underpasses (Yanes *et. al* 1995; Rodríguez *et al.*1996) as does the level of road noise (Clevenger *et al.* 2001), human activity (Clevenger & Waltho 1995) and proximity to vegetated cover (Hunt *et al.* 1987). Consequently, these factors have been taken into account in the current design.

5.3.1 Culvert Dimensions

The dimension of the underpasses is considered to be one of the most important variables in the design of passage ways for wildlife (Reed *et al.* 1975; Hunt *et al.* 1987) including small and medium sized mammals (Clevenger *et al.* 2001). Whilst there have been no detailed studies comparing culvert dimensions and their influence on potoroids in Australia a review of fauna underpass monitoring within known potoroo habitat found individuals had possibly used two underpasses on two occasions during the Brunswick Heads Bypass monitoring (AMBS 2001a) and may have on several occasions during the monitoring of the Bulahdelah to Coolongolook deviation (AMBS 2001b,c). At Brunswick Heads the dimensions of the culverts are 2.4 m wide x 1.2 m high and 18 m long while the Bulahdelah to Coolongolook culverts measured 3 x 3 m and had variable lengths from 39.6 –51.98 m (*see* Appendix 3).

The proposed culvert design dimensions have been presented in Table 3 with corresponding chainage values obtained from drawings by Ian Hill and Associates and PacificLink Alliance Boyd Street Overpass construction drawings. They comprise three dedicated fauna underpasses, four multiuse underpass/drainage culverts and

one drainage culvert[4] ranging in size from 2.4-3.0 m in width, 1.2-1.8 m in height and between 21-32 m in length as well as a bridge span incorporated into the overpass design[5]. The dimensions proposed are supported by previous monitoring of analogous fauna assemblages at Brunswick Heads (i.e. Swamp Sclerophyll Forest and Wet Heath) with the results indicating a range of fauna from frogs to Swamp Wallaby (*Wallabia bicolor*) using the 2.4 m x 1.2 m culverts. Whilst it would be advantageous that culverts be designed to provide the maximum opportunity for their use by target species this may not always be practical. Larger culverts at least in height dimensions are more likely to attract visitation by humans and the fact that tracks and easements at Cobaki are regularly used by trail bike riders and pedestrians suggests culverts that facilitate their passage should be discouraged. One other consideration is the increased construction cost in order to raise culvert heights would require significant fill from a nearby quarry site and raises the question of whether some of these financial resources are better aligned toward the mitigation devices themselves (i.e. the purchase of more culverts or a more rigorous monitoring design). More detail on each of the designs is provided below.

Where necessary, and in the vicinity of potoroo habitat, culverts running under the Tugun Bypass Project would be fitted with vertical grates. This would restrict use of these culverts by exotic predators and humans as a means of accessing potoroo habitat. Moreover, most of these culverts are likely to contain surface water throughout the year making them largely unsuitable to most fauna. A discussion of each culvert type is provided below.

i.) Dedicated Underpasses

The three dedicated fauna underpasses have variable lengths ranging from 30-32 m (*see* Table 3). The largest of these occurs at Chainage 175 and falls within the Boyd Street overpass. Its current dimensions are 2.4 m wide and 1.8 m high, and includes furniture at each egress point. The objective of this larger structure is to provide some opportunity for arboreal species which are likely to show some reluctance in using smaller culverts. Detailed drawings for this culvert, showing location and dimensions are provided in Appendix 4.

The remaining two dedicated fauna underpasses measure 3.0 m in width, are 1.2 m high and 30 m[6] in length. The objective of this design is twofold, firstly to reduce or at least discourage human visitation in these areas which can include pedestrians and trail bike riders, and secondly the increased width would provide a greater degree of openness[7] improving light levels for establishing vegetation and visibility for fauna. Similar cover dependant species such as Martens (*Martes spp.*) in North America had a tendency to use culverts with low clearance and high openness ratios (Buskirk & Powell 1994; Clevenger *et al.* 2001) so the proposed height would not present a major concern even after allowing for any build up of flood debris and sediment deposition. In order to address these later two issues all culverts would be constructed slightly above (up to 200 mm) the surrounding land in order to avoid water ponding as this has been a common design/installation problem on the Pacific Highway (John O'Donnell *pers. comm.*). The location of structure 9 (Chainage 2130) is dependant on the revegetation and habitat augmentation works proposed on the southern side of Boyd Street. Structure 8 is positioned in an area where several potoroo were known to have overlapping home ranges in Bali *et al.* (2003) thus increasing the opportunity of this underpass being used.

[4] Dedicated drainage culvert is required to facilitate the bulk of water flow. The multi use are designed for use during peak flow periods.

[5] Provided that ALL management actions (i.e. relocation of bikeway) are adopted.

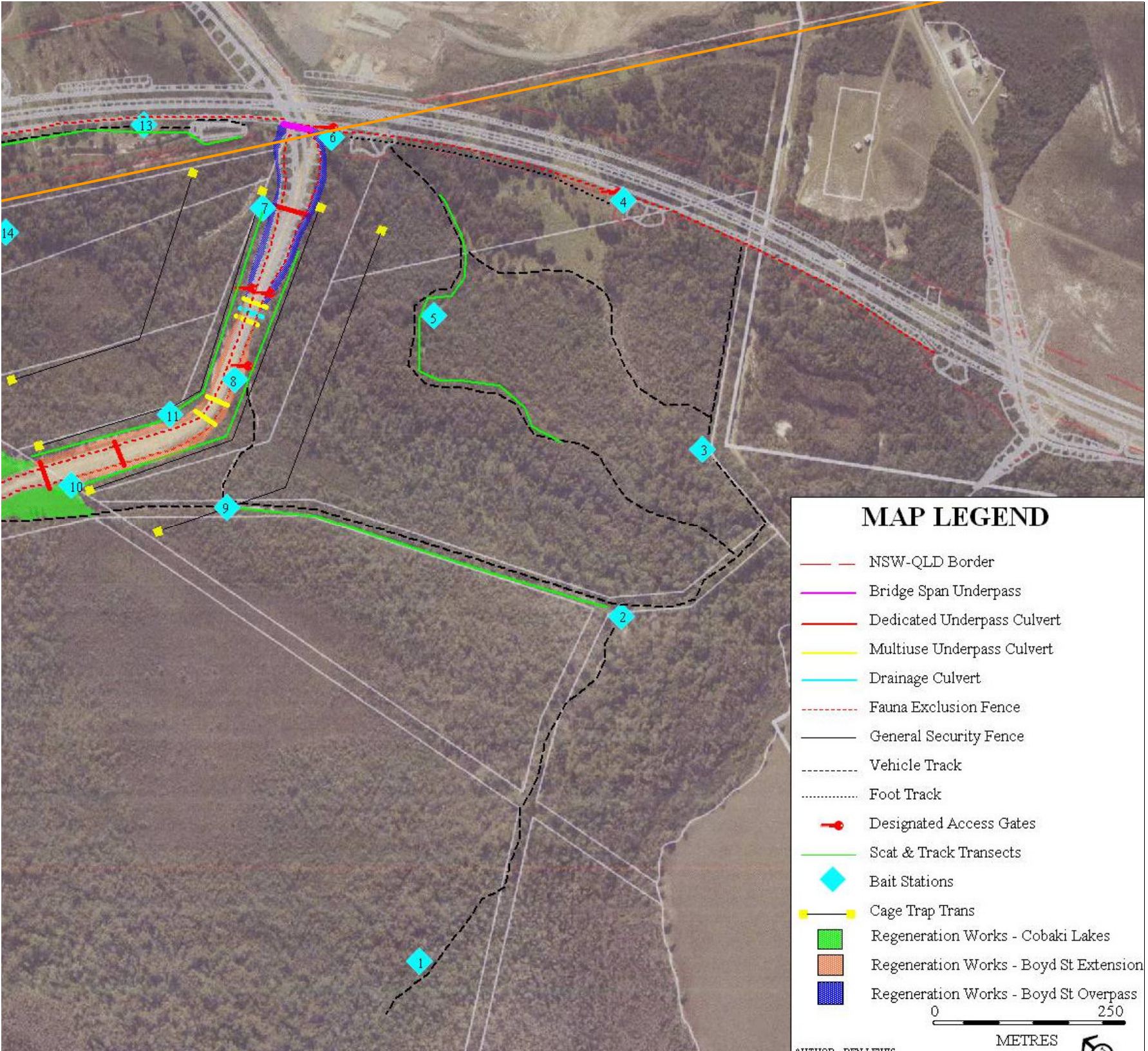
[6] The current road design does not allow for the provision of skylights. If the road design changes this should be investigated for culverts 8 and 9.

[7] An important component in culvert design is the openness which is defined as width x height/length (Reed and Ward 1985).

Table 3. Culverts and the bridge span proposed as fauna underpasses and/or drainage along Boyd Street.

Note – Chainage values derived from two different plans provided by Ian Hill and Associates and PacificLink Alliance.

Structure No	Chainage	Drawing ref	Intended Purpose	Horizontal Position	Dimensions (m) Width x Height	Special Features	Comments
1	300	Appendix 3 Drawing BYD-010-1002	Fauna-Drainage	Multi-grade	Fauna passage ~3 x 10 Drainage ~7 x 10	Bridge Span Enabling Unimpeded Drainage and Increased Light Levels	Potential movement during fire event. Potoroo (M831) regularly crossed this drainage line 100 m downstream in Bali *et al.* (2003).
2	175	Appendix 3 Drawing BYD-010-1001	Fauna	Above Grade (100-200 mm)	2.4 x 1.8	1 fauna refuge pole at each end measuring 1.2 high x 0.2 m width with fork at top (3003181-BYD-010-7306 Appendix 2)	Only culvert in place capable of facilitating movement for all fauna. Increased size has increased risk of human activity.
3	270	IH&A - /20	Fauna-Drainage	Multi -grade	2.4 x1.2 (with a 1 m wide 0.5 m raised ledge)	Ledge design shown in Figure 4	Split design for multiuse. Low potoroo numbers recorded in this area in 2003. Site inspection revealed habitat remains the same.
4	285	IH&A - /20	Drainage	Multi -grade	2.4 x 1.8	Facilitates bulk of drainage flow and address aquatic management issues such as fish passage	Primary purpose is drainage but may be used during low flow periods. Could present itself as bat roost for threatened Bent-wing Bats (*Miniopterus*) and Large-footed Myotis (*Myotis macropus*)
5	300	IH&A - /20	Fauna-Drainage	Multi -grade	2.4 x1.2 (with a 1 m wide 0.5 m raised ledge)	Ledge design shown in Figure 4	Split design for multiuse. Defines a boundary on fire management precinct and is more likely to be used during these times
6	420	IH&A - /20	Fauna-Drainage	Multi -grade	2.4 x 1.2 (with a 1 m wide 0.5 m raised ledge)	Ledge design shown in Figure 4. Ledge needs to be constructed on eastern edge of culvert.	Split design for multiuse. Potoroo known to traverse regularly through this area particular when Tree Broom Heathland is inundated.
7	450	IH&A - /20	Fauna-Drainage	Multi -grade	2.4 x 1.2 (with a 1 m wide 0.5 m raised ledge)	Ledge design shown in Figure 4. Ledge needs to be constructed on western edge of culvert.	Split design for multiuse. Potoroo regularly captured in this area and known to move in edge habitat particularly when Tree Broom Heathland is inundated.
8	2060	IH&A - /20	Fauna	Above Grade (100-200 mm)	3.0 x 1.2	Increased width to accommodate culvert length & visibility	Strategic location. Several potoroo home ranges known to overlap in this area on both north and southern sides of Boyd St
9	2130	IH&A - /20	Fauna	Above Grade (100-200 mm)	3.0 x 1.2	Increased width to accommodate culvert length & visibility	Provides egress point during fire management and designed to link the area identified for regeneration in EMP (1993)



MAP LEGEND

- NSW-QLD Border
- Bridge Span Underpass
- Dedicated Underpass Culvert
- Multiuse Underpass Culvert
- Drainage Culvert
- Fauna Exclusion Fence
- General Security Fence
- Vehicle Track
- Foot Track
- Designated Access Gates
- Scat & Track Transects
- Bait Stations
- Cage Trap Trans
- Regeneration Works - Cobaki Lakes
- Regeneration Works - Boyd St Extension
- Regeneration Works - Boyd St Overpass

0 250

METRES

ii.) Multiuse Culverts

Four multiuse culverts are proposed at Chainages 285, 300, 420 and 450 m (Figure 3). Their objective is to facilitate wildlife movement via the raised 0.5 m ledge (1.0 m wide) with the remainder (1.4 m) acting as a drainage culvert (*see* Figure 4). It is expected these culverts would be seasonally inundated for short periods of time but this is unlikely to significantly affect fauna movements and the viability of local wildlife populations.

Figure 4. Example of multiuse culverts showing ledge design. Note. Culverts in figure are larger dimensions than what is being proposed (Source: Goosem 2005).

Whilst all four of these culverts would have the same height and width dimensions (2.4 m wide x 1.2 m high) culverts 3 and 4 would be 21 m in length whilst culverts 6 and 7 would be increased to 25 m to accommodate road curvature. Their location has taken into account the obvious north south drainage features of the land but also the proposed fire management precincts and their corresponding fire regimes. For example the drainage line in the vicinity of Chainage 295 is not proposed for burning so during a control burn this would act as a refuge area and the culvert would maintain connectivity with lands on the southern side of Boyd Street. It is at these times that multiuse culvert 3 and 4 are most likely to be used by potoroo. For culverts 6 and 7, their location has also taken the drainage features into account, however, this area was also regularly used by potoroo in 2003 (Bali *et al.* 2003). One reason for its regular use is heavy rainfall tends to result in the flooding of the Tree Broom Heathland community and the area immediately adjacent Boyd Street provides one of the few dry passages in this area (B. Lewis *pers. obs*).

iii.) Drainage Culvert and Bridge Span

Culvert 4 located at Chainage 285 m has been designed specifically for drainage with its larger height dimensions capable of dispensing normal and minor flood flows. As such, this culvert is likely to have at least semi permanent water ponding and it would be of little value to most terrestrial vertebrates including potoroo. It should be noted that potoroo are capable of traversing flooded landscapes as one of the radio tracked animals in the baseline study (M831 in Bali *et al.* 2003) would regularly travel through 0.2-0.3 m of water adjacent to Boyd Street. The retention of surface water in this culvert may also discourage pedestrian traffic, address aquatic management issues and is likely to provide a potential roosting resource for no less than three threatened bat species known from the area: Large-footed Myotis (*Myotis macropus*), Little and Large Bent-wing Bats (*Miniopterus australis* and *M. schriebersii*).

The bridge span has been incorporated into the design of the Boyd Street overpass at Chainage 300 and would allow for the reinstatement of the hydrology in this area (*see* Appendix 4). Whilst this area is not exactly amicable towards promoting wildlife movements due largely to disturbance effects of movement, lights and noise from road traffic it does provide an alternative crossing point to wildlife that may become habituated to roads with high traffic volumes. For example, the Swamp Wallaby is likely to utilise this area given individuals have become habituated to the Pacific Highway at other locations (i.e. Broadwater National Park between Woodburn and Broadwater in northern NSW). The opportunity for semi aquatic species which have been recorded in this area (i.e. Lewins Rail *Rallus pectoralis*, Rough-scaled Snake *Tropidechis carinatus*, Bush-hen Amaurornis olivaceus, numerous frogs) would only improve over time. It may potentially be used

by other species including potoroo during stochastic events such as fire forcing individuals into this area. At other times the bridge span may be of little management value to potoroo.

5.3.2 Culvert Floor and Substrate

Sand mixed with a humus or mulch material (70/30 ratio) would be placed to a depth of ~100 mm on the bottom of each dedicated culvert and along the ledge sections of the multiuse culverts with these areas roughened with a broom finish to hold the material (*see* Appendix 4). The objective of this is to encourage their use by potoroo at any earlier phase of the monitoring program and has been proposed on the basis that potoroo are unlikely to utilize structures with unfamiliar substrates such as concrete. For example, bedding cage traps into the substrate was attributed to a marked increase in trap success during the study by Bali *et al.* (2003) over that of earlier investigations so it is likely to have a positive effect in the current application. No specific substrate material is intended for the drainage culvert.

5.3.3 Proximity and Type of Vegetation near Culverts

The presence and the amount of vegetative cover at culvert egress points is considered an essential component for designing effective underpasses (Hunt *et al.* 1987; Rodríguez *et al.* 1996). In order to promote the use of culverts by potoroo among other fauna, the planting schedule would comprise a number of shrub/ground cover species shown in Table 2. These would be planted up to the edge of the dedicated and multiuse culverts using two planting strategies. Firstly, dry heathland shrubs such as Midgen Berry and groundcovers, including *Lepidosperma*, would dominate plantings around dedicated culverts. Secondly, *Gahnia sp.*, *Restio sp.* and *Lomandra sp.* would be used at the multiuse culverts as these are more tolerant to periodic inundation (Harden 1996). These species have been selected because they are known to provide refuge habitat for potoroo adjacent to Boyd Street and thus provide the best means of encouraging culvert use. Moreover, this vegetation would provide fewer management issues[8] with respect to the fauna exclusion fence and periodic culvert maintenance.

5.4 FAUNA EXCLUSION FENCING

There have been several studies that have documented the effective use of wildlife exclusion fencing and its positive effect on directing fauna into wildlife culverts thus reducing road strike (e.g. Feldhammer *et al.* 1986; AMBS 1997; 2001a,b,c & 2002; Taylor & Goldingay 2003). It is also effective in the management of predators, pedestrians and motorcyclists.

The plan provides for a fauna exclusion fence, consisting of 1.8 m high chain mesh with 1.0 m of pinned ground mesh, to prevent animals from digging under the fence (*see* Figure 5, Appendix 4 & 5). This particular design would be installed along the boundary of the Tugun Bypass between Chainage 2400-3600 m (*see* Figure 3)[9]. Starting a considerable distance from known potoroo habitat in the north at Hidden Valley (Chainage 2125), this structure would be positioned at variable lengths from the road footprint (<20 m) in order to accommodate standard road design and safety considerations (Appendix 4). Adjacent to known potoroo habitat (Chainage 2700-3500) the fence largely abuts the road shoulder ensuring minimal disturbance to peripheral potoroo habitat and continues south well beyond the known distribution for potoroo at Cobaki (>4500; *see* Bali *et al.* 2003). An access track for the purposes of fence maintenance and emergency access would occur on the western side of the fence and is discussed in more detail in Section 5.7.

Signage would be displayed at 100 m intervals along the fauna fence identifying the presence of a 'Significant Environmental Area'. The signs would notify persons intending to carry out work in that area to ring the displayed phone number prior to commencing work. The signs would also provide instruction for reporting fence damage, with a contact number for either DMR or Leda being provided.

Fauna exclusion fence for Boyd Street Overpass and Extension would follow the same design and use the same materials as that for the Tugun Bypass. In addition, the fence would be connected to the 'spill through abutment' and continue on both sides of Boyd Street, to connect to an extension of the existing security fence at the Cobaki Lakes development (*see* Figure 3, Appendix 4 & 5). The fence is to be positioned at the toe of the batters thereby minimising the necessity for additional clearing. Further west along Boyd Street the

[8] Low growing species (<1.2 m) so they wont overhang exclusion fencing nor will they prevent fauna movement through the culverts.

[9] The majority of the Tugun Bypass is fenced, using a combination of security and fauna fence styles.

exclusion fence would be constructed within a few metres of the proposed bikeway[10] on the northern side of Boyd Street and within 4 m of the pavement on the southern side of Boyd Street in order to accommodate various road and utility infrastructure requirements. Where the exclusion fence approaches the culverts it would move over the headwall and aim to funnel fauna movements into the underpass (*see* Figure 6). Where the fence culminates along the boundary of the Cobaki Lakes development, fence returns of 5-10 m would be used to restrict and discourage fauna movement around the fence.

