



Roads in Rainforest:

Best Practice Guidelines for planning, design and management

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Part B: Roads in Rainforest: Science Behind the Guidelines Separate Report Enclosed

These Guidelines were developed as a framework for understanding the primary ecological issues to be addressed in the planning, design and management of roads in rainforest environments. The science supporting the development of these Guidelines is detailed in Part B – *Science Behind the Guidelines*.



Photo: Robyn Wilson

1. Introduction

1.1 Department of Transport and Main Roads: Commitment to Best Practice

These Guidelines were developed as a framework for understanding the primary ecological issues to be addressed in the planning, design and management of roads in rainforest environments. This document contains updated information that supplements the 1997 *Roads in the Wet Tropics* manual produced by the then Queensland Department of Main Roads in collaboration with the Rainforest Cooperative Research Centre (CRC). The Rainforest Cooperative Research Centre and the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF), in collaboration with the Queensland Department of Transport and Main Roads (TMR), have conducted an extensive applied research program into roads and other linear infrastructure in relation to their impacts on tropical rainforest environments. This growing body of knowledge has provided a basis for improving the best practice approaches for minimising and mitigating impacts of roads in tropical forests of Queensland. This revision includes practices applicable to all rainforests throughout the State, with most principles also applying to other closed and open forest habitats.

The Department of Transport and Main Roads' vision of 'Connecting Queensland' is guided by the Strategic Purpose to 'Plan, manage and oversee the delivery of a safe, efficient and integrated transport system that supports sustainable economic, social and environmental outcomes in Queensland' (TMR Corporate Plan 2009-2013¹). Of particular interest to this manual, the Strategic Purpose of the TMR Corporate Plan supports the Queensland Government's 'Green' objective of 'Protecting our lifestyle and environment'.

The Main Roads Environment and Heritage Policy and Strategy 2008-2013 (in the absence of a TMR policy at the time of publication) provides the Vision that 'environmental and heritage values associated with Queensland's State-controlled road network are recognised for their importance and are respected'. Further, TMR 'will manage road impacts on natural, human and cultural environments by:

- 'Meeting statutory obligations of all relevant environmental and heritage legislation as a minimum standard;
- 'Considering the effects on stakeholder and long-term relationships when carrying out statutory obligations, and seeking feedback on our performance;
- 'Acting as a good government agency and adopting a proactive approach to environmental and heritage management;
- 'Improving awareness of environmental and heritage management processes, standards and responsibilities among Main Roads employees and contractors; and
- 'Ensuring Main Roads' approach to the management of environmental and heritage impacts embrace the hierarchy of 'avoid, minimise, mitigate' in a financially feasible manner.'



Planning route corridors in rainforests poses many challenges.

¹ <http://www.tmr.qld.gov.au/about-us/corporate-information/publications/corporate-plan.aspx>

Our impacts on the natural environment are important considerations for the operation and planning of our road system because they affect our well being in the long term. The planning process for new or improved road infrastructure should consider the ultimate design standard of the road, because incremental upgrading can often lead to greater environmental impacts as well as poor road engineering. For example, a road upgraded to three lanes and then four lanes as traffic increases may have a greater negative environmental impact than a well-designed split dual carriageway. The planning of road corridors should protect the integrity of plant and animal communities and consider the long term benefits associated with their conservation.



Roads through the rainforest can be planned to minimise impacts to the environment.

This manual has been created to assist in reducing the main impacts of roads, which are primarily:

- Habitat loss and fragmentation;
- Reduction in habitat quality;
- Edge effects;
- Reduced animal movements, resulting in restricted genetic flows and diminished survival rates in some species;
- Population reduction through road kill of wildlife species;
- Erosion, sedimentation and pollution;
- Impacts on scenic quality;
- Disturbance from vehicular noise, headlights and movement;
- Facilitation of the spread of exotic pests, weeds and diseases; and
- Direct mortality from road construction activities.

Cumulatively, these impacts threaten the biodiversity and integrity of ecosystem processes throughout Queensland's tropical forests. It is therefore imperative that current and future road infrastructure be designed with consideration of these factors within the context of the natural environment. The rainforest environment and key impacts from roads are briefly described in Section 1.4 *Background* (these Guidelines).

1.2 Objectives of these Guidelines

This document provides a set of principles and supporting guidelines for implementing best practice planning, design and management for ecologically sustainable roads within rainforests throughout Queensland. The intention of these Guidelines is to describe the particular aspects of rainforest environments that are unique and thus require particular consideration when designing and constructing roads in these habitats. Importantly, these key values, which will be further described in the Principles (Section 2, these Guidelines), require rainforest-specific planning and design strategies that minimise and mitigate any significant impacts from road building.

Therefore, these Guidelines have been specifically developed to:

- **Inform** planners, engineers and managers about the key ecological elements (Principles) to consider when building roads in rainforest environments;
- **Identify** the most important issues to consider when planning, designing and implementing plans for road infrastructure so that the impacts to the primary ecological elements of rainforests are minimised. Each major issue is clarified within its own 'Guideline'; and
- **Provide a set of steps and checklists** within each Guideline to ensure that the core Principles are maintained throughout the different phases of planning, design and construction.

This manual does not replace design standards nor other manuals and standards for engineering design and construction and environmental management (such as Erosion and Sediment Control or Drainage). In fact, these Guidelines should be read in the context of the various Manuals and Standards published by Austroads and the Queensland Department of Transport and Main Roads (TMR). For example, the TMR 'Road Project Environmental Processes Manual' (May 2004 or current edition) contains environmental assessment and management processes and relevant legislation, and therefore its contents are only referred to in these Guidelines.

Relevant TMR manuals and documents to be consulted² include the:

- Road Project Environmental Processes Manual;
- Environmental Legislation Register;
- Road Landscape Manual;
- Pest Management Strategy;
- Environmental and Heritage Policy and Strategy, recent edition;
- Fauna Sensitive Road Design Volumes 1 and 2; and
- Road Drainage Design Manual.

In order to ensure consistency in the application of current legislative policies and administrative procedures, these Guidelines have been reviewed by the Queensland Department of Environment and Resource Management and the Wet Tropics Management Authority. However, new and amended policies are continually being introduced, so it is incumbent upon the user to contact a TMR environmental officer and, if necessary, the appropriate agency, when undertaking environmental processes, or when uncertainty about a particular situation is encountered.

² These documents available for download:
<http://www.mainroads.qld.gov.au/en/business-and-industry/road-builders/technical-publications>