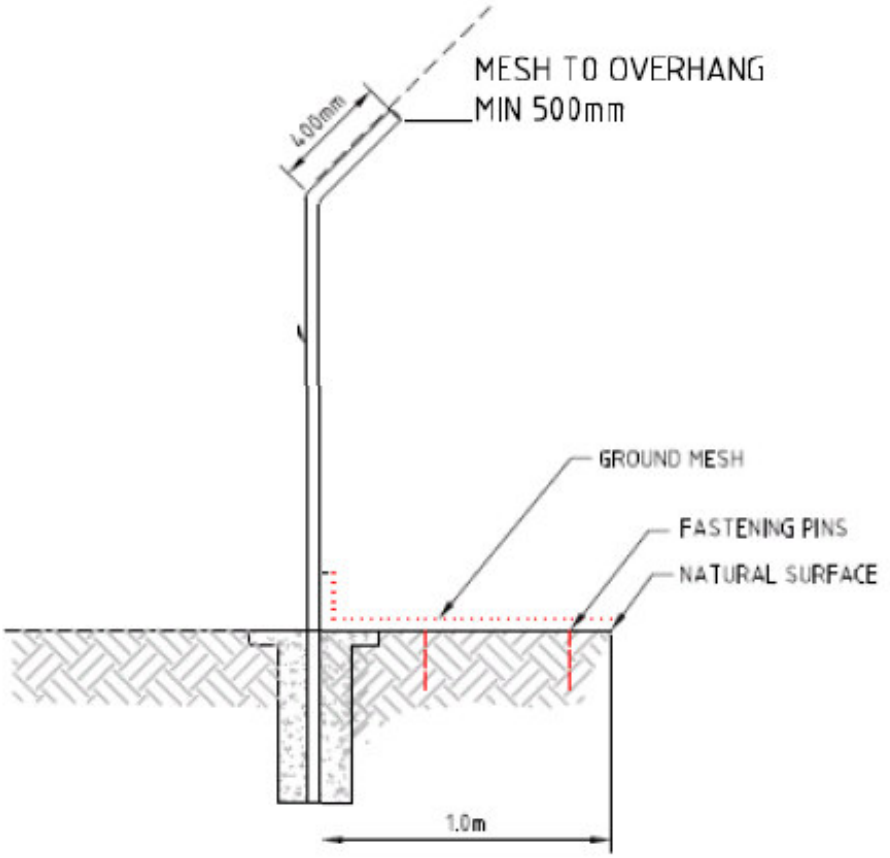


Figure 5. Drawing detail showing structure of fauna fence, including floppy top overhang and pinned ground mesh (from Tugun Bypass Project Drawing 3003181-BFF-020-6003).

Internal access points along the fence have been shown in Figure 3. They include four points along Boyd Street and a further four where the fence adjoins the Pacific Highway. Each access point would comprise a gate of sufficient width (3.25 m) in order to allow unhindered access by maintenance, landholder and emergency vehicles and their personnel.

The adoption of this design would:

- Reduce wildlife mortality rates resulting from road strike;
- Reduce the opportunity for domestic fauna (i.e. dogs, cats) and limit exotic predator (i.e. fox, cats) movements in and around potoroo habitat;
- Improve the effectiveness of fauna underpasses by directing wildlife into culverts;
- Indirectly result in better management of pedestrian and cyclist traffic in those areas;
- Facilitate the current management program by having less disturbance issues; and
- Attempt to retain the current ecological values of the adjoining habitat including a reduction in edge effects.

[10] Proposed location of the bikeway now adjoins Boyd Street.

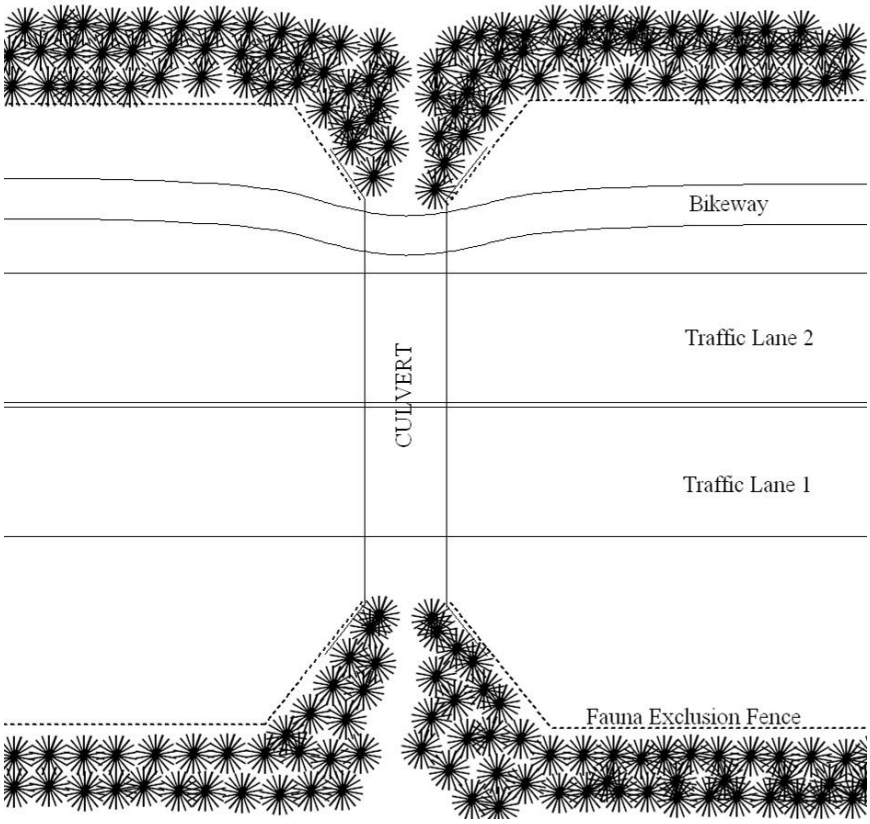


Figure 6. Sketch of Boyd Street extension and bikeway footprint in relation to fauna exclusion fence, culverts and revegetation works.

5.5 PREDATOR CONTROL

Predation by exotic species has been attributed to the decline and localised extinction of a wide range of native species including potoroo (Seebeck 1978; NPWS 2001; Reddiex & Forsyth 2004). Within Australia these exotic predators include the red fox, feral and domestic cats and wild and domestic dogs, with the former two species listed as key threatening processes (KTPs) under the *TSC* Act 1995. National Threat Abatement Plans (TAPs) have been developed for both the fox and the cat. These plans aim to coordinate exotic predator control between states and territories by providing a set of common objectives and goals. Broadly, the objectives of the fox and cat TAP include promoting the recovery of species and ecological communities that are impacted upon by exotic predation, preventing spread of these exotic species and improving knowledge of these exotic species impacts and researching control methods.

The Cobaki potoroo population is considered to be particularly vulnerable to predation by exotic animals for a number of reasons:

- This population is small, isolated and disjunct;
- The species itself is considered to be within the 'critical weight range'[11] (Burbidge & McKenzie 1989);
- The habitat is fragmented by roads and management trails, allowing easy movement of introduced predators; and
- There is a known resident fox population.

Currently there is no direct evidence to suggest whether exotic predators exert direct (i.e. predation) or indirect (i.e. behavioural responses) impacts on the potoroo population. However, it is known that potoroo is a prey item of fox in southern NSW and Victoria (Seebeck 1978; Lunney *et al.* 1990) and additional behavioural studies in western Victoria suggest that potoroo may enter more open habitats during daylight hours in the absence of foxes (Long 2001).

[11] Animals weighing < 5 kg.

5.5.1 Exotic Predator Control in the Tweed area

Given the recorded predation of fox on other potoroo populations, and the presence of a resident fox population, initial predator control methods would focus on this species. Baiting using 1080 has been shown to be the most effective and target-specific methods of canine control currently available (McIlroy & King 1990; Thompson & Fleming 1994; Bloomfield 2003; Reddiex & Forsyth 2004). The ability of any baiting program to impact upon a fox populations is limited by a number of factors, including immigration and reproduction, the proportion of the population exposed to baits, the proportion of bait-shy individuals within the population and the potential for compensatory increase in survival among unexposed and bait-shy foxes (Thompson & Fleming 1994; Bloomfield 2003; Reddiex & Forsyth 2004). With small scale baiting programs (<1000 ha), there is the need to consider establishing and maintaining an effective control or buffer zone which aims to reduce the potential population of immigrating foxes that seek to re-establish the unoccupied territories (Saunders *et al.* 1995).

Exotic predator control in NSW is administered through the RLPB. Typically this varies from offering advice, reviewing plans of pest management and supplying and governing the use of 1080. A similar role is performed in Queensland by DPI&F.

Currently Gold Coast Airport, Tugun Hill Conservation Block and the Tugun Bypass Compensatory Habitat Blocks A and E, on the south-western shores of Cobaki Broadwater, represent areas of known fox control. These programs are intermittent and are not presently coordinated by a central body. Coordinating these current programs with the one outlined here with the help of the RLPB would provide a progressive step towards an integrated exotic predator control program covering the areas surrounding Cobaki Broadwater, and thus provide an appropriately sized control or buffer zone.

The predator management program comprises monitoring, clean baiting and control via 1080 baiting. Monitoring is a fundamental part of the overall predator control program and aims to give a sound measure of the fox population before and after implementation (*see* Section 6.5). The predator control program (monitoring and control) would be undertaken in spring (November) over a 21 day period (*see* Appendix 6).

5.5.2 Control Baiting

Fifteen bait stations would be established using FOXOFF® 1080 baits and left for a period of 14 days, thereby allowing sufficient time for uptake. During this time stations would be inspected every second day (*see* Section 6.5). All bait stations would be constructed using a raised sand bed, with baits buried at a minimum depth of 100 mm, taking care to minimise the human scent transferred onto and near the bait station (i.e. construct using rake). Stations would be smoothed over to enable the detection of tracks made by the animal removing the bait. This approach would also enable an evaluation on the likelihood of non-target species such as Lace Monitor[12] (*Varanus varius*) and Spotted-tailed Quoll[13] (*Dasyurus maculatus*) accessing the bait stations

The location of the bait stations is shown in Figure 3 and Table 4. This has taken into account the restrictions associated with their use in NSW, whilst adjusting for the need to address concerns that predators may concentrate around some of the proposed mitigation devices, i.e. underpasses and the edge of fauna exclusion fencing. This has previously been identified as a problem in other studies where predators used new culverts more often than older established culverts (*see* Hunt *et al.* 1987), and often moved/hunted along existing pathways and fence lines (NPWS 2001; Bloomfield 2003).

The proposed location of bait stations aims to control exotic predators across four areas of potoroo habitat:

- Those areas bordering Boyd Street Extension which would be subject to fauna exclusion fencing and underpasses (5 stations);
- Areas to the north of Boyd Street (4 stations);
- Areas to the south of Boyd Street (5 stations); and
- Peripheral habitat along Sandy Lane and near the GCA-Tweed Byron Aboriginal land boundary (1 station).

[12] Lethal dose of 1080 for Goanna, 36.62mg; compared to fox 0.56mg (McIlroy 1983).
[13] Has not been recorded in this area despite intensive field surveys.

There are a number of restrictions associated with using 1080 in NSW, including no baiting to occur within 150 to 500 m of residential premises, no baits allowed to contaminate water bodies, and notification and signage to be utilised throughout the process. The positioning of the bait stations has taken these considerations into account with further details on procedure and guidelines available in the *Pesticide* Act 1999 (Pesticide Control Order under Section 38). In accordance with this act all neighbouring landholders must be notified in writing informing them of the impending predator control program. Signage would also be displayed at the eight points identified in Table 4. These signage points currently represent the main avenues for accessing the control zone.

Table 4. Location of bait stations and proposed signage display areas.

Bait Station No	Location	Land Tenure
1	E:548020 N:6883720	Tweed-Byron Aboriginal Land Council
2	E:548510 N:6883930	Tweed-Byron Aboriginal Land Council
3	E:548730 N:6884040	Tweed-Byron Aboriginal Land Council
4	E:548850 N:6884360	Tweed-Byron Aboriginal Land Council
5	E:548550 N:6884400	Tweed-Byron Aboriginal Land Council
6	E:548590 N:6884650	Crown Road Reserve
7	E:548460 N:6884640	Crown Road Reserve
8	E:548310 N:6884470	Crown Road Reserve
9	E:548180 N:6884350	Tweed-Byron Aboriginal Land Council
10	E:548180 N:6884500	Crown Road Reserve
11	E:548300 N:6884490	Crown Road Reserve
12	E:547970 N:6884690	Tweed-Byron Aboriginal Land Council
13	E:548400 N:6884820	Road Reserve*
14	E:548170 N:6884820	Tweed-Byron Aboriginal Land Council
15	E:548090 N:6884980	Road reserve*

Signage	Location
1	E:548130 N:6884980
2	E:548540 N:6884740
3	E:548600 N:6884680
4	E:548840 N:6884380
5	E:548380 N:6884580
6	E:548310 N:6884490
7	E:548740 N:6883910
8	E:547930 N:6884530

Note: (*) Bait stations 13 and 14 are within the Tugun Bypass road reserve, QLD. Placement of 1080 baits at these locations may need to be reviewed with QLD DPI.

5.5.3 Den Fumigation

Fumigation of fox dens would also form part of the control program and would be undertaken in spring (November) when fox cubs remain in their dens during the day. All dens being utilised would be subject to fumigation using one of three methods depending upon advice from NSW DPI and RLPB given at that time. Where necessary those undertaking the fumigation would be appropriately trained and licensed, and in the very least would consult with RLBP prior to fumigating. Fumigant options include:

- Chloropicrin (trichloronitromethane);
- Phosphine gas generated from aluminium phosphide; or
- Carbon monoxide cartridges, i.e. such as Den-Co-Fume®.

If den monitoring finds that sites are being reutilised following a fumigation session, a more permanent control method would be investigated.

5.6 FIRE MANAGEMENT

The use of fire is recognised as an important ecological tool toward effective management of Australia's flora and fauna. Fire has the capacity to:

- Maintain biological diversity;
- Stimulate the regeneration of particular plant species;
- Develop structural characteristics in vegetation communities; and
- Increase the abundance and distribution of wildlife habitat resources[14].

The fact that different ecosystems and vegetation communities are adapted to fire in different ways, can be used to manipulate an area, altering a vegetative characteristic so that the needs of specific flora or fauna are met. For example, fire has been used to restore open grassy habitat (Sorghum and Poa dominated grassland) in open eucalypt forest for the endangered Eastern Bristlebird (*Dasyornis brachypterus*) on the NSW/QLD border (B. Lewis *pers. comm.*).

[14] From ACF 1970; Tolhurst *et al.* 1992; Deeker 1993; Baird *et al.* 1994; Gill 1996; Law & Dickman 1997; Victorian Fire Ecology Working Group 1999; Moran & Watson 2000; Watson 2001.

Reflecting the above considerations, this fire management plan addresses mitigation and management of fire within and immediately adjacent to areas identified as potoroo habitat (*see* Figure 7). The broad objectives for this plan are as follows;

- Objective 1: provide a mosaic landscape that contains areas with varying fire histories and therefore stages of regeneration;
- Objective 2: ensure suitable habitat for the potoroo without significantly impacting upon other flora and fauna species;
- Objective 3: minimise the potential for wildfire events by breaking up fuel loads; and
- Objective 4: ensure that between 50 and 70% of known habitat is suitable for the potoroo within 4 yrs post burn.

5.6.1 Local Area Fire History

Little information is available regarding historical burns in this area. There is however, one record for August 1991 that identifies a fire which burnt through a large section of the NSW Crown Land Border Reserve. In this instance a controlled burn-off in the Tugun Hill area was affected by changing wind conditions, and resulted in an out-of-control burn which extended into the heathland and shrubland communities (Warren 1994). Warren (1992) hypothesized the understorey in this area would recover within 2-3 years and would then provide vegetation dense enough to support potoroo. As it has now been 15 years since this burn, this vegetation has returned to its pre-burn composition.

5.6.2 Vegetation communities and fire regimes

Nine vegetation communities (Forest Red Gum Forest, Scribbly Gum Mallee Heathland, Paper Bark Forest, Swamp Mahogany/Paper Bark Forest, Scribbly Gum Forest, Tree Broom Heathland, Swamp Mahogany Forest, Swamp Mahogany Scribbly Gum, Black She-oak Heathland) have been identified within the known potoroo habitat (Bali *et al.* 2003). Following the classification system outlined in Watson (2001) these communities have been grouped into three broad vegetation types (dry forest complex, scrubland/heath complex, and *Melaleuca* wetland), and have been assigned a corresponding fire regime (Table 5). This guideline identifies a burning regime threshold for each vegetation type which is based on the shortest and longest period of time for which burning can be applied to allow sustainability of the identified vegetation type. Table 5 outlines the fire regime thresholds associated with each zone, and also lists the strategies or objectives necessary for each vegetation type.

Table 5. Identification of fire regime thresholds for each of the nine vegetation communities considered in this fire management plan.

Vegetation Type	Vegetation Community	Fire Regime Threshold
Dry Forest Complex	Forest Red Gum Forest Swamp Mahogany/Paper Bark Forest Scribbly Gum Forest Swamp Mahogany Forest Swamp Mahogany/Scribbly Gum Forest	❑ Decline expected if more than two successive fires occur at intervals of less than 5 years. ❑ Decline predicted if there are no fires for more that 30 years. ❑ Decline expected if successive fires occur which totally scorch or consume the tree canopy.
Scrubland/Heath Complex	Scribbly Gum Mallee Heathland Tree Broom Heathland Black She-Oak Heathland	❑ Decline expected if more than two successive fires occur at intervals of less than 8 years. ❑ Decline expected if an interval of more than 15 years occurs between fires.
Melaleuca Wetland	Paper Bark Forest	❑ Decline expected if more than two successive fires occur at intervals of less than 15 years. ❑ Decline expected if an interval of more than 30 years occurs between fires. ❑ Planned burns would be conducted when the substrate is wet, to avoid the risk of peat fire.

5.6.3 Low Intensity and Ecological Mosaic Burning

To ensure safe and effective burning is undertaken, activities would follow the NSW RFS Standards for Low Intensity Bush Fire Hazard Reduction (2006). This document details various aspects of controlled burning, including the provision of fire breaks to ensure burning within a controlled area, knowledge of topography and fire behaviour, and use of lighting patterns to influence patchiness. When considered together these elements provide the best toolkit for an effective and safe burn.

A fire regime consists of four main characteristics; frequency, intensity, extent, season (RFS n.d.; Moran & Watson 2000; RFS 2006). A variable frequency of fire would result in differing intensity (due to high or low fuel loads, season etc; Tolhurst *et al*. 1992; Watson 2001). A lower intensity fire, using multiple ignition points, would result in a more 'patchy' burn, thus ensuring that the whole area of a particular vegetation type is not burnt all at once and that areas of burnt, unburnt and partially burnt vegetation remain throughout the landscape. This approach also maintains areas of variable fuel load, helping to prevent wildfires (Tolhurst *et al.* 1992; Watson 2001), as well as providing areas of refuge for fauna (Tolhurst *et al.* 1992; Law & Dickman 1997; Moran & Watson 2000) and opportunities for recolonisation by plants and animals (Tolhurst *et al.* 1992; Law & Dickman 1997; Catling *et al*. 2001). The exact size of each burnt patch would be determined by topography, surrounding landscape, and the location of fire breaks used to confine the fire (RFS n.d.). These variables, and others, have been taken into consideration when determining the division of precincts shown in Figure 7, and are further discussed in Section 5.6.4. Consideration of time of year, season and daily weather conditions is also crucial to meet fuel reduction, safety and environmental goals (Watson 2001; RFS 2006). Within the Tweed LGA, the optimal conditions for prescribed burning occur from late autumn to early winter, and from late winter to early spring offering only a brief window of opportunity (L. McCoy 5 February 2007 *pers. comm.*).

5.6.4 Implementation

The implementation of mosaic burns will require a degree of flexibility (i.e. adaptive management) in order to accommodate for prevailing seasonal conditions and administrative issues.

There are a number of safety and environmental considerations which would need to be addressed prior to undertaking any burns. One critical factor is to ensure there is adequate communication with relevant bodies or stakeholders. For example, to ensure fulfilment of the ecological objectives outlined in this plan, burns would be coordinated by RTA and DMR in consultation with DECC (NPWS) and QPWS. Those reviewing the burning regime and schedule would do so in light of post-burn monitoring results. Further guidelines for undertaking each burn is given in Table 6.

Burns would be undertaken by either the NSW RFS or DECC (NPWS). NSW RFS will be consulted regarding safety aspects of the burn. For example, NSW RFS would be able to advise on the recent demarcation of any Asset Protection Zone (APZ) or Bushfire Advantage Protection Zone (BAMZ) (RFS n.d.; RFS 2006). Other safety considerations involve consultation with GCAPL, Leda, RTA and other relevant land owners and administrators who would need to be advised as to the timing of burns. In particular, GCAPL would have safety restrictions limiting burning opportunities.

Within potoroo habitat, a number of existing control lines would be used to contain any burns (Figure 7). To ensure these lines remain functional their location would be GPS'd and mapped and where necessary would be maintained, either by the landowner, NSW RFS or DECC. Any maintenance which involve additional clearing of vegetation would undergo the appropriate assessment, i.e. Review of Environmental Factors. The control lines and associated widths are:

- The vehicle management trail bordering the Tugun Bypass footprint (up to 6 m);
- Boyd Street Extension (3 m);
- Eastern Boundary of Cobaki Lakes Development (up to 6 m);
- Several small sand trails which bisect the Tweed-Byron Indigenous Land Council owned land (up to 6 m);
- North-south drainage lines;
- Cleared Lands associated with Cobaki Lakes (in accordance with APZ); and
- Wet depressions associated with Tree Broom Heathland.

It is also proposed that vegetative and moisture gradients would provide effective containment during low intensity burns as would topographic variations associated with Tugun Hill (ignition at the top of the hill resulting in fire moving down slope). Additional fire breaks or control lines, beyond those listed above would only be created during wildfire events if an emergency situation is declared.

After considering the vegetation type and existing control lines 11 fire precincts have been nominated (Figure 7). They comprise four on the northern side of Boyd Street and seven on the southern side varying in area from 0.9-32 ha (Table 6). The objective of breaking the area into precincts is to ensure that at any one time there is sufficient and suitable habitat for potoroo on either side of Boyd Street, thus achieving both Objectives 1 and 2. The main north-south drainage lines and the large Tree Broom Heathland depression have not been identified for prescribed burns (i.e. no shading) for three reasons. Firstly, these vegetation communities generally possess low fuel loads and are often subject to inundation suggesting they pose little threat in supporting a wildfire, secondly, they provide a mosaic of long term residual habitat for potoroo unaffected by the proposed plan and may from time to time be of particular importance, and thirdly, these areas comprise important habitat for the Wallum Froglet (*Crinia tinnula*), a fire sensitive species of wallum habitats (Lewis & Goldingay 2005).

Ideally, prescribed burns would be undertaken in autumn or early winter when conditions become conducive to low intensity fires, which is also subsequently compliant with the local NSW RFS burning schedule. Precinct A (2012), C (2010), E(2012), F (2012) and K (2010) would be burnt during the first five years of the implementation. Burning H and B during the early stages of the plan aim to achieve two criteria; a) encourage the use of the culvert at Chainage 175 by burning both the north and south of the structure; and b) to reduce the fuel load and therefore risk of wildfire, in areas immediately adjacent to the overpass.

The remaining precincts are identified for burns in the proceeding 10 yrs (2014-2024), thus making a 15 year cycle. The schedule includes both years when multiple burns will be undertaken, as well as years when no burns will be undertaken, ensuring that more than 60% of known potoroo habitat remains suitable (i.e. >4 yrs post fire).

For ease of implementation, each precinct is generally small and contains a number of existing contaminant lines (i.e. drainage lines, wet depressions, cleared land, road infrastructure). In addition, two water source points have been identified adjacent to the fire management area and include retention ponds located at Pacific Beach Estate and Cobaki Lakes (Figure 7). Several high pressure water sources are also accessible in close proximity (<2 km) to the site.

Whilst this proposal is detailed and comprehensive, it does contain a level of flexibility. As burning is not an exact science, variables such as the success of revegetation (particularly around the culverts), success of predator control, and extent of previous burns, would all need to be taken into consideration prior to a burn. Thus, adjustments to the proposed schedule are likely. The inclusion of gap years would also allow a level of flexibility for those undertaking the burns.

Table 6. Fire management prescriptions for each precinct identified in the plan. Refer to Figure 7.

Precinct	Approx Area (ha)	Broad Veg Description	Proposed Burn	Guidelines
A	2.5	Scribbly Gum Forest – Heath Understorey	May-June 2012	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patch work ignition from eastern management trail on state border
B	2.6	Swamp Mahogany Scribbly Gum and Scribbly Gum Mallee Heathland	May-June 2019	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patch work ignition from eastern management trail on state border and from central foot trail
C	5.2	Swamp Mahogany Scribbly Gum and Scribbly Gum Mallee Heathland, Tree Broom Heathland	May-June 2010	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patch work ignition from eastern management trail and northern open paperbark forest at base of Tugun Hill
D	2.3	Swamp Mahogany Scribbly Gum and Scribbly Gum Mallee Heathland, Tree Broom Heathland	May-June 2016	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patch work ignition from western boundary of Cobaki Lakes and on boundary of precinct C & D.
E	1.4	Scribbly Gum Mallee Heathland	May-June 2012	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ Vehicle use along sand management trail for containment. ❑ No use of retardants ❑ Patch work ignition from southern and western sand trails and southern side of Boyd Street.
F	6.9	Black She-oak, Tree Broom Heathland, Scribbly Gum Mallee Heathland, Swamp Mahogany Forest	May-June 2012	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ Vehicle use along sand management trail for containment. ❑ No use of retardants ❑ Patch work ignition from main north south sand trail directing fire east into moist drainage line.
G	0.9	Scribbly Gum Forest and Scribbly Gum Swamp Mahogany Forest	May-June 2014	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patch work ignition from Boyd Street and the north-south drainage line
H	13	Scribbly Gum Forest and Scribbly Gum Swamp Mahogany Forest	May-June 2014	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patchwork ignition from eastern management trails which can be accessed by vehicle burning west into drainage line
I	13	Swamp Mahogany Forest, Scribbly Gum Forest	May-June 2016	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ Vehicle access along east west management trail for containment ❑ No use of retardants ❑ Patch work ignition burning south toward Cobaki Broadwater
J	13.7	Swamp Mahogany Forest, Black She-oak, Tree Broom Heathland, Scribbly Gum	May-June 2014	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ Vehicle access along north-south and east-

Precinct	Approx Area (ha)	Broad Veg Description	Proposed Burn	Guidelines
		Mallee Heathland		west trails used for ignition and containment ❑ No use of retardants ❑ Patchwork ignition initially from western side of precinct on east-west trail. Containment and further ignition along the north-south trail directing fire into wet Tree Broom Heathland
K	32	Scribbly Gum Forest, Scribbly Gum/Swamp Mahogany, Scribbly Gum Mallee heathland	May-June 2010	❑ Fire interval of 10-15 yrs ❑ No Use of Earth Moving Machinery ❑ No use of retardants ❑ Patchwork ignition from eastern Tree Broom Heathland and north western trail adjacent Cobaki Lakes development.

5.7 VEHICLE ACCESS AND TRACK MAINTENANCE

Vehicle (single lane) and pedestrian (1 m) maintenance tracks within potoroo habitat are shown in Figure 3. They include maintenance tracks on both sides of the fauna exclusion fence between Chainage 2600-3800. The objective of providing a maintenance track on either side abutting the Tugun Bypass is to conform with the fire management plan (*see* Section 5.6).

No vehicle tracks are proposed on the external side of the fauna exclusion fence along Boyd Street as this would reduce the effectiveness of the revegetation plan. In order to control vegetation growing up along the fence line a 1 m pedestrian maintenance track would be provided allowing a foot operator to whipper snip. This is also consistent with the revegetation plan which identifies the use of low maintenance species.

The existing sand trails on the southern side of Boyd Street would be retained and maintained in their current state. At widths of <6 m and dense vegetation on either side they do not present a significant barrier to regular movements by potoroo. For example, one of the radio-tracked potoroo in the baseline study (M950n in Bali *et al*. 2003) regularly crossed these sand tracks and several captures in this area suggest that a number of other individuals probably did.

The largely overgrown track which bisects the northern side of Boyd Street would be allowed to naturally regenerate but has been identified as a walking trail for the purposes of fire management (ignition points) in Figure 7.

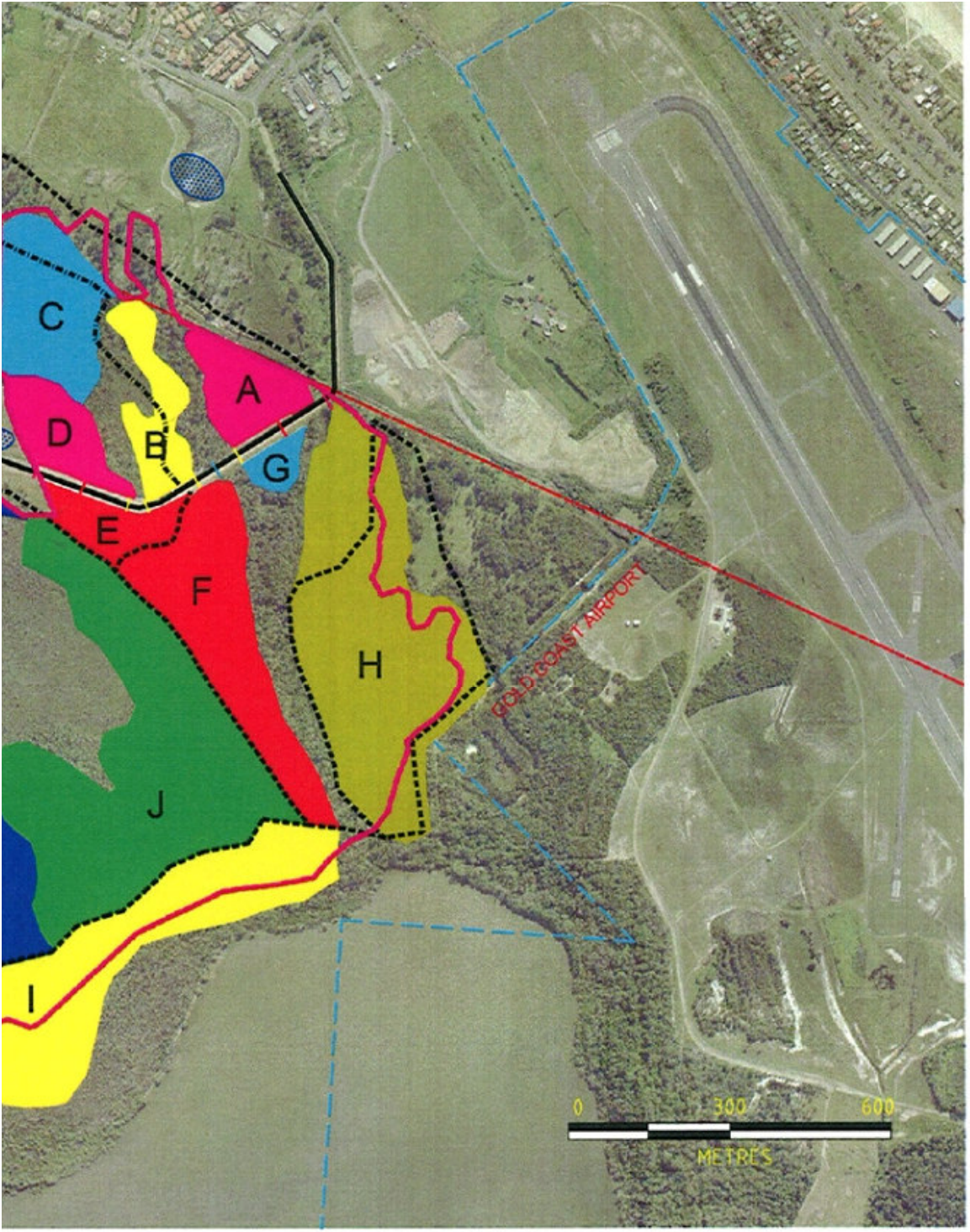
5.8 RELOCATION OF BIKEWAY

The current location of the bikeway that links the State Border to Cobaki Lakes Residential development, would result in additional clearing of vegetation, and is likely to reduce the effectiveness of proposed mitigation measures. It is therefore recommended that the bikeway be repositioned to the northern side of Boyd Street Extension abutting the road (*see* Figures 3 & 6). Whilst this may result in an increase to the current culvert dimensions by ~3 m it is considered a better ecological outcome. Re-aligning the bikeway would achieve the following outcomes;

- Improve the effectiveness of proposed mitigation measures, for example, given the location of the bikeway, the fauna underpasses would have to be longer and would therefore be less likely to be used by potoroo and other cryptic fauna;
- Reduce the need for culverts of greater dimensions both in length and height or the need for a low elevated bridge structure thereby reducing the overall construction costs;
- Improve fire management for the area. The previous bikeway location has an increased risk to life and property damage because the fauna exclusion fence would effectively limit escape routes. The previous bikeway location would also increase the risk of arson as persons would have direct access to vegetated lands; and
- Reduce human disturbance to surrounding vegetation thereby reducing the 'edge effect'.

In addition, the bikeway itself also raises additional as users may lobby for streetlights to illuminate the bikeway[15]. While this is purely speculative at this point in time it should be considered among other points as a reason for its re-alignment.

[15] No street lights proposed in any of the plans/documents accessed – namely document 2764/9-3 Is 010 and plans within.



GOLD COAST AIRPORT

LONG-NOSED POTOROO HABITAT BOUNDARY

QUEENSLAND/NSW BORDER

BRIDGE SPAN

DEDICATED FAUNA UNDERPASS

DRAINAGE

MULTIUSE UNDERPASS

VEHICLE TRACK

PEDETRIAN TRACK FOR FIRE MANAGEMENT

BOYD STREET

WATER REFUELING POINTS

NOT FOR CONSTRUCTION

REVISION	DATE	AMENDMENT / REVISION DESCRIPTION
01	04.06.2007	ORIGINAL ISSUE

DATE
30.05.2007

SKETCH

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PacificLink Alliance

PROJECT TITLE: TUGUN BYPASS

FIGURE 7 DISTRIBUTION OF FIRE PRECINCT AND THE PROPOSED TIMING FOR EACH BURN WITHIN & IMMEDIATELY ADJACENT TO KNOWN POTOROO HABITAT

DATE | PROJECT / SKETCH No. | REVISION

5.9 OTHER MANAGEMENT CONSIDERATIONS

On the northern side of Boyd Street the quarantine stock fence located to the north of the overpass would be removed and the existing easement allowed to naturally regenerate. Consultation with DPI&F (Quarantine) has resulted in verbal agreement for this works to be undertaken, however they would be notified immediately prior fence removal. The remaining stock fences would be left *in situ*, as it is enveloped in surrounding vegetation and attempts to remove it are likely to create a greater level of disturbance.

5.10 LICENCES AND PERMITS

There are a number of licenses and permits which may be necessary to undertake the various management actions detailed in this plan. Table 7 provides an indicative list of these authorities, the prescribing legislation and the administrating body. Whilst this list is current at the time of writing it should not be considered an exhaustive list. The responsibility to determine the legislative requirements, particular to an activity, are the responsibility of the individual undertaking or coordinating the action.

Table 7. Licenses and permits necessary to implement the management measures detailed in this plan.

Management Action	License/ Permit	Legislation	Regulatory Body	Comments
Access to Crown land	License to Occupy	Crown Lands Act 1989 – Section 34	DoL	
Access to Freehold land	Not applicable	Not applicable	Registered Owner	Written authority to be obtained prior to work
Monitoring – NSW	Scientific License Section 132c	National Parks and Wildlife Act 1974	DECC/NPWS	The Tugun Bypass has been approved under Section 3A of the *EP&A Act 1979* Section 75U provides a number of exemptions to the requirements to the *NPWS Act 1974*. In effect it is not an offence to undertake works which involve a threatened species, and as such a permit under Section 132c is not necessary for activities as associated with the Tugun Bypass.
Monitoring – NSW	Ethics Approval	Animal Research Act 1995	NSW DPI	Approval through an approved Animal Care and Ethics Committee
1080 Baiting	Not applicable	Pesticide Act 1999 (Pesticide Control Order Under Section 38)	NSW RLPB	Not authority is required, however, a risk assessment must be completed in consultation with the RLPB prior to the release of 1080
Fire Management	Bushfire Hazard Reduction Certificate	Rural Fires Act 1997	RFS	Landowner may be able to self-certify in some instances.

5.11 MANAGEMENT ACTIONS TIMETABLE

An indicative timetable of the management actions is provided below in Table 8.

Table 8. Timing of the management actions

Management Action/ Year Number	2007	2008	2009	2010	2011	2012	2013
Fauna Underpass							
Boyd Street Overpass	√	√					
Boyd Street Extension				√			
Fauna Exclusion Fencing							
Tugun Bypass	√						
Boyd Street Overpass	√						
Boyd Street Extension				√			
Revegetation Works							
Tugun Bypass	√						
Boyd Street Overpass		√					
Boyd Street Extension				√			
General Mitigation							
Tugun Bypass	√						
Boyd Street Overpass	√						
Boyd Street Extension				√			
Fire Management Plan							
Potoroo Habitat*				√		√	
Predator Control							
Potoroo Habitat*			√	√	√	√	√
Monitoring							
Potoroo Habitat*			√	√	√	√	√
Relocation of Bikeway							
Boyd Street Extension				√			
Vehicle Access and Maintenance							
Tugun Bypass		#	#	#	#	#	#
Boyd Street Overpass		#	#	#	#	#	#
Boyd Street Extension		#	#	#	#	#	#
Potoroo Habitat		#	#	#	#	#	#

Note: (1) Culvert monitoring will commence upon the construction of all fauna underpasses.
(*) Potoroo habitat as defined as 'Known Habitat' in Figure 2.
(#) As required to achieve plan outcomes.

5.12 DESIGN REVIEW

A design review of relevant road features (i.e. culverts, fencing, etc) would be undertaken prior to their construction, and would take into consideration how they relate to the various management actions (Table 9). The objective of the review process is to ensure all Conditions of Approval are addressed and structures are able to meet all intended purposes, including those not directly related to the potoroo.

Table 9. Design review process

Item	Location	Review Considerations	Reviewer
Road Layout	Tugun Bypass	Overall location of road structures and design features. Ensure compliance with relevant Conditions of Approval in Table 1 as well as other relevant approvals.	PLA, RTA/DMR, other relevant stakeholders
	Boyd Street Overpass	Overall location of road structures and design features. Ensure compliance with relevant Conditions of Approval in Table 1 as well as other relevant approvals.	PLA, TSC
Landscaping/ Revegetation	Tugun Bypass	Review species list, planting schedule, ensure compliance with relevant Conditions of Approval as well as suitability as potoroo habitat.	PLA, RTA, Hassell
	Boyd Street Overpass	Review species list, planting schedule, ensure compliance with relevant Conditions of Approval as well as suitability as potoroo habitat.	PLA, Hassell, TSC
	Boyd Street Extension	Review overall species list, ensure compliance with relevant Conditions of Approval as well as suitability as potoroo habitat.	PLA, Leda
Culverts	Tugun Bypass	Review culvert access with regards to restricting fauna movement, i.e. placement of grates.	PLA, RTA
	Boyd Street Overpass	Review culvert dimensions, location, horizontal position and additional features. Ensure culverts fulfil all intended purposes, with regards to both encouraging fauna movement and water flow.	PLA, TSC
	Boyd Street Extension	Review culvert dimensions, location, horizontal position and additional features. Ensure culverts fulfil all intended purposes, with regards to both encouraging fauna movement and water flow.	PLA, Leda
Fencing	Tugun Bypass	Review fence location and structure with regard to controlling fauna movements, including placement of ground mesh to restrict predator access.	PLA, RTA
	Boyd Street Overpass	Review fence location and structure with regards to controlling fauna movements with regards to predator access and reducing the likelihood of road mortality. Including location and placement of ground mesh.	PLA, TSC
	Boyd Street Extension	Review fence location with regards to controlling fauna movement with regards to predator access and reducing the likelihood of road mortality. Including location and placement of ground mesh.	PLA, Leda
Access and Maintenance Tracks	Tugun Bypass	Reviewing location and necessity of access and maintenance tracks in light of reducing the amount of clearing and allowing maximum regeneration or revegetation. Include considerations for gate locations and maintenance access to road features, as well as access for RFS during controlled burns.	PLA, RTA
	Boyd Street Overpass	Reviewing location and necessity of access and maintenance tracks in light of reducing the amount of clearing and allowing maximum regeneration or revegetation. Include considerations for gate locations and maintenance access to road features, as well as access for RFS during controlled burns.	PLA, TSC
	Boyd Street Extension	Reviewing location and necessity of access and maintenance tracks in light of reducing the amount of clearing and allowing maximum regeneration or revegetation.	PLA, Leda
Bikeway	Boyd Street Overpass	Review location and necessity of bikeway in light of reducing the amount of clearing and allowing maximum regeneration or revegetation.	PLA, TSC
	Boyd Street Extension	Review location and necessity of bikeway in light of reducing the amount of clearing and allowing maximum regeneration or revegetation. Also avoids the need for a culvert redesign to larger culverts and possible need for low-level bridge span. Also improves potoroo mitigation devices and allows for better management of pedestrian and cyclist traffic.	PLA, Leda

5.13 OTHER SPECIES WHICH MAY BENEFIT FROM THESE MEASURES

Results of the Tugun EIS field studies suggest the local area (<5 km) supports a high diversity of vertebrate fauna with 261 species recorded with many of these found on lands subject to this management plan (Tugun Bypass Alliance 2004a,b). Most of these species would benefit from the management actions contained within this plan. For example, the exotic predator control program is likely to reduce impacts on a range of rare and threatened fauna including the Coastal Planigale (*Planigale maculata*), Lewins Rail and Bush Hen[16] whilst one of the culverts would provide suitable roost habitat for Large-footed Myotis and both Bent-wing Bats. The successful implementation of the fire plan alone is likely to benefit both the flora and fauna values of this area whilst making allowances for fire sensitive species such as the Wallum Froglet.

[16] Pursuant to relevant state legislation

6.0 THE MONITORING PROGRAM

Equally as important as the management actions outlined in this plan is the need to design and implement an effective monitoring program for potoroo and then evaluate its success by comparing measurements derived from both the pre and post construction phases of the Boyd Street Extension and the Tugun Bypass project. The monitoring program would include:

- Assessing potoroo population size and structure;
- Monitoring fauna underpass culverts;
- Monitoring the integrity of fauna exclusion fencing;
- Road strike transects;
- Habitat condition surveys;
- Exotic predator control program; and
- Ongoing review of the fire management plan once prescribed burns have commenced.