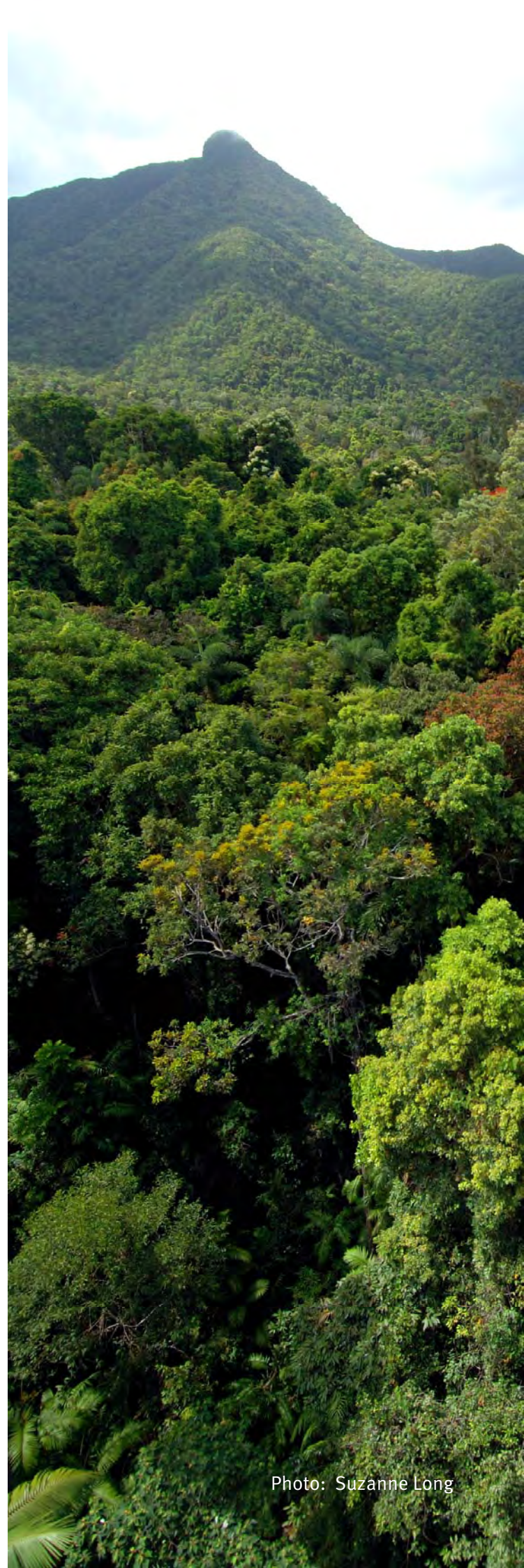


Photo: Suzanne Long

1.3 How to use these Guidelines

The Guidelines have been developed with the Queensland Department of Transport and Main Roads user in mind, so that the broader context (Principles) can first be understood and users can then go directly to the specific phase of road development that concerns their project (Planning, Design and Management). Often, it will be useful to read all guidelines within a particular section, particularly if the manual is consulted for the first time. There may also be relevant information in other sections.

Further, inter-related Guidelines refer to each other and it is important to read these as a 'suite' to ensure a thorough understanding of the issue and all potential solutions.

When Using this Manual:

1. Read the Overview Chart to clarify the key issues for your project.
2. Read ALL Principles for ALL road infrastructure phases.
3. Refer to the Guidelines within the road infrastructure phase relevant to you.
4. Refer to additional material recommended within the Guidelines relevant to you.
5. Contact the project environmental officer if further clarification/advice is required.

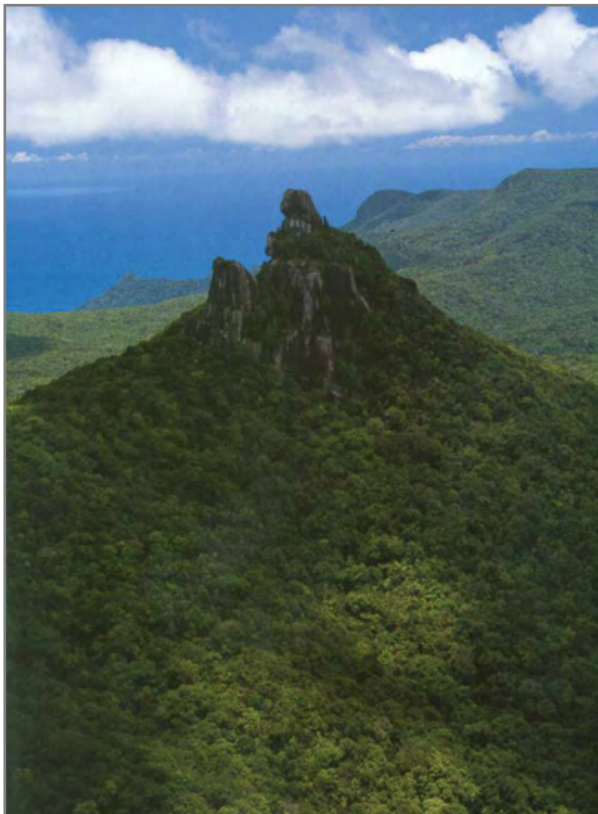
Overview Chart

Phase	Principles	Guidelines
Plan	R1) Preserve and Value Sensitive Ecosystems R2) Maintain Plant and Animal Populations R3) Ensure Catchment Integrity	P1) Understand Ecological Values of Road Corridor P2) Balance Transport and Environmental Objectives P3) Minimise Impacts to Environmental Values P4) Mitigate and Offset Significant Impacts P5) Showcase Natural Values
Design	R4) Reduce Edge Effects R5) Promote Habitat Corridors R6) Provide Canopy Connectivity	D1) Assess Safety and Environmental Impact Trade-offs D2) Reduce Vegetation Loss and Minimise Edge Effects D3) Ensure Habitat Connectivity for Fauna Movement D4) Install Canopy Crossing Devices D5) Maintain Stream Integrity and Ensure Fish Passage
Manage	R7) Maintain Habitat Quality	M1) Reduce Erosion and Manage Sediment M2) Minimise Pollutants M3) Manage Disturbance to Prevent Spread of Diseases, Pests and Weeds M4) Manage Topsoil M5) Revegetate Disturbed Sites M6) Maintain and Monitor Ecological Works and Devices