6.1 POTOROO POPULATION SIZE AND STRUCTURE

A live trapping survey would be undertaken with the objective of providing a comparable measure of potoroo density and population structure (i.e. breeding, sub adults) to that of the baseline survey (i.e. Bali *et al.* 2003). The trapping survey would comprise four transects of 10 cage traps positioned at 50 m intervals parallel to Boyd Street effectively creating a linear trap grid on either side of the road (Figure 3). Two transects would be established on either side of Boyd Street at intervals of 10 m (TN1, TS1) and 90 m (TN1, TS2) from the edge of remnant vegetation. The objective of this is to enable sampling of 'edge' and more 'interior' habitat and to establish whether potoroo use both in light of the changing surrounds. The results of this survey design would also facilitate in our understanding of culvert use by potoroo. For example, no potoroo captures in the 'edge' habitat may suggest the opportunity for 'natural' movements through the culverts is currently limited at that time and has little to do with the culvert design itself. In considering the proposed survey design, any attempt to position the 'interior' trap transect further to the north (i.e. beyond 80 m) must consider the confounding affects of road induced disturbance arising from the Tugun Bypass.

The duration of each trapping event would initially be four nights conducted twice a year in May and November. After one year this will be reviewed through annual reporting mechanisms as part of adaptive management. These time periods have been chosen because they reflect when the baseline study was undertaken (May) whilst November represents the maximum time period from May (i.e. 6 months) and the characteristic dry springs are likely to result in different habitat use by potoroo. The trapping program would be undertaken on an annual basis and reviewed in consideration of the performance measures outlined within this plan. It is currently necessary to undertake seasonal surveys for potoroo because little is known about their seasonal movements at Cobaki or elsewhere in northern NSW and Queensland. Victorian studies investigating potoroo foraging habits and diet suggest they may move in response to the abundance of sporocarps which change in response to seasonal cues of temperature and rainfall but also fire (Claridge *et al.* 1992 & 1993).

The data obtained from this survey design would be used in a mark-recapture study whereby all captured potoroo would be fitted with passive integrated transponder tags (PIT Tags) using subcutaneous methods. The subsequent recapture of individuals within the north and south transects would be used to derive a population density estimate relevant to that area and facilitate in our understanding of localised movements including their use of the culverts.

It is beyond the scope of this plan to go about using other techniques for measuring the relative densities of other fauna by means of Elliott trapping, spotlighting, pitfall trapping and hair tubing. Although the later is a known technique in surveying for potoroo its success is somewhat limited both at Cobaki (*see* Bali *et al.* 2003) and numerous other locations (B. Lewis unpub. data).

6.2 MONITORING UNDERPASS CULVERTS

The findings of other studies suggest that direct and indirect monitoring methods of underpass culverts are required (*see* Goosem 2005). Accepting this, it is proposed that sand plots and infra-red cameras be used to monitor the use of all seven fauna culverts and one bridge span[17]. The main objective of the sand plots is to provide a backup source of information should equipment failure occur. The methods proposed for each have been outlined below.

6.2.1 Sand Plots – A Backup System

The tracking material would consist of a dry, loamy mix of sand, silt and clay laid on 2 m sections on either end of culverts as well as the middle section (*see* Figure 8). This method has been successfully used on other highway projects (i.e. AMBS 2001 & 2002; Taylor & Goldingay 2003) and elsewhere around the world (Clevenger & Waltho 2003 & 2005). The objective of this is to determine whether a particular species of animal investigated the edge of the culvert (tracks at one plot only), travelled at least half way through the culvert (tracks at two plots) or made a complete passage (tracks in same direction across all three plots). The middle sand plot is to be used because it is uncertain and to what extent potoroo may actually use underpass structures of this design.

Table 10. Sand plot monitoring program.

Sampling Regime/ Time Period	May	November	Totals
No Culverts	7	7	14
No. Monitoring Events In Each Survey	5 x 2 days	5 x 2 days	10 x 2 days
No. Days Monitored in Each Season	10	10	20
No. Days Per Year	70	70	140
No Days Over 5 years	350	350	700

Monitoring would consist of inspecting sand plots every two days and recording all fauna tracks to species (i.e. fox) or group level (i.e. bandicoot) before smoothing the plot over for the next sampling event. This would be continued over a 10 day period in autumn (May) and again in spring (November) and repeated on an annual basis for 5 years. Human activity would also be recorded during each underpass visit in order to derive a relative disturbance measure. Despite the length of each monitoring event being shorter (no. days) than previous monitoring studies (i.e. Taylor & Goldingay 2003) it compensates by being undertaken during two pronounced seasons over a 5 year period[18] (*see* Table 8).

6.2.2 Infrared Camera Systems – a means of collecting continuous data

Having the ability to continuously record data for this type of project is particularly important because the efficiency of the underpass is reliant on capturing a complete passage by one or more potoroo or secondary successes revolving around other native fauna using the culverts. This type of data collection would also provide an important component in the adaptive management of exotic vertebrate pests such as the fox, dog and cat.

The proposed system includes the use of a Faunafocus Automated Surveillance Camera with passive infrared and microwave sensors[19] (*see* Figure 8). The advantage of using a microwave sensor is it would enable the collection of data for smaller vertebrates (i.e. Dasyurids). The installation of two cameras in each culvert (one at either end) would be advantageous, however the current design of one camera in each culvert reflects a compromise between sampling more culverts and the overall cost of the monitoring program. The advantages and disadvantages of this system have been summarized by Goosem (2005). The advantages include it is locally designed and manufactured and therefore theoretically easier to source repairs and technical advice, the digital camera has a large photo capacity and is easy to download and export, and the

[17] Monitoring of bridge span will be subject to review of the security of the equipment from theft and vandalism.

[18] Subject to performance review.

[19] Cost is ~ $3000 Aus per unit.

sensors are waterproof to several metres thereby making them more applicable to the multiuse culverts. Among the disadvantages is the need to remove the equipment if the culvert is likely to be completely flooded and the initial cost may appear prohibitive.

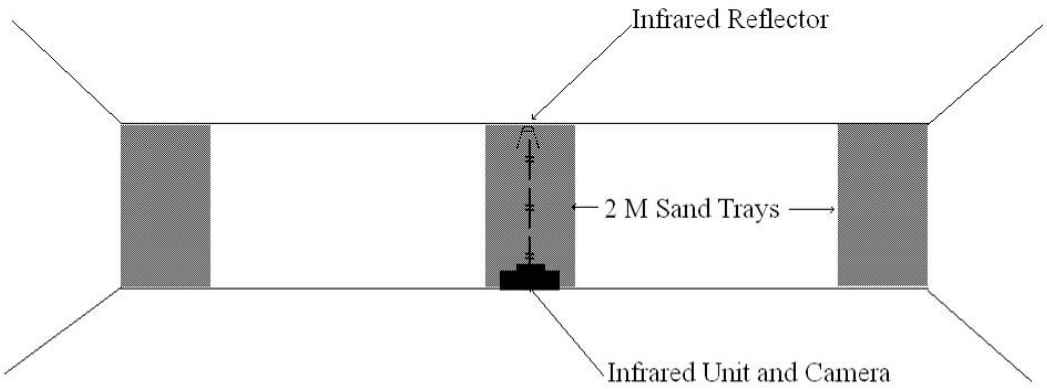

Figure 8. Sand trays and infra red monitoring equipment at each culvert.

The monitoring program would include infrared cameras mounted in all seven fauna culverts[20] (*see* Figures 3, 7 & 8). Each camera would be suspended from the roof of the culvert and enclosed in a security cage to reduce theft or damage. Monitoring would start six months after all the relevant management actions are in place (i.e. exclusion fencing, culverts, revegetation works for Boyd Street overpass and extension). The objective of this is to allow time for fauna to become habituated to underpass structures and the plantings have started to become established. After this time the cameras would remain operational for a four month period at four week intervals in spring, summer, autumn and winter. In the event that potoroo are recorded using the culverts during the initial two years of monitoring this component of the plan would be substituted for sand plots for the remainder of the monitoring period.

Figure 9. Fauna focus automated camera equipment available from Faunatech.

[20] Bridge span subject to review and there is no monitoring proposed in dedicated drainage culvert.

6.3 MONITORING THE INTEGRITY OF FAUNA FENCING

The integrity of the fauna fencing would be monitored concurrently with the road strike transects (i.e. quarterly during year 1 and biannually for years 2-5), as well as after major storm events (*see* Section 6.4). The objective of this is to identify if and where any fence breaches have taken place and may facilitate in interpreting the road strike data. The type of fence breach would also be recorded (i.e. animal dug under fence, fence has been cut through vandalism).

6.4 ROAD STRIKE TRANSECTS

For many road projects there is justifiably a need to collect information on the nature and extent of road killed wildlife such as in the case of road widening/duplication projects. In the present case, both Boyd Street and Tugun Bypass projects represent new roads so the level of baseline data in a pre construction/operation stage is set at zero (i.e. no roads there previously so zero wildlife mortality as result of road strike). Whilst it is acknowledged that a widened construction track has been in place since 2000 (~ April) its impact has been analogous to that of a powerline easement (i.e. barrier to movement, edge effects) because traffic has seldom travelled along it.

Walk transects would be undertaken on either side of Boyd Street overpass and again for 500 m north and south of the Boyd Street Overpass along the Pacific Highway. This would enable all road struck wildlife to be recorded in a format outlined in Appendix 8. In order to avoid the confounding effects of differing traffic volumes the data would be recorded individually for both Boyd Street and the Pacific Highway.

Initially two surveys would be undertaken following the opening of the road to vehicles with the first survey after 7 days of operation and the second survey one month later (~ July-August 2008). The objective of this is to document the initial impact of the road at a time when animals are most at risk. Following these initial surveys, the road strike transect would be undertaken quarterly for 1 year (February, May, August, November) and biannually in May (autumn) and November (spring) for the proceeding 4 years, thereby corresponding with the other monitoring events (i.e. population monitoring). If road strike is identified as an ongoing problem in year 1, then monitoring in subsequent years would be quarterly until the provided mitigation is shown to be effective. Surveys would be undertaken at dawn in order to reduce the number of unidentified wildlife as a result of increased traffic volumes driving over them (*see* Goosem 2001). Road kill transects would be undertaken on Sunday mornings along both the Tugun Bypass and Boyd Street because they currently represent the period of lowest traffic flow thus enabling a greater likelihood of identifying road kill wildlife to species level. It also provides the lowest risk to surveyors as outlined in the Health Emergency and Safety Plan (HESP). All road killed wildlife would be left *in situ* in order to reduce observer effects.

In addition to the results obtained from road strike transects, information (on road strike) would also be collected from maintenance contractors (working on behalf of the QLD Department of Main Roads and the NSW Roads and Traffic Authority) and local wildlife rescue groups (i.e. Currumbin Valley Wildlife Carers and Currumbin Wildlife Hospital). This would apply to individuals found on the Tugun Bypass or Boyd Street Extension.

6.5 MONITORING PREDATORY PRESSURE

Monitoring is an essential yet often ignored component of any pest control program (Reddiex & Forsyth 2004). In this instance monitoring would involve pre and post-control surveys using 'free-feeding' bait stations, predator scat and track transects and general traverses to locate den sites. Non-control baiting, scat and track transects would all provide indices of population size. Indices of predator activity would also be obtained via the infra-red camera culvert monitoring (*see* Section 6.2).

The baiting program (comprised of poison baiting and associated monitoring) would initially be undertaken once a year and where possible, coordinated with other components of this plan and other participants of the predator control program (i.e. Gold Coast Airport, Leda Manorstead). If monitoring (bait-take, scat and track) shows a substantial and maintained reduction in the fox population, the regularity of baiting may be reduced,

though other studies have found that if baiting is left for more than two years, the population returns to pre-baiting numbers (Reddiex & Forsyth 2004). [21]

The predator management program would be undertaken in spring (November), over a three week period comprising one week of pre-control monitoring and free-feeding and two weeks during which 1080 baiting and den fumigation would be undertaken. Monitoring would be ongoing throughout the 3 week period, thus providing constant assessment of the program. The full schedule for the predator control program is included in Appendix 6.

6.5.1 Non-control Baiting

Fifteen 'free-feeding' stations (i.e. baited with non-lethal baits) would be established at the locations shown in Figure 3 and Table 4. These would be used to collect information on the activity levels of exotic predators. Stations would be constructed as per the methods in Section 5.5. The 'free-feeding' period would commence following the installation of the fauna fencing and fauna culverts for the Tugun Bypass and Boyd Street overpass and extension. Daily inspections of bait stations would be undertaken over seven consecutive days (*see* Appendix 6). As the baits are consumed the station would be reported as having 'active' predatory pressure, tracks would used to identify the species, and the station would be rebaited and smoothed over.

The use of a 'free feeding' period of between 5 and 7 days often results in the target species entering into a regular feeding pattern, which increases the likelihood of poison bait taking, and therefore the success of the control program (Thompson & Fleming 1994; Bloomfield 2003). Control baiting would immediately follow non-control baiting as detailed in Section 5.5.

As non-lethal baits would be used during this initial survey no signage warning of a baiting program is required.

6.5.2 Control Baiting

During the 14 day 1080 baiting period (FOXOFF®), bait stations would be inspected every two days, at which time any tracks would be recorded, followed by a brief inspection of the surrounds to identify any destroyed individuals. At the completion of the 14 day baiting period all unconsumed baits would be collected and disposed of appropriately.

6.5.3 Den Fumigation

As mentioned earlier, survey for fox dens and subsequent fumigation would take place on an annual basis in spring. The number of active fox dens fumigated would be recorded and used as a relative index of fox activity. If monitoring results find that dens are being reutilised following a fumigation session, then permanent destruction of the den would be investigated.

6.5.4 Predator Scat and Track Transects

Predatory scat and track surveys would be undertaken along five 500 m transects shown in Figure 3. All predator scats observed during the transect surveys would be collected and sent to an appropriate person for analysis. The objective of collecting scats is to firstly obtain data on prey items taken by exotic predators in this area, and secondly, in order to reduce recorder bias in subsequent surveys (i.e. to stop scats counted on one survey being counted again in subsequent surveys). Undertaking scat surveys has the advantage of providing an alternative data set in which to base the pre control activity levels of fox, cat and dog. Predator tracks would also be recorded during these transects using a simple measure of presence/absence. The presence of tracks would be defined at two activity levels set at high (present for over 50% of the transect with tracks in both directions) and low (present for less than 50% of the transect). Scat and track transects would be undertaken on the first and last day of the non-control baiting period, once midway through the 1080 baiting period, and once on the last day of the program (*see* Appendix 6). Any scat and tracks immediately around bait stations will also be recorded as per Section 6.5.1 above.

[21] Any changes in control frequency should made in consultation with relevant stakeholders.

6.5.5 General Traverses

General traverse would be undertaken in areas bordering roads, easements, clearings and excavations in order to adequately survey for fox dens. The location of each den would be recorded using a hand held GPS, notes taken on whether it represents an active or unoccupied den site and a picture taken to facilitate in locating it at a later date. General traverses would be undertaken at the final day of the non-control baiting period, with any subsequent den fumigation occurring within the first two days of 1080 baiting (*see* Appendix 6).

6.6 MONITORING PRE AND POST BURNING

Due to the relative uncertainty regarding the impacts of mosaic patch burning on all aspects of biodiversity, it is important to monitor the area in the context of pre and post-burning. Pre burn surveys have been undertaken as part the vegetation surveys for the Tugun Bypass EIS[22]. From this information there is an adequate level of baseline data in which to gauge changes resulting from fire at Cobaki.

Basic surveys of the area immediately post-burn would involve measuring the extent of burn patches using a handheld GPS, with representative photographs being taken from at least 4 positions. These patches could then overlain on the fire precinct map (*see* Figure 7) to determine the percentage of the area burnt, and whether the fire was contained to the bounds of the precinct. The habitat monitoring techniques described in Section 6.4 would also be used to ascertain the suitability of the habitat in a post fire state for potoroo and incidentally for other species of fauna and flora. For example, Wallum Froglet heard calling from an area burnt 2 years ago.

Once the prescribed burns commence a series of performance criteria would be used to monitoring the success of the program. This would include the following:

- Has the burn covered the intended area (within 15% either way);
- Has the fire burnt at the correct intensity to remove the required amount of fuel load or vegetation. For example, has the total fuel load for that precinct been reduced by >50% (less than 50% = fire too cool) or, has >25% of the canopy vegetation in that precinct been burnt (higher than 25% = fire too hot); and
- Was the fire easily managed (qualitatively measured through communication with those undertaking the burn)?

6.7 HABITAT SURVEYS

The floristic and structural features of vegetation are often useful descriptors of the habitat cues with which small and medium mammals may respond (Braithwaite & Gullan 1978; Fox & Fox 1981). It therefore reflects an important component of this management plan because it proposes to revegetate a number of areas bordering known potoroo habitat, attempts to promote the use of underpasses via strategic revegetation up to the edge of culverts, and manage residual habitat via a fire management plan.

Four criteria have guided selection of habitat variables for measurement and the way they are measured:

1) Each variable should provide a measure of the structure of the environment which is either known or reasonably suspected to influence the distribution and local abundance of potoroo;
2) Each variable should be reasonably quick yet be precisely measurable with non destructive sampling procedures;
3) Each variable should have a intraseason variation that is small relative to interseason variation; and
4) Each variable should describe the environment in the immediate vicinity of the capture site.

Habitat monitoring would be undertaken across three broad areas including those areas identified for revegetation, habitat in the immediate vicinity of the cage trap transects and occasionally within the broader area (i.e. potoroo habitat south of Boyd Street Extension). The objective of this approach is to ensure changes in each area can be monitored as a result of management actions undertaken in this plan. For example, is the fire management regime altering the broad habitat attributes considered important to potoroo

[22] Numerous other vegetation surveys carried out at this location would further guide any assessment.

(shrub and ground cover species such as Midgen Berry and Flat-leaved Lepidosperma). Surveys would be undertaken in years 1, 3 and 5 of the plan using the survey design outlined below.

i.) Remnant (Residual) Vegetation

The following measurements would be undertaken at each of the cage trap locations using a 4 x 4 m quadrat:

- Cover/abundance of vascular plant species using the (Braun-Blanquet scale, *see* Appendix 9). This approach would enable the data to be sorted using a clustering program grouping those sites as having similar species compositions. This is more precise than what currently exists and it would help to further define the vegetation/habitat communities present;
- Vegetation density would be measured at five regular intervals along the 4 m transect[23] (0,1,2,3,4) using a narrow 3 m pole (10-15 mm) divided into 0.2 m vertical intervals. The presence or absence of plant material touching each 0.2 m interval would be noted and by summing for all point measurements a comparative index from 0-5 would be obtained for each interval at each site. Total vegetation density (<3.0 m) would be obtained by summing all contacts for each site. This component would be particularly important for potoroo which is regarded as a cover dependant species;
- Canopy Cover – Foliage projection cover (FPC) estimated using a basic scoring system of 1 (<25% cover), 2 (25-50% cover) and 3 (>50% cover);
- Trees – The number of trees (>0.1 m) within a 3 m radius of each trap site would be counted and their diameter measured to obtain a figure for basal area;
- Logs – The number of logs (>50 mm diameter) within a 3 m radius of each trap site using a simple scoring system of 0 (no logs), 1 (one log), 2 (2-3 logs) and 3 (>3 logs);
- Litter – An estimate of litter cover based on the simple scaling system of 1 (<20% cover), 2 (20-50% cover) and 3 (>50% cover);
- Bare Soil - An estimate of soil cover based on the simple scaling system of 1 (<5% cover), 2 (5-30% cover) and 3 (>30% cover);
- The number of potoroo/bandicoot diggings[24] within a 3 m radius of the trap site; and
- The site marked with a steel picket and a north facing photo point established for future reference.

ii.) Revegetation Areas

Habitat monitoring points would be established at all dedicated and multiuse culverts and at eight other locations along Boyd Street. These areas would be subject to the same methods described above (including photo points) for remnant vegetation monitoring so direct comparisons can be made over time. For example, at year three have the plantings in the revegetated areas become dense enough to be considered suitable potoroo habitat now or in the foreseeable (5-7 yrs) future? If not what is the difference in density and is remedial/corrective action required to enhance vegetation density? Such an approach would facilitate in the understanding of culvert use by potoroo.

iii.) Remnant Habitat beyond the impact zone

A series of control points (18) would be established beyond the recognised 'edge effect' and at other locations within known potoroo habitat. They would include habitat monitoring points within Scribbly Gum – Mallee Heathland, Tree Broom Heathland, Scribbly Gum-Swamp Mahogany, Black She-oak Heathland, Swamp Mahogany Forest and Scribbly Gum Forest because they are known to represent potoroo habitat (*see* Bali *et al.* 2003). These locations would be selected randomly to the north[25] and south of Boyd Street and reflect the range of habitats present. The objective of this is to capture baseline habitat data before any further fire events.