1.4 Background

Rainforest Environments

Tropical rainforests have tremendous biological significance. They cover only seven per cent of the Earth's surface, yet contain more than half of the Earth's biodiversity (plant and animal species). Additionally, rainforests provide an immeasurable number of natural ecosystem services, such as maintaining soil stability, providing clean air and water, and acting as a source for new pharmaceuticals.



Queensland's tropical forests and rainforests contain incredible biodiversity. They include two rainforest World Heritage Areas (the Wet Tropics and CERRA) and forest areas from as far north as the Iron Range National Park, on Cape York, south to the New South Wales border (Photo: WTMA).

About one-third of the world's population lives in regions containing tropical rainforest. These ecosystems are generally facing enormous pressures from commercial logging and changes in land use from forest to pasture, agriculture and urban areas. Lowland forests and easily accessible areas are being cleared first.

Australia contains a very small proportion of the planet's rainforest but it has a high number of species found nowhere else on earth. Scientists propose that the large diversity of plants and animals may be due to prehistoric climatic cycles of global freezing and warming. As a result, Australia has numerous small areas of unique vegetation and habitat.

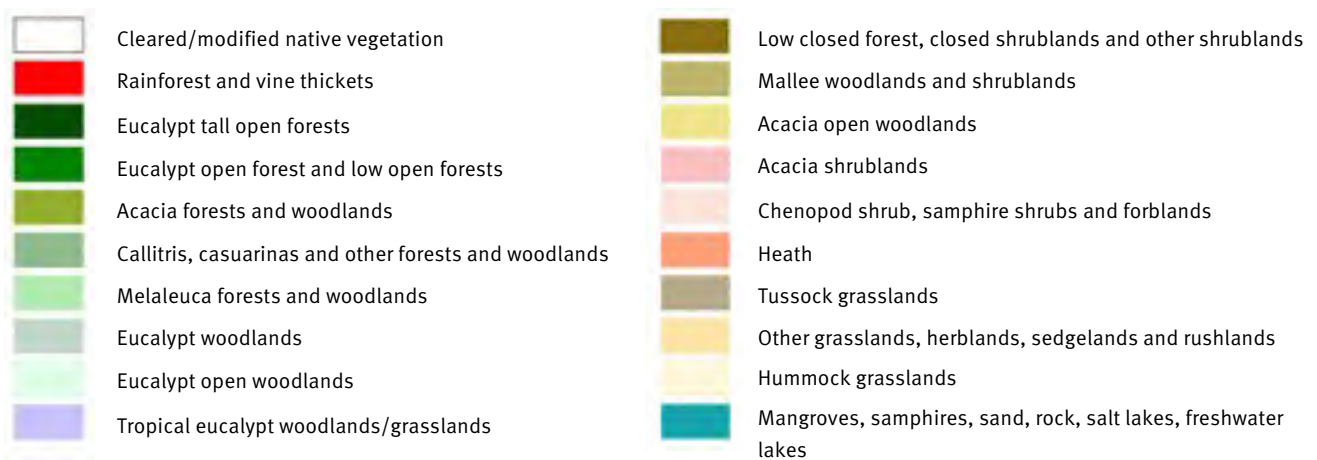
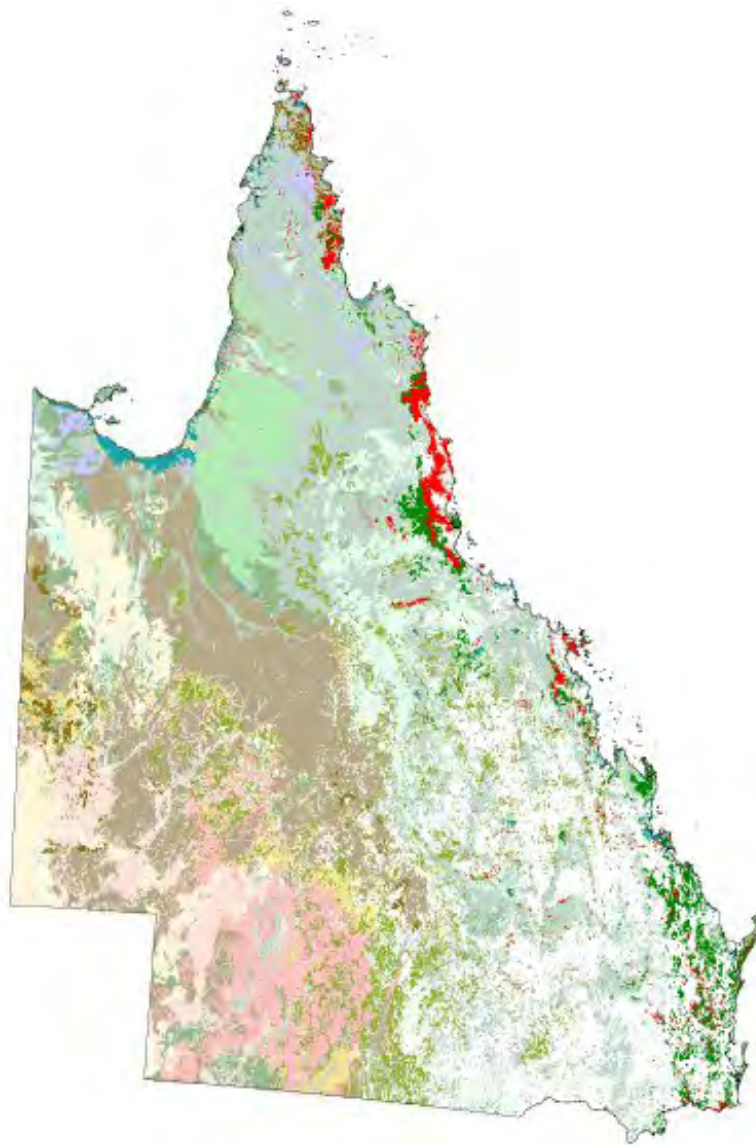
Australia's relative affluence compared to other nations containing rainforests gives us an opportunity to demonstrate the importance and benefits of best practice forest management (including in the construction of roads) that incorporates a strong environmental basis into planning, design and management.