[23] Placed through the middle of the transect on a north south axis.

[24] Potoroo and bandicoot diggings are indistinguishable.

[25] If there are suitable locations that are at least 150 m from the Pacific Highway and Boyd Street.

6.8 SUMMARY OF MONITORING PROGRAM

A summary of the monitoring program is provided below in Table 11.

Table 11. Summary table of monitoring regime

Method	Description Summary	Frequency	Subject For review
Potoroo Population Monitoring	❑ Cage trapping in four transects parallel to Boyd Street at 80 m intervals with each transect containing 10 traps 50 m apart. ❑ Captured individuals weighed, aged, females assessed for pouch young, PIT tagged or scanned for recapture to derive a population density estimate and/or evidence of movement.	❑ Four night trapping program twice a year in May and November for 5 years.	❑ Review and compare population numbers / density with that of earlier baseline study. Also scan animals (PIT tags) for signs of movement between north and south of Boyd St.
Culvert Monitoring	❑ Sand plots at both ends and middle sections of culvert. Activity levels assessed every 2 days over a 10 day period and record all fauna. Record any signs of human visitation. ❑ Infrared cameras mounted in middle sections of culvert.	❑ Sand plots monitored twice a year in May and November for 5 years. ❑ Infrared cameras mounted in middle sections of culvert and run in continuous mode for 4 week periods in each season.	❑ Infrared cameras subject to review if potoroo recorded using culverts and monitoring revert to sand plots.
Predatory Pressure	❑ Poison baiting at 15 stations monitored, inspection every 2 days, left for 14 days. ❑ Clean baiting at 15 stations initially monitored daily over 7 day period. ❑ Predator scat searches along 500m transects. ❑ Fox den surveys for occupancy, fumigation. ❑ Culvert monitoring (as above).	❑ Annually to begin with, may increase or decrease dependant on monitoring results, but no less than every two years if numbers are controlled. ❑ Track and scat transects are undertaken before, during and after baiting. ❑ Annually in spring. ❑ As above.	❑ Review for presence of other predator species following the completion of the Cobaki Lakes Development, and resulting need to include other forms of control. Review of frequency of control, increasing or decreasing as necessary.
Fire management Plan	❑ Mosaic patch burns undertaken within designated precincts. ❑ Access tracks and fire breaks maintained.	❑ Variable frequency (*see* Figure 6 and Appendix 5). ❑ Maintenance ongoing as needed, confirmed prior to undertaking burns.	❑ Ongoing review prior to each burn to ensure mosaic results being achieved, and sufficient regrowth occurring.
Habitat Surveys	❑ Record cover and abundance of vascular plant species, assess vegetation density, canopy foliage projection cover, tree basal area, ground cover attributes of log, litter, bare soil using simple scaling system or absolute numbering system. ❑ Record the number of potoroo/bandicoot diggings in the immediate area. ❑ All measurements taken within 3 m radius of cage trap location.	❑ Approximately 5 days in years 1, 3 and 5 of the plan.	❑ Review at years 1, 3 and 5 to assess progress of revegetation and regeneration of any burnt areas.
Road Strike Transects	❑ Transect along Boyd Street and along Pacific Highway for 500 m either side of Boyd St overpass. ❑ Record all road struck fauna. ❑ Where available additional data obtained from relevant road agencies and/or local wildlife rescue groups.	❑ Initially 7 days after road is opened to public traffic and again 4 weeks later. ❑ Following initial surveys, undertake quarterly for 1 year (February, May, August, November), and then biannually	❑ Review for breaches and address as necessary.

Method	Description Summary	Frequency	Subject For review
		for 4 years (May and November). If road strike is identified as an ongoing problem in year 1, then monitoring in subsequent years would be quarterly until mitigation is shown to be effective.	
Fauna Fence Surveys	❑ Traverse fauna exclusion fence within known potoroo habitat and record the number and type of breaches.	❑ Undertake quarterly during year 1 and biannually for during years 2-5, concurrently with the road strike transect surveys. ❑ Undertake additional surveys following major storm events.	❑ Review for breaches and address as necessary.

7.0 PERFORMANCE MEASURES

The performance indicators are presented within each of the monitoring schedules and summarised in Table 12. It must be recognised that when assessing each of the management actions that potential confounding variables be taken into account. These may include the location, extent and any breaches in the exclusion fencing, the level of human activity and the variable edge effects of noise and lights from roads of different traffic volumes (i.e. eastern underpasses may be more susceptible to the effects of vehicle traffic). Without this, spurious results may mask the overall performance and cost effectiveness of the program.

7.1 POPULATION MONITORING

The performance of the potoroo population monitoring would be measured in four ways;

- Comparing the density and number of potoroo captured along each transect with the baseline study (Bali *et al*. 2003). Captures of similar numbers of potoroo in each of these areas would be regarded as a success;
- The capture of potoroo at one or more cage trap locations along each transect would be considered a success. This would indicate potoroo have some tolerance or become habituated to the changing abiotic and biotic influences on the landscape;
- Population structure of the potoroo population on both the north and south of Boyd Street. Evidence of sub adult and/or pouch young would be considered a success; and
- Individuals moving between the north and southern sides of Boyd Street would be considered a success and indicate that culverts are being utilised.

7.2 FAUNA UNDERPASS CULVERTS

The performance of culverts would be viewed at multiple levels. Firstly, these structures should not be viewed as a direct extension of natural habitat but rather a safer avenue to enable important life cycle processes of the population. For example, potoroo may tend to use the underpass structures when undertaking more large-scale movements such as emigration by juveniles and sub adults, as a result of seasonal food resources or in response to stochastic events such as flood and wildfire or controlled burns. We can only speculate about the natural movement of individuals bordering Boyd Street prior to its widening in April 2000 but it is likely that individuals moved across this track given it was only several metres wide, a statement supported by the results of the background studies for the Tugun Bypass EIS (Bali *et al.* 2003).

The performance measures proposed for culverts include:

- Their suitability to potoroo and frequency of use. The culverts would be considered successful if used by one or more potoroo;
- Their suitability and frequency of use by other fauna;
- Their ability to provide a suitable avenue for movement on a year round basis (i.e. do the multilevel culverts get regularly flooded and for how long);
- Are they being used and to what extent by exotic predators; and
- Their susceptibility to human disturbance.

In considering the performance indicators nominated above the confounding effects including the stage of revegetation, adjacent culverts, location to road induced effects such as differing noise, light, visual movement and susceptibility to disturbance by human interference/presence, the extent of existing environmental (fire, flood) and seasonal factors (breeding) would also be considered.

7.3 FAUNA EXCLUSION FENCING

The performance of the exclusion fencing would be measured in four ways:

- Against the amount of wildlife recorded during the road kill transect surveys. Because there is no comparable data from an existing road the collated data would be compared to comparative studies on road kill incidence interval data (i.e. 3.8 km per road kill in Taylor & Goldingay 2004) and previous monitoring of fauna exclusion fences (i.e. AMBS 2001a;b;c & 2002). It should be recognized by regulatory bodies and others readers of this plan that exclusion fencing would not mitigate against all road kill but rather an acceptable means of reducing it. For example, frogs, most reptiles, arboreal

mammals and birds would probably be placed at similar levels of risk if the fence wasn't installed, however, it would be quite effective for many of the ground dwelling mammals including bandicoots, wallabies and potoroo. The absence of these latter species during road kill transect surveys would be viewed as a success of installing the fencing;
- The number of fence breaches both through and under the fence;
- The ability to reduce pedestrians, trail bike riders and domestic pets from entering potoroo habitat. Much of this data would be obtained during the culvert and exotic predator control monitoring; and
- The fences ability to reduce the dispersal of exotic predators using Boyd Street via culvert monitoring techniques.

7.4 EXOTIC PREDATOR CONTROL PROGRAM

The performance of the exotic predator control program would be based around the activity levels collected in the pre-construction phase and compared with each subsequent monitoring/control period. Each successive year would then be compared to both the pre-construction exotic predator activity levels and the previous monitoring event addressing the following questions;
- Has the uptake of baits by exotic predators declined since the last monitoring control event?
- How do the current fox monitoring levels compare with the data collected in the pre-control phase of this plan?
- Have the control actions implemented at den sites been successful?
- Are exotic predators using underpass structures and fence lines (using results from scats and track transects), and to what extent? How does this compare with previous monitoring/control events?

A decline in the activity levels of exotic predators as a result of the actions undertaken would be viewed as a success. These performance measures would be reviewed at the completion of each monitoring event and recommendations made accordingly. It is unlikely that information collected would be directly attributed to a measurable response in the potoroo population. This would require detailed surveys over several years prior to implementing the exotic predator control program.

7.5 FIRE MANAGEMENT REGIME

The performance of the fire management plan would be gauged at multiple levels including:
- Its ability to implement and control a mosaic burn regime within the 11 precincts at suitable intervals, and to ensure this is undertaken safely;
- Its ability at preventing wildfire from burning large (>30%) areas of potoroo habitat; and
- Its ability to maintain the current distribution of potoroo now and into the future, as tested through the population monitoring program.

Obviously these performance measures are based around longer commitments than what is currently proposed in this plan but they should form the basis for direction for long term management of the area.

7.6 HABITAT MONITORING AND REVEGETATION WORKS

The performance of the habitat monitoring program would be viewed at two levels. The first level would compare the difference between the remnant 'edge habitat' identified for cage trapping and that of the adjacent 'interior' habitat. Is there any obvious difference in the habitat that may explain the trapping rates of potoroo? If not, could other factors be responsible (i.e. road noise, lights)? Overall how do these areas compare with the control points elsewhere in residual habitat?

The second level would gauge the progress of the revegetated areas by direct comparison. Are there habitat attributes identified as desirable to potoroo increasing at the revegetation sites between years 1, 3 and 5? These desirable habitat attributes would be based on the trapping and corresponding habitat data collected at each trap site. The performance would be gauged as a success if these attributes are increasing over time and recommendations made according to their progress. For example, a lack of sufficient shrub layer species would result in a corrective action such as some additional plantings of preferred species (i.e. Midgen Berry).

7.7 SUMMARY OF PERFORMANCE MEASURES AND CORRECTIVE ACTIONS

A summary of performance criteria, relevant to each monitoring class is provided in Table 12 below.

Table 12. Performance criteria and corrective actions

Monitoring	Period	Success	Period	Unsuccessful	Corrective Actions
Population Monitoring	❑ Years 1-5	❑ Trap success (i.e. capture rate) and estimated population density* > 80% of baseline data collected in Bali *et al.* (2003). ❑ Potoroo captured along 3 or more of the 4 transects. ❑ Evidence of breeding defined by presence of pouch young and/ or sub adults (1 pouch young/sub adult or more). ❑ PIT tagged individuals moving between north and south Boyd Street (1 individual or more).	❑ For any one year between Years 1-5.	❑ Trap success (i.e. capture rate) and estimated population density* < 80% of baseline data collected in Bali *et al.* (2003). ❑ Potoroo only recorded along 'interior' transects. ❑ No signs of breeding (pouch young or sub adult) in north sub population (i.e. north of Boyd Street). ❑ No sign of individuals moving between north and south sub populations.	❑ Review and amend trapping transects if deemed necessary. Also consider the adequacy of survey timing and/or seasonal variation in the decision making process.
			❑ Two or more consecutive year(s) between Years 1-5.	❑ Trap success (i.e. capture rate) and estimated population density* < 80% of baseline data collected in Bali *et al.* (2003).	❑ Notify agencies within 28 days of 2nd annual monitoring event. Review effectiveness of predator control, drainage structures (Boyd Street) and habitat condition – relocate trap locations if predator numbers, culvert function and habitat condition is not of concern. Modify predator control, drainage and or fire management programs to improve habitat condition if required. Consult and develop contingency actions with government agencies and update plan accordingly.
				❑ Potoroo only recorded along 'interior' transects.	❑ Review effectiveness of predator control, habitat condition and edge effects (adjacent to Boyd Street) – relocate trap locations if predator numbers, habitat condition and edge effects are not of concern and estimated population density >80%. Modify predator control, drainage and or fire management programs to improve habitat condition if required. Consult with government agencies and update plan accordingly.

Monitoring	Period	Success	Period	Unsuccessful	Corrective Actions
				❑ No signs of breeding (pouch young or sub adult) in north sub population.	❑ Review effectiveness of predator control and habitat condition; modify predator control and or fire management programs to improve habitat condition if required. Consult with government agencies and update plan accordingly. ❑ Review survey timing and prevailing seasonal conditions that could contribute to influencing breeding behaviour. ❑ Review male/female ratio; translocate required individuals in Year 5 if still no signs of breeding. Consult with government agencies and update plan accordingly. ❑ Relocate trap locations if predator numbers, habitat condition and male/female ratio not of concern.
				❑ No sign of individuals moving between north and south sub population.	❑ Review revegetation works around fauna underpasses, effectiveness of predator control and potential edge effects along Boyd Street; reinstate vegetation around underpasses (as prescribed by the approved project landscape drawings), modify predator control and or fire management programs to improve habitat condition if required. Consult with government agencies (modifications only) and update plan accordingly.
Fauna Underpass Culverts	❑ Years 1-5	❑ One or more potoroo make complete passage through an underpass. ❑ No evidence (fresh scats or tracks i.e. <1 week old) of exotic predators within fauna underpass culverts. ❑ No sign of use (tracks) by pedestrians and trail bike riders.	❑ One year between Years 1-5.	❑ No potoroo pass through a constructed underpass. ❑ Scats/tracks (1 week old) within fauna underpass culverts. ❑ Pedestrian/trail bike rider tracks present within fauna underpass culverts.	❑ Review revegetation works around fauna underpasses, presence of vertical grates within underpasses and dry access to and through underpasses (the later only applying to dedicated fauna underpasses and not combination – drainage culverts). Reinstate vegetation/log hides around underpasses (as prescribed by the approved project landscape drawings), if required. Also provide dry access to and or through culverts, if required. Earth material (sand/mulch) recommended for use. Reinstate vertical grates, if required.

Monitoring	Period	Success	Period	Unsuccessful	Corrective Actions
			❑ Two or more consecutive year(s) between Years 1-5.	❑ No potoroo pass through a constructed underpass. ❑ Fresh scats/tracks (1 week old) within fauna underpass culverts. ❑ Pedestrian/trail bike rider tracks present within fauna underpass culverts.	❑ Review revegetation works around fauna underpasses, presence/suitability of vertical grates within underpasses and dry access to and through underpasses (the later only applying to dedicated fauna underpasses and not combination drainage culverts). Reinstate vegetation/log hides around underpasses (as prescribed by the approved project landscape drawings), if required. Modify predator control and or fire management programs to improve habitat condition if required. Modify vertical grates, if required. Consult with government agencies (modifications only) and update plan accordingly. Also provide dry access to and or through culverts, if required. Earth material recommended for use.
Fauna Exclusion Fencing	❑ Years 1-5	❑ Fauna (potoroo) not subject to road strike. ❑ No visual signs of pedestrians and trail bike riders within potoroo habitat or underpasses.	❑ One year between Years 1-5.	❑ Potoroo (1 or more individuals) struck by road vehicle.	❑ Fence to be inspected by Maintenance Contractor (DMR/TSC) within 7 days of observation. Breaches (holes or lifted ground mesh) to be repaired/re-instated within 7 days of inspection.
				❑ Visual signs of pedestrians and trail bike riders within potoroo habitat or underpasses.	❑ Fence to be inspected by Maintenance Contractor (DMR/TSC) within 7 days of observation. Breaches (holes or lifted ground mesh) to be repaired/re-instated within 7 days of inspection. ❑ Review fence design if repeated/persistent intrusion occurs - structural integrity and or additional security features to be installed.
Trapping Surveys	❑ Years 1-5	❑ Sufficient mark recapture data of individuals to derive potoroo population density in habitat adjoining the north and southern side of Boyd Street. ❑ No trap deaths of potoroo.	❑ Years 1-5.	❑ Insufficient mark recapture data of individuals to derive potoroo population density in habitat adjoining the north and southern side of Boyd Street.	❑ One year - Review survey techniques including trap locations and the contractors' performance/ability to undertake the project. ❑ Two consecutive years; notify agencies within 28 days of 2nd annual monitoring event.

Monitoring	Period	Success	Period	Unsuccessful	Corrective Actions
				❑ One or more trap deaths of potoroo.	❑ Cease trapping. Notify the Department of Environment, Water, Heritage and the Arts and the National Parks and Wildlife Service within 24 hours of discovery. ❑ Follow procedures defined in the NSW Animal Care and Ethics Guidelines and licensing arrangements. ❑ Review trap survey design and consult with agencies. Review need for further trapping in adjacent area to substantiate population status adjacent to Boyd Street. ❑ Review and evaluate the importance for the need to obtain mark–recapture data. For example, use less invasive methods such as infrared cameras. Consult with agencies and update plan.
Habitat Monitoring	❑ Years 1-5.	❑ Cover/abundance of vascular species within remnant vegetation (impact zone) > 75% of remnant vegetation (non-impact zone).	❑ Two or more consecutive year(s) between Years 1-5.	❑ Cover/abundance of vascular species within remnant vegetation (impact zone) < 75% of remnant vegetation (non-impact zone).	❑ Assess potential cause (natural and anthropogenic) and identify relevant corrective actions within 28 days of monitoring event (2nd consecutive year). Advise regulatory agencies and associated landowner/s.
Regeneration Areas	❑ Years 1-5.	❑ >75% of landscaping plants viable and actively showing Signs of Growth (SoG) within regeneration and habitat augmentation areas.	❑ Years 1-5.	❑ <75% of landscaping plants viable and actively showing SoG within regeneration and habitat augmentation areas.	❑ Maintenance period: Responsible party to determine cause of poor growth/absence. Re-instate/replace landscaping plants (as prescribed on the project drawings) if suitable and within 28 days of observation. ❑ Post maintenance period: Approval body/regulatory agency/landowner to determine cause of poor growth/absence. Re-instate/replace landscaping plants (as prescribed on the project drawings) if suitable and within 28 days of observation. If original species are considered not suitable, then substitute with recommended species at similar densities or at a rate that achieves required plant cover for potoroo. Undertake work within 28 days of observation.
Predator Control Program	❑ Years 1-5.	❑ >25% of control baits (compared to preceding 'free-feeding') consumed by exotic predators (fox, cat, dog). ❑ >50% reduction in the taking of 'free feed' baits between Year 1.	❑ Years 1-5.	❑ <25% of control baits (compared to preceding 'free-feeding') consumed by exotic predators (fox, cat, dog).	❑ Review station location and bait preparation (i.e. smoothing, human scent minimisation etc) and ensure appropriate standard maintained.

Monitoring	Period	Success	Period	Unsuccessful	Corrective Actions
		and 3. ❑ > 50% reduction in the taking of 'free feed' baits between Year 3 and 5. ❑ > 50% reduction in actively used fox dens between Year 1 and 5. ❑ > 50% reduction in exotic predator tracks or scats (between Year 2 and 5) within or immediately adjacent to dedicated underpass structures and fauna exclusion fences.		❑ < 50% reduction in the taking of 'free feed' baits between Year 1 and 3. ❑ < 50% reduction in the taking of 'free feed' baits between Year 3 and 5.	❑ Review poison effectiveness. Consult with regulatory agency on type and strength. ❑ Review the suitability of bait station locations ❑ Increase station numbers by 25%.
				❑ < 50% reduction in actively used fox dens between Year 1 and 5. ❑ < 50% reduction in exotic predator tracks or scats (between Year 2 and 5) within or immediately adjacent to dedicated underpass structures and fauna exclusion fences.	❑ Modify den fumigation agent and or application method if specified 'free feed' baits consumption is > 25%. ❑ Add bait station to entry and exit of each dedicated fauna underpasses (of which is subject to visitation by predators) and/or one bait station to associated fauna exclusion fence.
Fire Management Plan	❑ Years 1-5	❑ Precincts C and K burnt in Year 1 and A E and F burnt in Year 3 by low intensity fire. ❑ > 75% of precinct (C,K,A,E,F) area burnt. ❑ > 50% reduction in understorey fuel load of precinct. ❑ < 25% of precinct canopy burnt. ❑ > 50% of burnt precinct suitable for potoroo within 4 yrs of event (assessment will only apply to Precinct A,C,E,F in the life of this plan). ❑ Dedicated firebreaks and access tracks maintained to pre-existing widths (as detailed within the plan) with variation < ± 1 metre.	❑ Years 1-5	❑ Precincts C,K,A,E,F not burnt within 1 year of required interval i.e. delay < 1 year.	❑ Report on non-compliance to be provided to the Department of Environment, Water Heritage and the Arts within 13 months of the prescribed burn interval. Report must justify delay and detail when prescribed burns are to occur.
				❑ < 75% of precinct (C,K,A,E,F) area burnt.	❑ Burn remaining area within 8 weeks (weather depending) if burn < 50% of intended area. Burn remaining area in conjunction with next program burn (i.e. next programmed precinct).
				❑ < 50% reduction in understorey fuel load of precinct.	❑ Burn remaining area within 8 weeks (weather depending).

Monitoring	Period	Success	Period	Unsuccessful	Corrective Actions
		❑ Prescribed burns do not extend (< 20 m) into precincts not programmed for burning.	❑ Years 1-5.	❑ > 25% of precinct canopy burnt.	❑ Identify cause in consultation with RFS and or NPWS. Document and agree on measures to improve future performance. Notify regulatory agencies and amend plan within 28 days of event. Implement measures during next prescribed burn.
				❑ < 50% of burnt precinct suitable for potoroo within 4 yrs of event.	❑ Review the cause of slow regeneration rates and implement agreed corrective actions prior to next programmed burn. Review process is to include notification/consultation with regulatory agencies and environmental specialists. Consider increasing fire intervals (as to reduce fuel loads and thus fire intensity) or decreasing fire intervals (to allow vegetation a longer period to recover). Modify and seek approval of plan if changes are required.
				❑ Errant fire (as part of programmed burns) extends into precincts other than C,K,A,E,F i.e. premature burn. 'Loss' of un-programmed precinct > 15%.	❑ Identify cause in consultation with RFS and or NPWS. Document and agree on measures to improve future performance. Notify regulatory agencies and amend plan within 28 days of event. Implement measures during next prescribed burn.
				❑ Dedicated firebreaks and access tracks maintained to pre-existing widths (as detailed within the plan) with variation > ± 1 metre.	❑ Work to re-establish dedicated firebreaks and access tracks to be undertaken within 4 weeks of non-compliance.

Note: * - Estimates of population density would be calculated from 'baseline' data detailed in Bali *et al.* (2003) with adjustment being made for the percentage difference in trap success (number of traps used and actual number of potoroo caught) between current and baseline survey.

8.0 TIMING AND TASK COMMITMENT

The proposed timing and commitment of relevant tasks is shown in Table 13 below.

Table 13. Summary of tasks and commitment to implement the proposed plan.

Action	Number	Commencement	Completion	Commitment/ Responsibility
Development of an Integrated Potoroo Plan of Management	❑ Development of the integrated potoroo plan of management	❑ Approval of Tugun Bypass 21st Dec. 2006 – 16th Feb. 2007	❑ 5th June 2007 ❑ Revised 9th April 2008 and 6th March 2009	❑ DMR/RTA
Boyd Street Overpass (Culvert and Bridge Span)	❑ 1 x dedicated fauna culvert ❑ 1 x bridge span to reinstate drainage flow	❑ Approval of Boyd Street Overpass (13th Feb. 2007)	❑ June 2008	❑ DMR Construct ❑ TSC to maintain
Boyd Street Extension Culverts (Dedicated, Multiuse, Drainage)	❑ 2 x dedicated fauna culvert ❑ 4 x multiuse culverts ❑ 1 x drainage culvert	❑ Anticipated 2010	❑ Anticipated 2010-2012	❑ LEDA Construct and Maintain
Fauna Exclusion Fencing	❑ 1600 m fauna exclusion fence along Pacific Highway	❑ 21st Dec. 2006 – 16th Feb. 2007	❑ June2008	❑ DMR Construct and Maintain in NSW (10 years)
	❑ 480 m fauna exclusion fencing for Boyd Street overpass	❑ Approval of Boyd Street Overpass (13th Feb. 2007)	❑ June 2008	❑ DMR to construct ❑ TSC to maintain
	❑ 2300 m fauna exclusion fence along Boyd Street Extension and around potoroo habitat	❑ Anticipated 2010	❑ Anticipated 2010-2012	❑ LEDA Construct and Maintain*
Relocate Bikeway	❑ Relocate 650 m of bikeway along Boyd Street so that it abuts the roadway	❑ Anticipated 2010	❑ Anticipated 2010-2012	❑ LEDA Construct and Maintain*
Revegetation	❑ Tugun Bypass Adjacent Known Potoroo habitat (as per prescribing planting schedule)	❑ 21st Dec. 2006 and 16th Feb. 2007	❑ June 2008	❑ DMR Construct and Maintain in NSW (10 years)
	❑ Boyd Street Overpass (as per prescribing planting and habitat augmentation schedule)	❑ 13th Feb. 2007	❑ June 2008	❑ DMR to Construct ❑ TSC to maintain
	❑ Boyd Street Extension (as per prescribing planting and habitat augmentation schedule)	❑ Anticipated 2010	❑ Anticipated 2010-2012	❑ LEDA Construct and Maintain*

Action	Number	Commencement	Completion	Commitment/ Responsibility
Implementation and Monitoring of Mitigation Measures	❑ Implement baseline surveys for potoroo	❑ Baseline surveys completed in 2003 (Bali *et al.* 2003)	❑ 2003	❑ DMR
	❑ Implement a biannual trapping and monitoring program	❑ 2010(1)	❑ Up to a maximum of 5 years	❑ DMR and LEDA for duration of plan: 5yrs
	❑ Habitat surveys at years 1, 3 and 5.	❑ Upon completion of ALL mitigation structures: fauna underpass culverts, fauna exclusion fencing, revegetation works	❑ Year 5 of plan	❑ DMR and LEDA for duration of plan: 5yrs
	❑ Implementation of fire management plan	❑ 2010	❑ Ongoing	❑ Coordinated by RTA and DMR in consultation with DECC (NPWS) and QPWS, and undertaken by RFS (QLD/NSW) or NPWS
	❑ Implement exotic predator control program	❑ 2010	❑ Ongoing	❑ DMR and LEDA for duration of plan: 5yrs. Also RLPB
Public Review	❑ Provision for public review after 5 yrs	❑ 2014	❑ Six months prior to end of year five	❑ Coordinated by RTA and DMR

Note: (1) Culvert will commence upon the construction of all fauna underpasses and associated exclusion fencing and revegetation works.
(*) Maintenance handover from Leda to Tweed Shire Council. Tweed Shire Council to confirm timeframe.

9.0 REPORTING REQUIREMENTS

Reporting will be undertaken as outlined below in Table 14. it includes a comprehensive end of year report detailing and interpreting the results for each of the monitoring components for the past 12 months, and a mid year summary (data only) for the preceding 6 months. The comprehensive report will be issued within 12 weeks of the completion of November monitoring and the mid year summary issued within 8 weeks of the completion of May monitoring (*see* Table 14).

Review of monitoring results would be undertaken in consideration of performance measures and used in an adaptive management process. At the end of year 5 a summary report would be prepared and form the basis for public review. The annual report would be submitted to DMR, RTA and LEDA for distribution to other relevant stakeholders including but not limited to TSC, DECC and DEWR.

Table 14. Reporting requirements of the plan.

Reporting Year	Population Monitoring	Culvert Monitoring	Habitat Monitoring	Predator Control	Road strike Monitoring	Fauna Fence Monitoring	Fire Management	Summary Report For Public review	Distribution
Brief Description	Trapping twice a year	Sand plots and infrared cameras	Quantitative monitoring program in three areas (i.e. north and south of Boyd St and regeneration area)	Once a year depending on performance, may be reduced to every second year. Includes all predator scat transects, culvert monitoring, den surveys)	Transects of Boyd Street and adjoining Pacific Highway undertaken quarterly in year 1 and biannually in years 2-5.	Transects of Boyd Street and adjoining Pacific Highway undertaken quarterly in year 1 and biannually in years 2-5. Also undertaken following major storm events.	Part of yearly report detailing and assessing prescribed and un-prescribed fires	Collaborate on 5 years of management	
2010	√	√[1]	√	√	√	√	√		DMR; RTA; TSC, LEDA, DoP, DEWR
2011	√	√[1]		√	√	√			DMR; RTA; TSC, LEDA, DoP, DEWR
2012	√	√[1]	√	√	√	√	√		DMR; RTA; TSC, LEDA, DoP, DEWR
2013	√	√[1]		√	√	√			DMR; RTA; TSC, LEDA, DoP, DEWR
2014	√	√[1]	√	√	√	√		√	DMR; RTA; TSC, LEDA, DoP, DEWR

Note: (1) Monitoring and management actions to commence once the construction of all fauna underpasses, fauna exclusion fencing and revegetation works have been completed.

10.0 ADDITIONAL REQUIREMENTS

10.1 SURVEY AND MONITORING PERSONNEL

In order to ensure the monitoring and the data collected is undertaken in a robust manner, the company and/or its representative must have demonstrated ability in all aspects in which they are to be engaged. This includes at least 10 years experience in vertebrate fauna surveys for field staff, have experience in statistical analysis and the ability to interpret and translate meaningful relationships within. The person/company undertaking the work would also be endorsed by the DEWR/DEHWA.

10.2 DESIGN CHANGES AND AMENDMENTS

This plan does not address any additional infrastructure associated with either Boyd Street (2 lanes increasing to four) or its overpass and any need arising to construct north or south bound interchanges. Any further amendments to the current design would require re-appraisal of this plan as they may jeopardise the current mitigation and monitoring measures. Similarly, the failure to adopt the repositioning of the bikeway would require a review of the current culvert designs and may include the need for an elevated road way in the vicinity of the drainage lines to encourage potoroo movement.

11.0 CONCLUSION

This integrated potoroo plan of management has proposed a series of management actions and a monitoring program designed to evaluate the effectiveness of offsetting impacts for the Tugun Bypass Project, the construction of Boyd Street and its overpass along with the cumulative impacts arising from them over the next 5 years. It has assessed the population in a pre development capacity to accurately define its current distribution, preferred habitat, its population size and demographic structure and identified existing and likely threats to the population including but not limited to habitat fragmentation, wildfire, further edge affects and predatory pressures from exotic fauna and domestic pets. Some of these threats have been initially addressed through footprint realignments for the Tugun Bypass and reduced construction footprints for both Boyd Street projects and the current document provides the framework to address these threats further through a series of management actions centred around fauna exclusion fencing, the construction of specific and multiuse culverts, predator control programs, implementation of a fire management plan and revegetation works. The detailed monitoring program would measure and assess the performance of each management action on a yearly basis and present an annual report from which stakeholder groups can gauge their progress and usefulness. The endorsement of this plan would provide a sound basis for the long term management and conservation of this important population.

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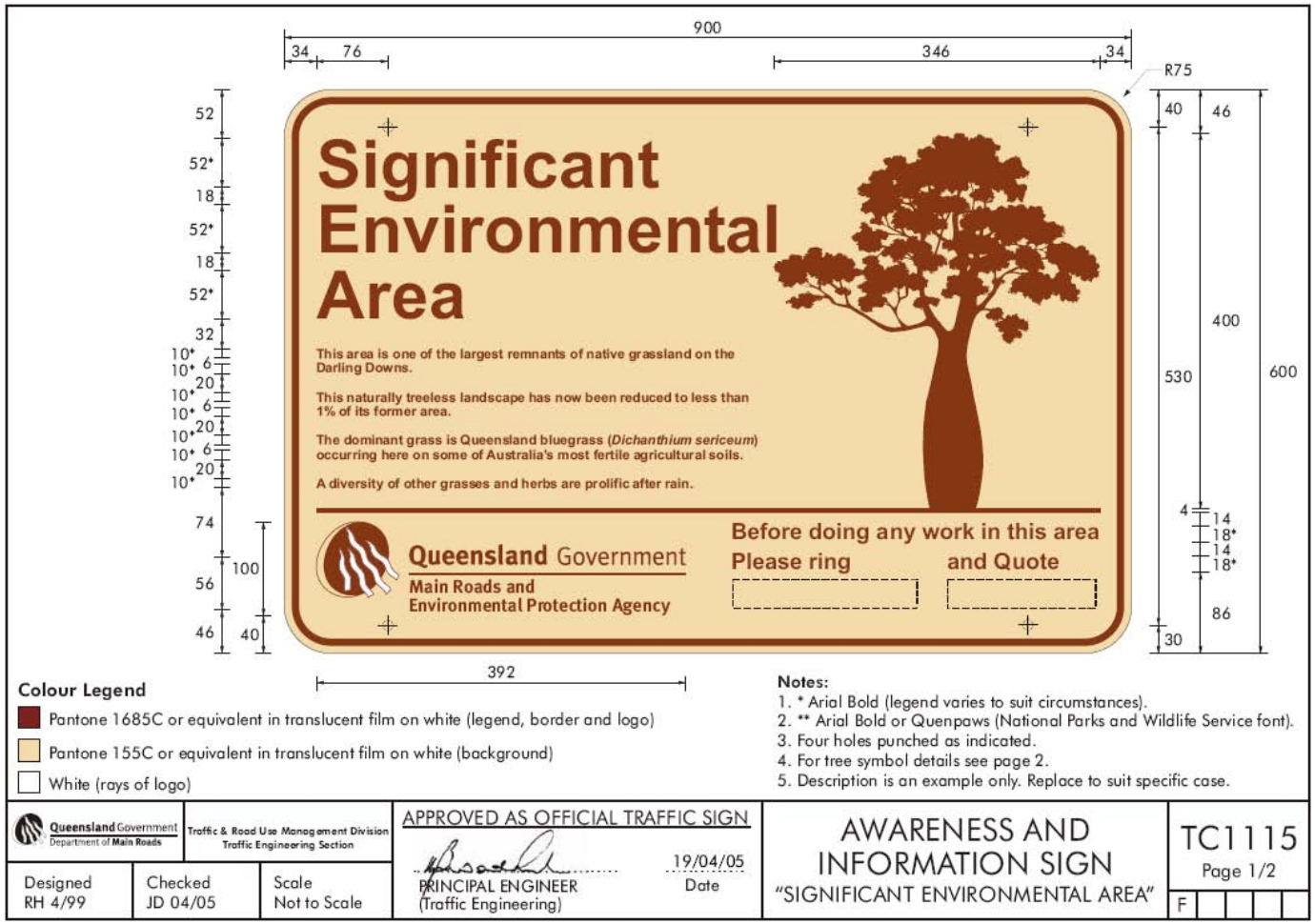
APPENDIX 1 – EXAMPLE OF PROPOSED SIGNAGE IN QLD ROAD RESERVE



APPENDIX 2 - LANDSCAPING FOR BOYD STREET OVERPASS

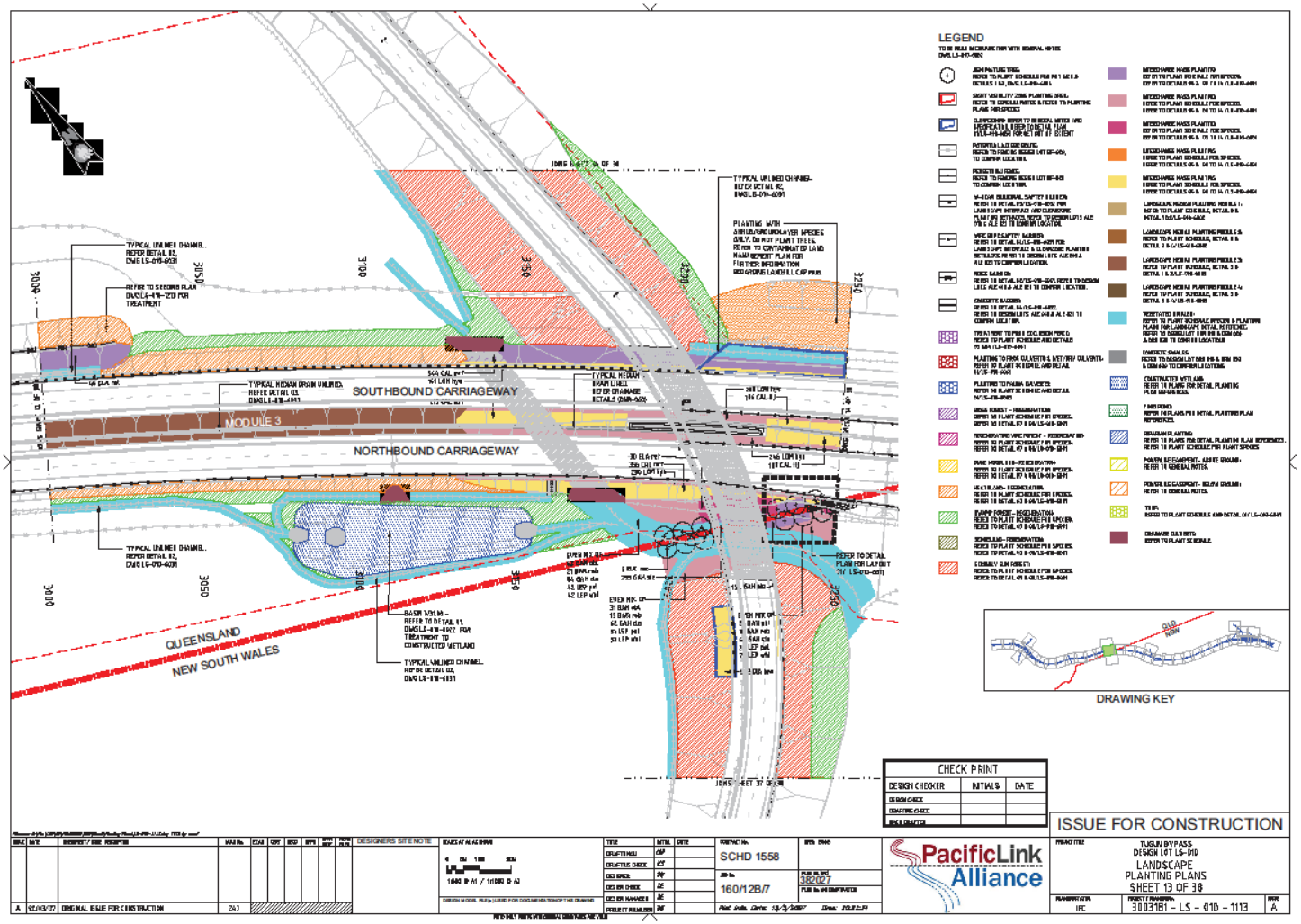


Figure A. Boyd Street Overpass centre

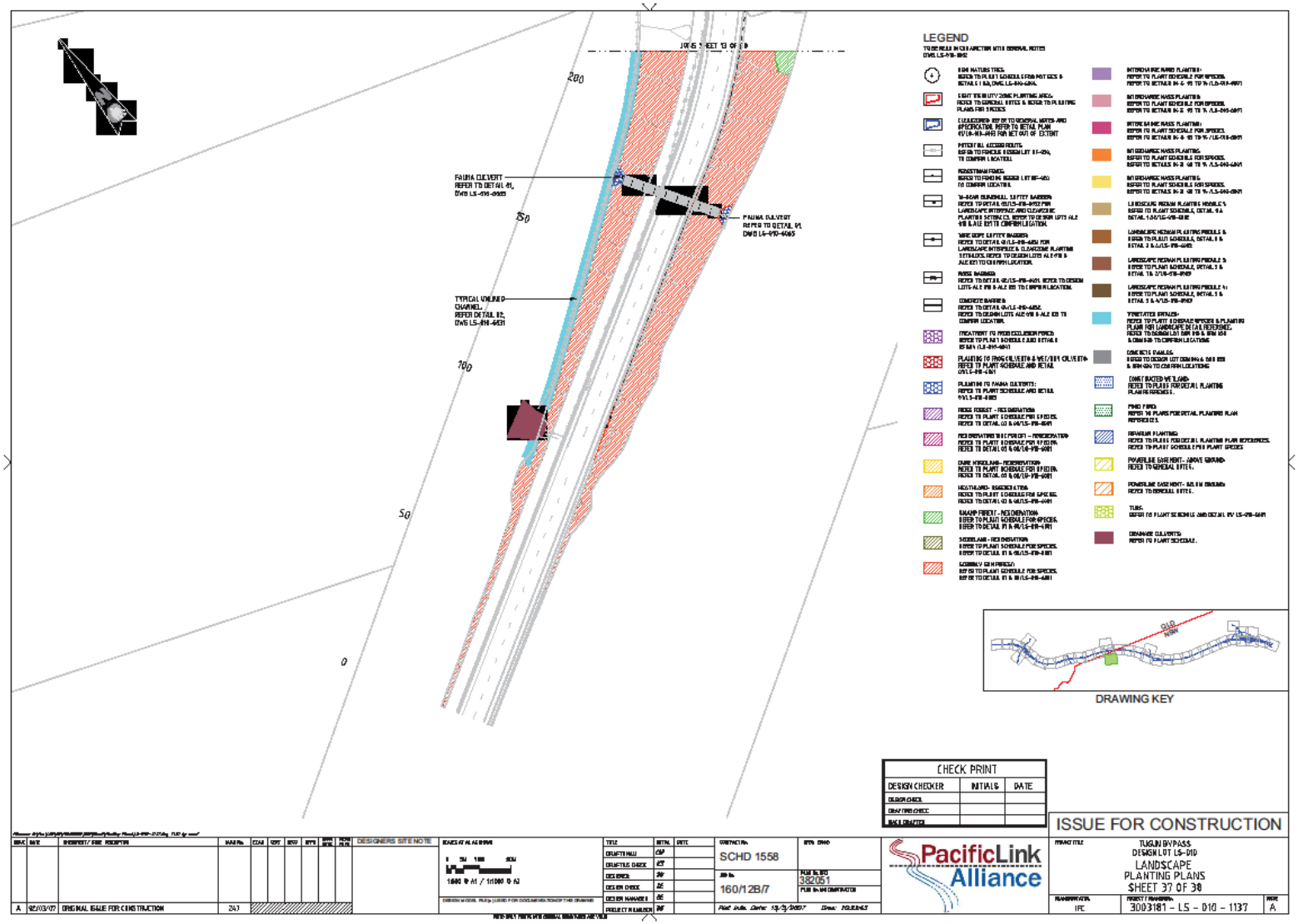


Figure B. Boyd Street Overpass west

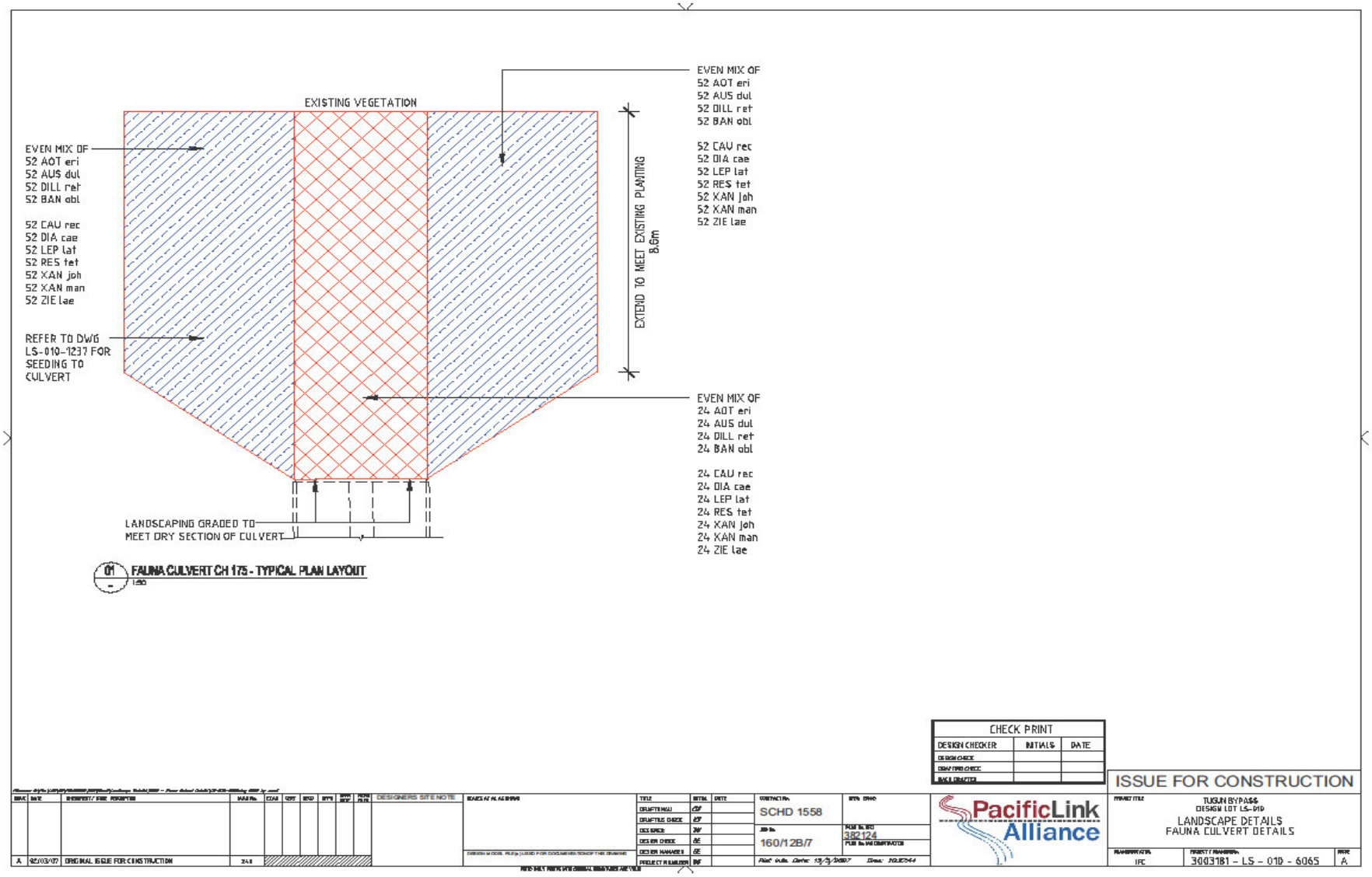


Figure C. Culvert treatment.

APPENDIX 3 – HABITAT AUGMENTATION

Below is habitat augmentation strategy for the revegetation areas adjacent to Boyd Street Overpass and Boyd Street Extension. The objective of this is to encourage cover dependant fauna including potoroo into the regeneration areas which will inturn encourage their use of other management actions including culverts. The use of large woody debris (200-600 mm diameter x 1.0-3.0 m) will also discourage the use of these areas by bikes and pedestrians and provide greater definition of maintenance areas to site staff (i.e. not likely to undertake vegetation management works in these areas). The density and arrangement of the material is shown below and allows for 12 logs and 6 tree limbs on either side of the Boyd Street Overpass at intervals of 8-15 m apart. This approach should be adopted for Boyd Street Extension.

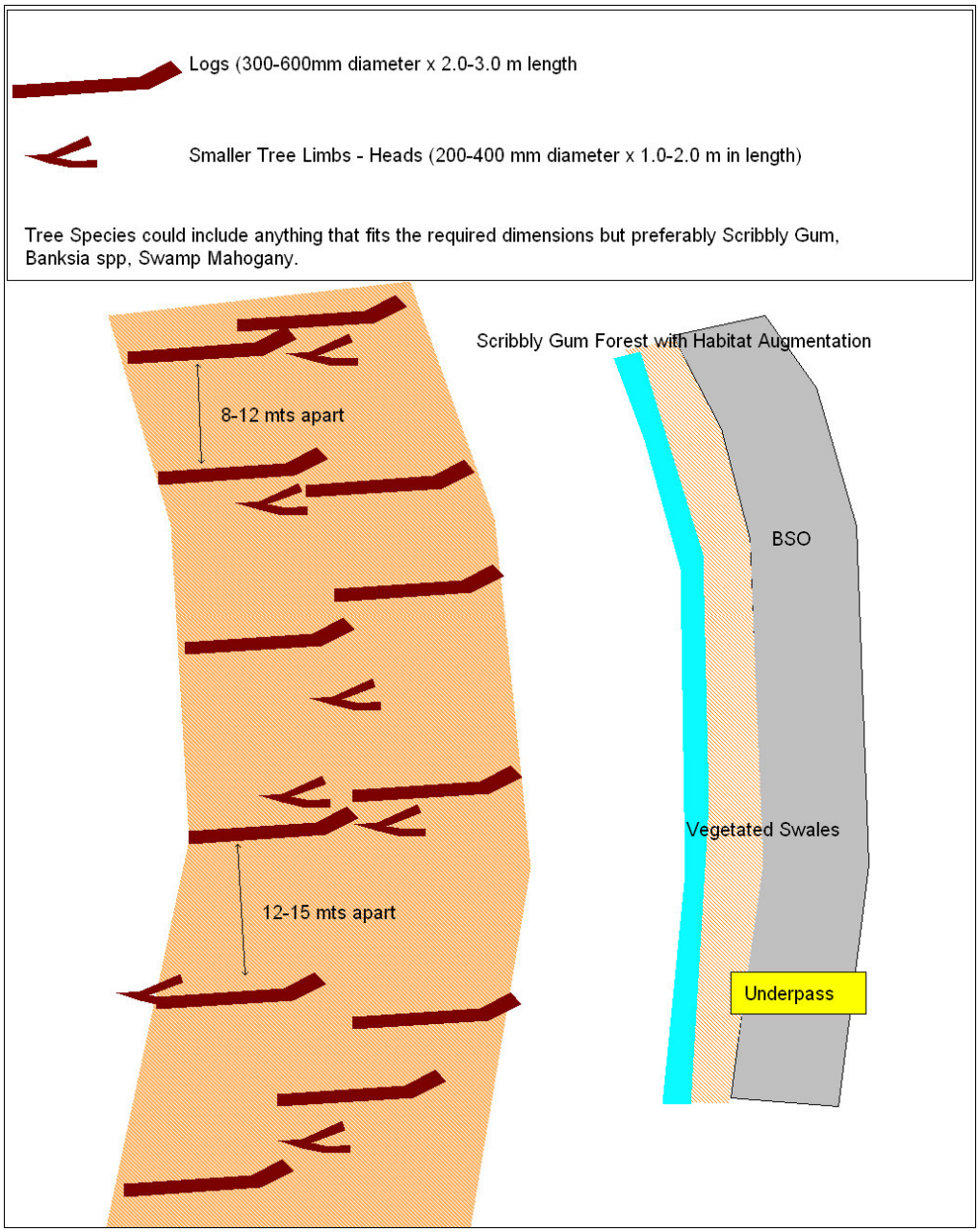


Figure D. Sketch of habitat augmentation strategy for Boyd Street overpass and extension.

APPENDIX 4 – FAUNA UNDERPASSES AND CONSTRUCTION DESIGN

Table A. Summary of fauna underpasses Long Nosed Potoroo are thought to have used along the Pacific Highway, NSW (Source: AMBS 2001a,b,c and 2002).

Site	Underpass Reference No	Height	Width	Length	Openness ratio (WxL/H)	Vegetation Description Bordering Culvert		Fauna Exclusion Fencing		Floor Substrate	No. Records	No. Complete Passages
						East	West	East	West			
Bulahdelah-Coolongolook	BC11	3	3	51.98	51.98	Revegetation + weeds 30m	Grass 40m	Floppy Top Continuous	Floppy Top Continuous	Mud	9	9
	BC12	3	3	nd	nd	No data	No data	Floppy Top Continuous	Floppy Top Continuous	nd	1	1
	BC13	3	3	39.66	39.66	Grass + revegetation 20m	Reeds 5m	Floppy Top Continuous	Floppy Top Continuous	Mud	3	3
	BC17	3	3	39.68	39.68	Reeds + Long Grass 60m	Sparse Veg 20 m	Floppy Top Continuous	Floppy Top Continuous	Mulch	1	0
	BC19	3	3	39.66	39.66	Grass, Juncus, Native Plantings 40m	Grass, Juncus, Native Plantings 40m	Floppy Top Continuous	Floppy Top Continuous	Mulch	1	1
Brunswick Heads	B1	1.2	2.4	18	36	No data	Pastureland (Sataria & Molasses Grass)	Floppy Top Continuous	Floppy Top Continuous	Silt & Small Stones	1	1
	B5	1.2	2.4	18	36	No data	No data	Floppy Top Continuous	Floppy Top Continuous	Silt & Small Stones	1	1

Boyd Street Overpass Drawings

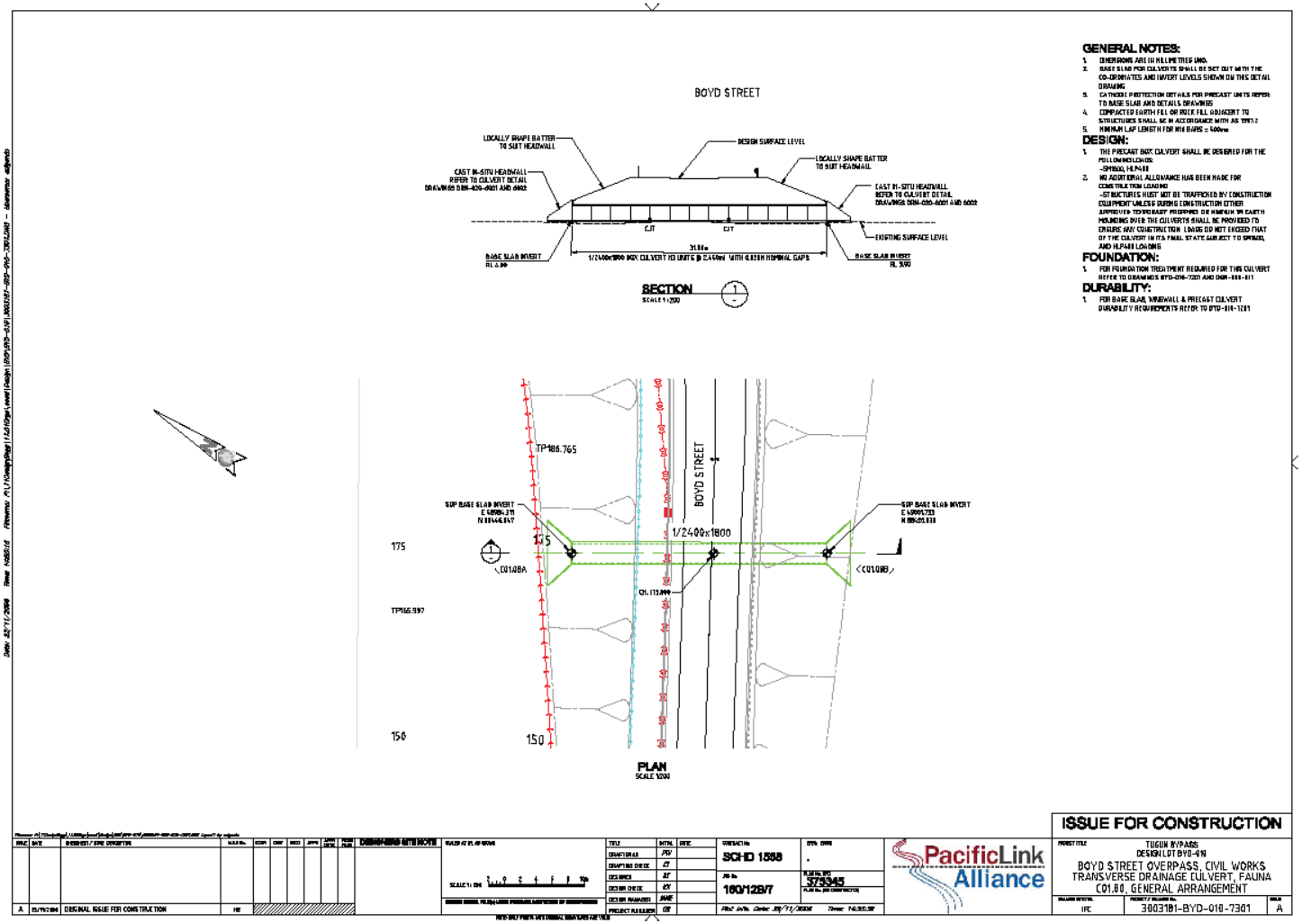


Figure E. Cross section view of fauna underpass for the Boyd Street Overpass (see attached).

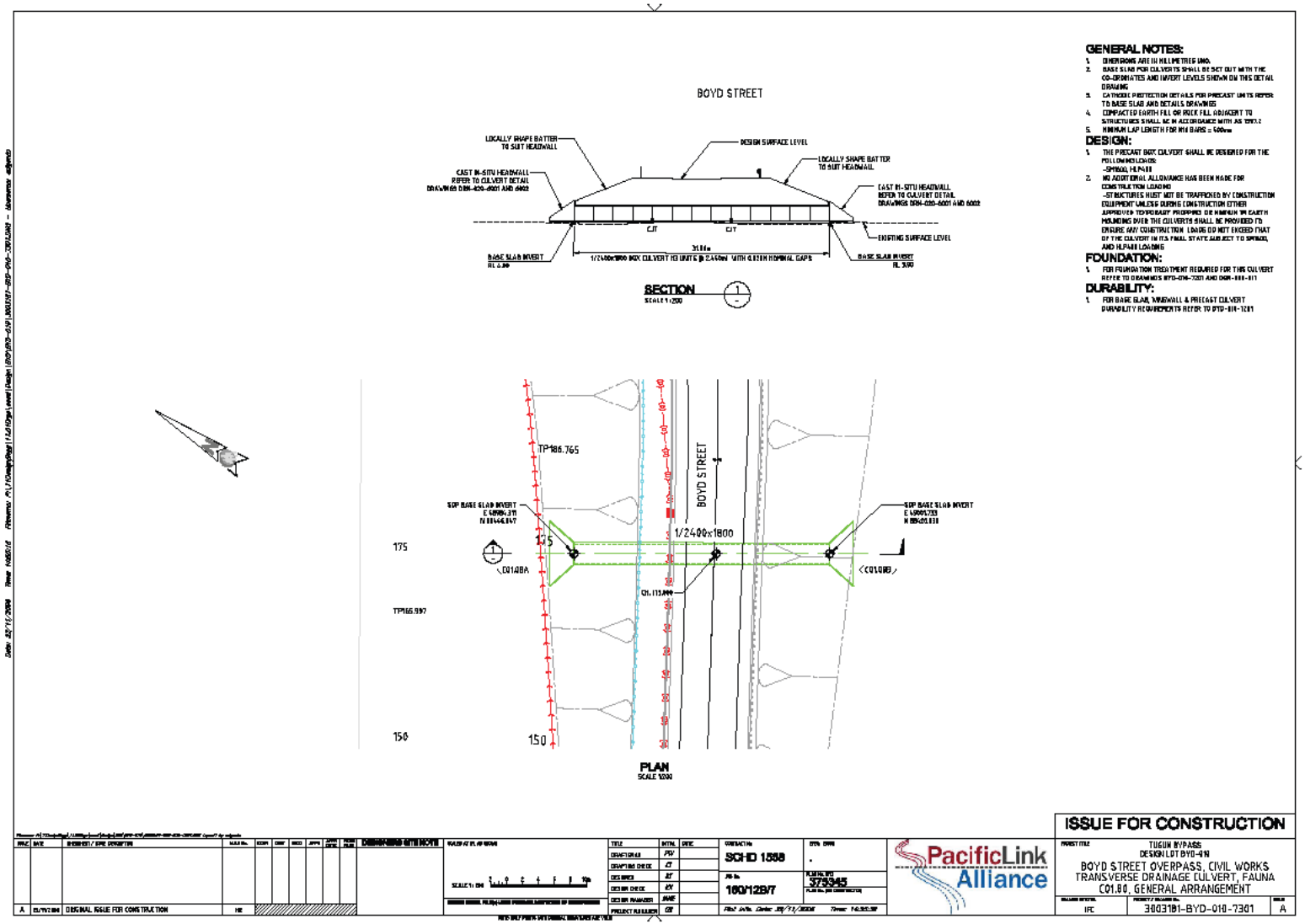


Figure F. Construction design drawing for the Boyd Street Overpass including arrangement of furniture.

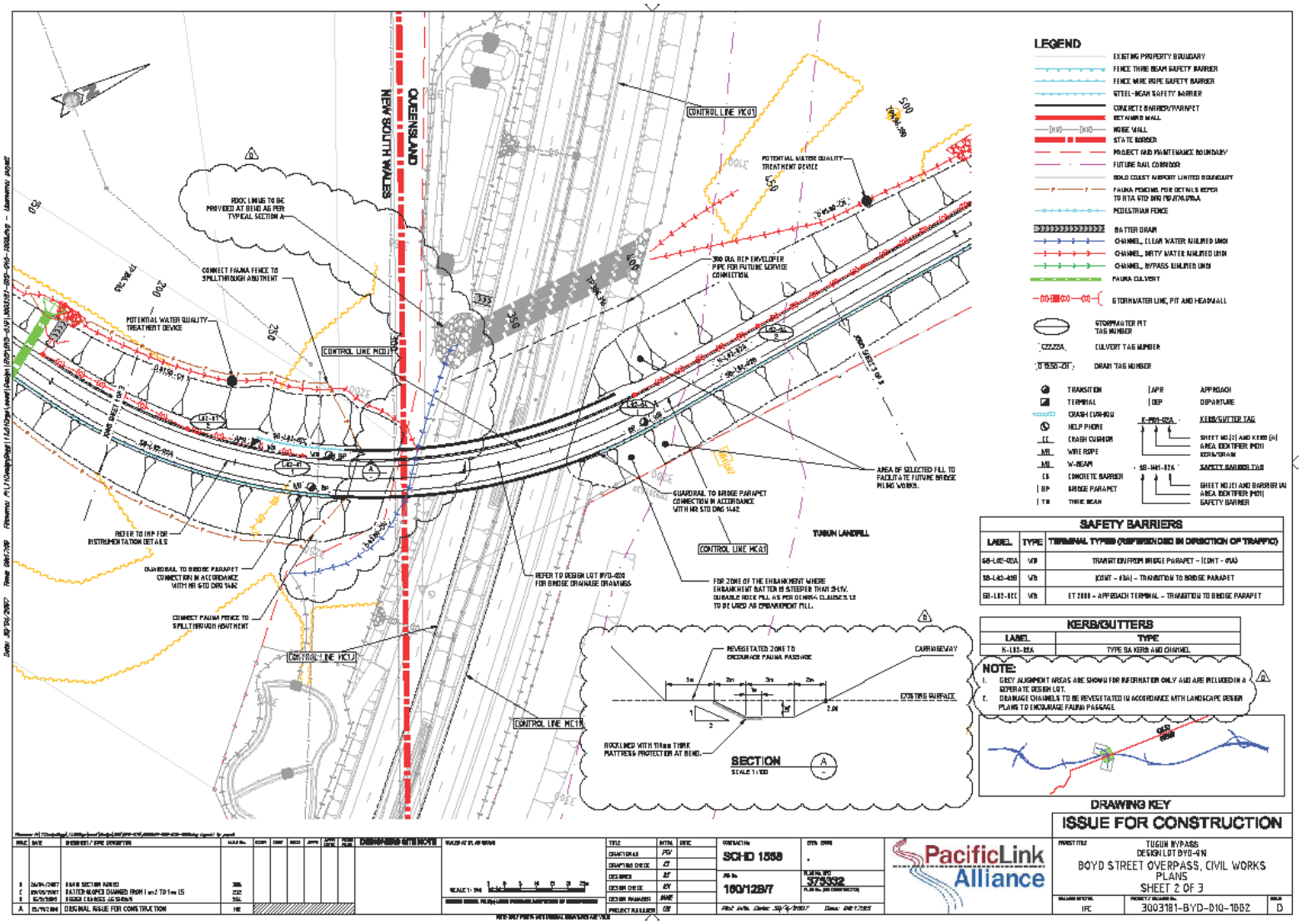


Figure G. Boyd Street layout centre (see attached).

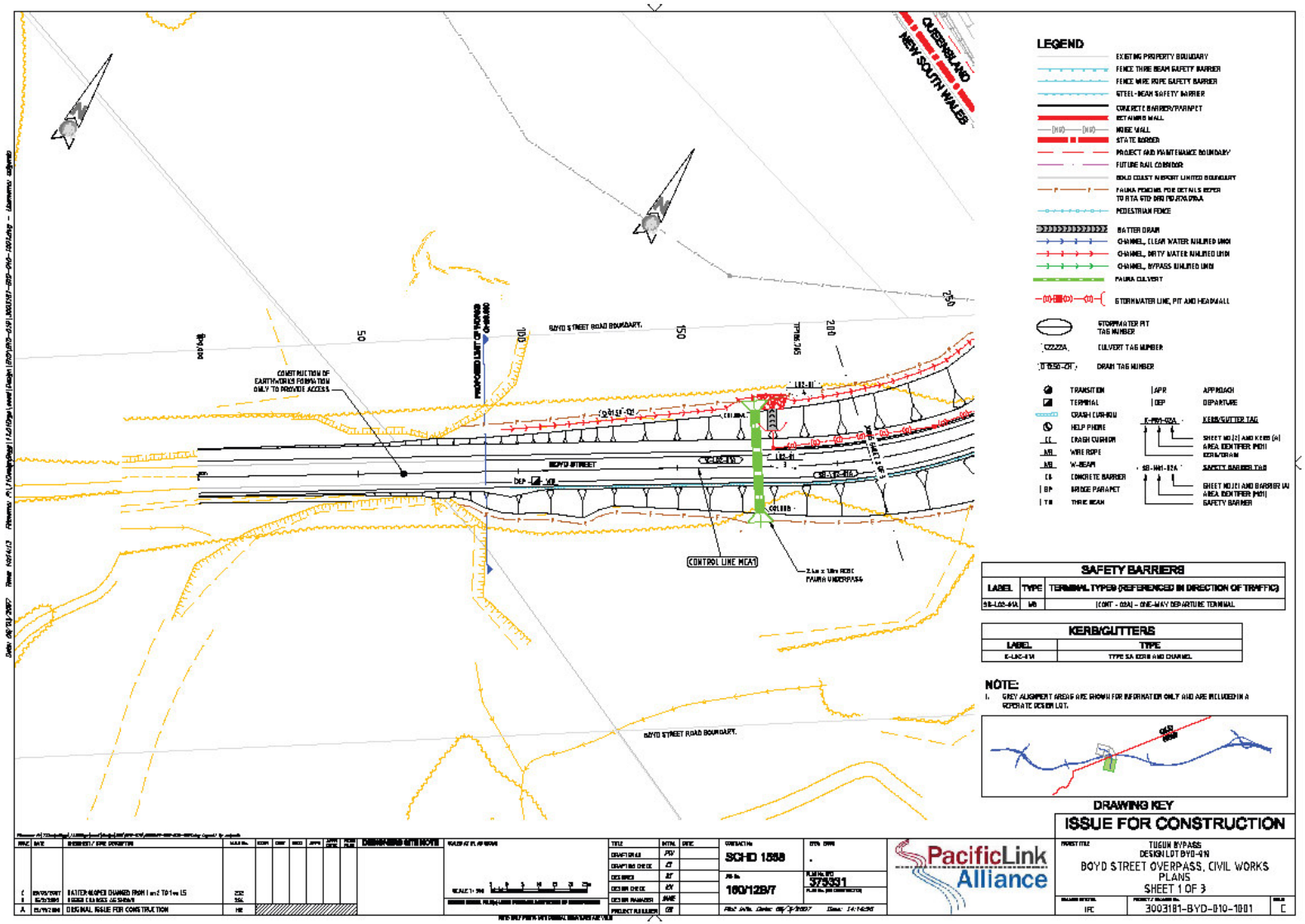


Figure H. Boyd Street layout west.

APPENDIX 5 – FAUNA EXCLUSION FENCING

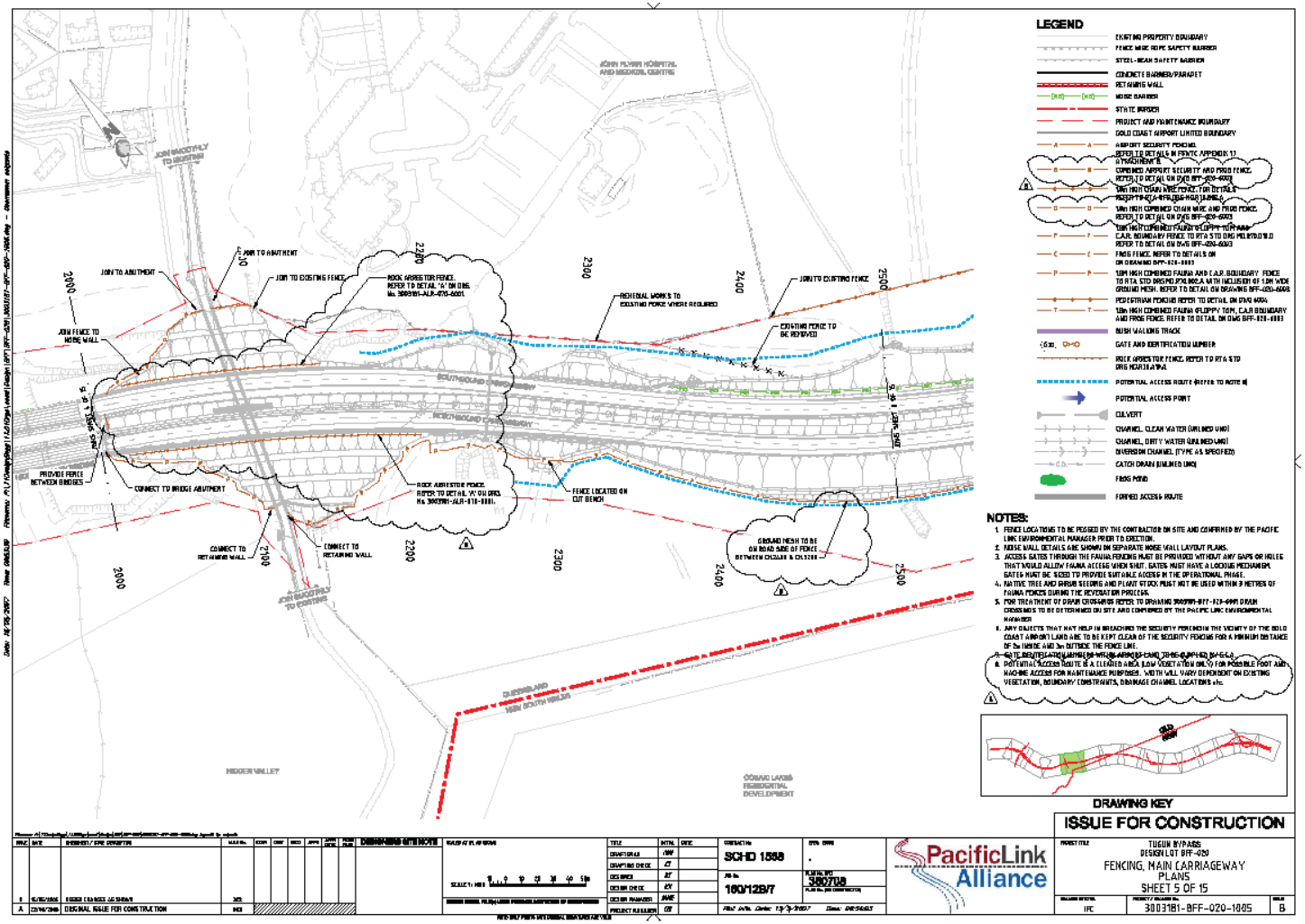


Figure 1. Fauna exclusion fencing in the vicinity of Tugun Bypass Project.

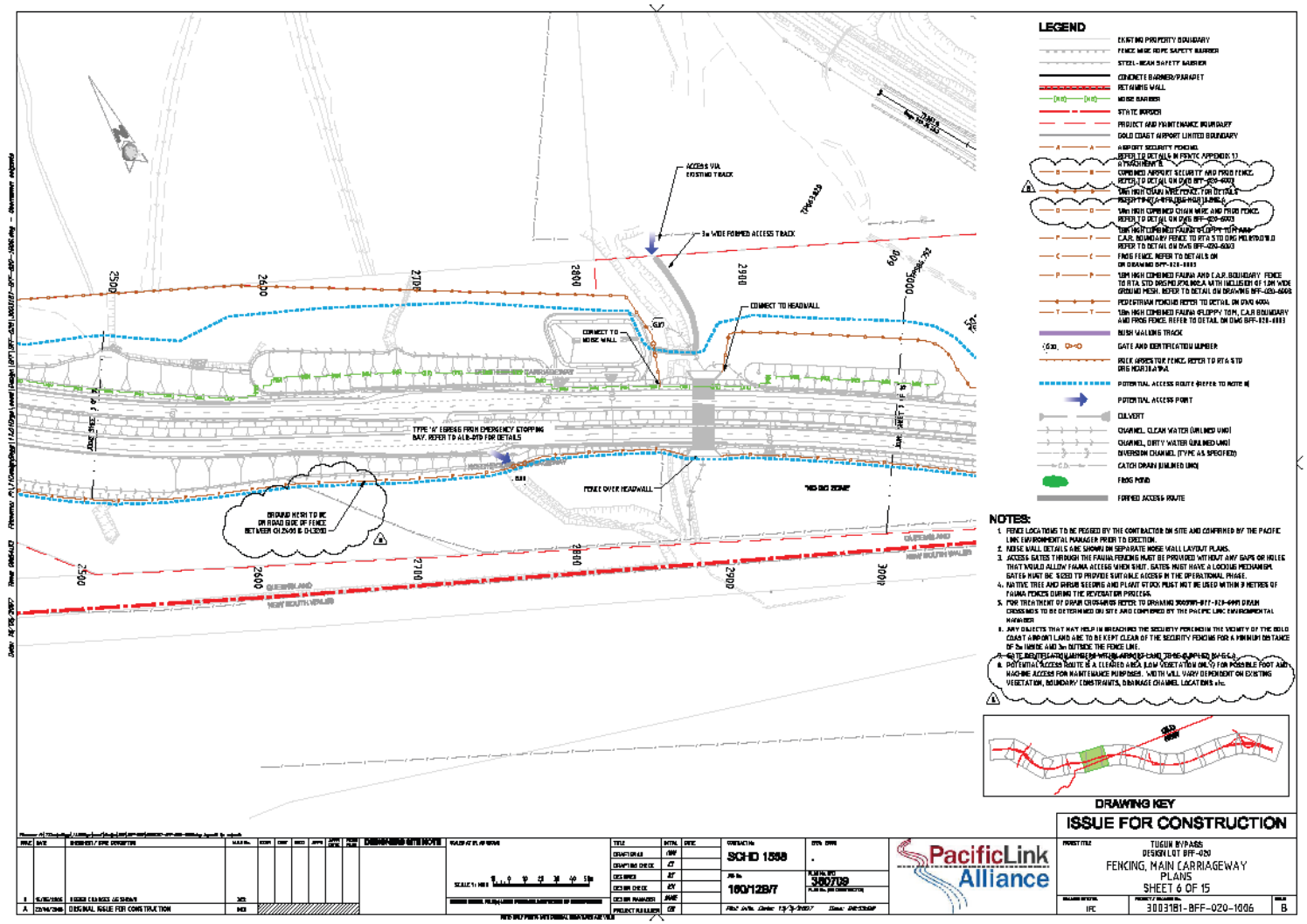


Figure J. Fauna exclusion fencing in the vicinity of Boyd Street Overpass Ch. 2500-3000.

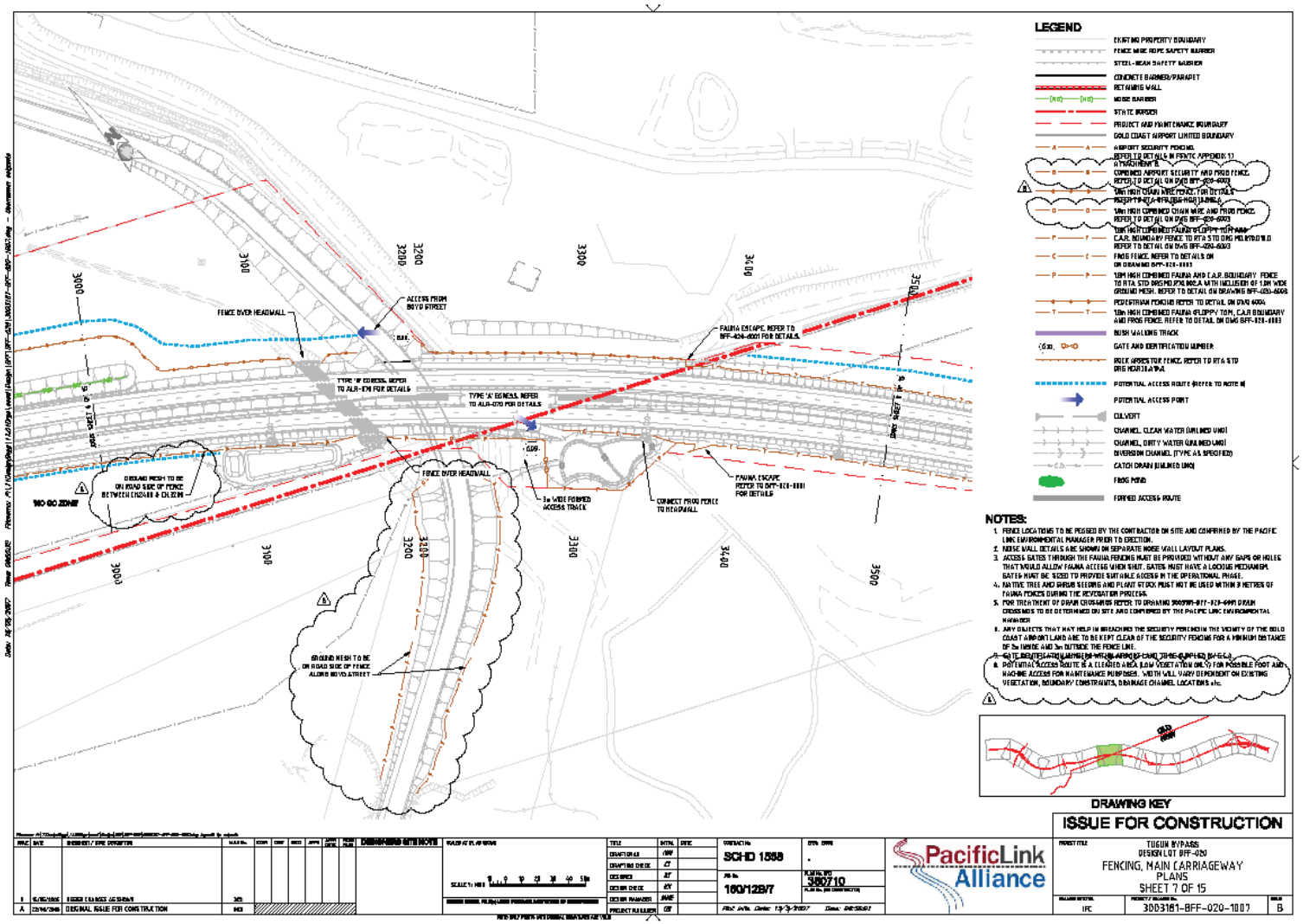


Figure K. Fauna exclusion fencing in the vicinity of Boyd Street Overpass Ch. 3000-3500.

APPENDIX 6 – PREDATOR CONTROL PROGRAM SCHEDULE

Table B. Schedule for predator management, including pre-control monitoring, 1080 baiting and den fumigation.

Activity/ Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Clean Bait Stations	X	X	X	X	X	X	X														
Den Search Transects							X														
Track/ Scat Transects	X						X							X							X
Install 1080 warning signs							X														
Baiting with 1080								X		X		X		X		X		X		X	
Den fumigation								X	X												
Site Clean-up																					X

APPENDIX 7 – PROPOSED FIRE REGIME

Proposed fire regime for known potoroo habitat, 2010 to 2024. Showing year of proposed burn and the 4 year post-burn period.

Table C. Proposed fire regime for known potoroo habitat over the 15 year period 2010-2024. PoM = Plan of Management.
Note: parts of potoroo habitat have been previously fired in August 1991.
Fire precincts displayed in Figure 7 on page 29 with additional information in Table 6 on page 28.

Precinct	Area	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Year Plan for Potoroo PoM		1	2	3	4	5										
Northern Side Boyd Street																
A	2.3			Burn	Year 1	Year 2	Year 3	Year 4								
B	2.6										Burn	Year 1	Year 2	Year 3	Year 4	
C	5.2	Burn	Year 1	Year 2	Year 3	Year 4										
D	2.3							Burn	Year 1	Year 2	Year 3	Year 4				
Southern Side Boyd Street																
E	1.4			Burn	Year 1	Year 2	Year 3	Year 4								
F	6.9			Burn	Year 1	Year 2	Year 3	Year 4								
G	0.9					Burn	Year 1	Year 2	Year 3	Year 4						
H	13.0					Burn	Year 1	Year 2	Year 3	Year 4						
I	13.0							Burn	Year 1	Year 2	Year 3	Year 4				
J	13.7					Burn	Year 1	Year 2	Year 3	Year 4						
K	32.0	Burn	Year 1	Year 2	Year 3	Year 4										

APPENDIX 8 – ROAD KILL TRANSECT PROFORMA

A – Boyd Street; Pacific Highway North (north of Boyd Street Overpass) and Pacific Highway South (south of Boyd Street Overpass).
B – Non-flying Mammal, Flying Mammal, Bird, Frog, Reptile.
C - 1 = past 12 hrs 2 = 12-72 hrs 3 = >72 hrs.

Date		Location[A]		Start Time		Finish Time		
Animal No.	Easting	Northing	Vertebrate Group[B]	Species	Sex (m/f/u)	Age (a, s/a, u)	~ Time Dead (1,2,3[C])	Comments
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

APPENDIX 9 – BRAUN – BLANQUET SCALE

Braun-Blanquet scale	Scale Cover %
5	~100
5	>75 but less than complete cover
4	50-75
3	33-50
3	25-33
2	10-25
2	5-10
1	1-5
1	<1
+1	<<1 (seldom, insignificant cover)
r	<<<1 (solitary, insignificant cover)

Cover-Abundance Scales

Vegetation description, and surveys of fauna and habitat often require an estimation of **species quantities**. Authors sometimes use terms of **relative magnitude** (very rare, rare, uncommon, moderately common, ...), **code values** (0, 1, 2, ...), **densities** (number of individuals per unit area), or **frequencies** (number of times a species is found in a set of samples). Special problems arise when trying to estimate plant quantities. Individuals may be difficult to delimit (as with bracken and couch grass). Counting individuals may be misleading; one moss plant is considerably smaller than a Mountain Ash and will have quite a different impact on the surrounding organisms and microclimate. Relative magnitude is imprecise. The **Cover-Abundance Scale** is one way of quantifying plants that sidesteps these difficulties. A set of absolute scale values is divided into intervals that represent the cover provided by a plant species, stratum or community. The cover of a given item is estimated as falling into one interval from the scale. This method requires much less time than detailed counts. It can be applied to communities of vascular plants, as well as most bryophyte and lichen communities.