Characteristics and Distribution

In general, rainforest occurs where rainfall exceeds evaporation for much of the year³. These forests generally form closed canopies because growth is not limited by water but by light, and thus the trees compete to intercept all available light. Rainforests are characterised by high plant diversity, high biomass and rapid rates of nutrient cycling. A large proportion of the system's nutrients are located within the plants and animals (biomass) rather than in the soil. Therefore regrowth of rainforest after clearing or logging takes longer than expected because nutrients once held in the trees above the ground and in the organic surface material have been completely removed.

Within the State, rainforests occur from the northern tip of Cape York, along the coastal ranges to the southeast border with New South Wales. Queensland has three World Heritage Areas containing rainforest: Fraser Island, the Wet Tropics, and the Central Eastern Rainforest Reserves of Australia (CERRA). The latter includes the Queensland National Parks of Lamington, Mount Chinghee, Main Range and parts of Springbrook and Mount Barney. In addition to these Areas there are many other significant regions of rainforest, including those to the west of the Sunshine Coast (including the Conondale Ranges), the Eungella/Finch Hatton area near Mackay, and Iron Range on Cape York. A high proportion of Queensland rainforests are within National Parks or other protected tenures.

³ See Lal, R. (1993) (Reference) in *Roads in Rainforest: Science behind the Guidelines*.



The distribution of tropical rainforests in Queensland (in red) in relation to other habitat types
(Source: National Land and Water Resources Audit, 2001).

The Importance of a 'Sealed' Canopy

Rainforest ecosystems have evolved with a closed canopy, which means they have a specific sensitivity to any canopy loss caused by clearing. In these forests, the canopy creates a characteristic microclimate which provides low light, low wind, lower temperatures, higher humidity, reduced raindrop penetration and higher soil moisture at lower levels of the forest. Due to the lower light levels, many plants reach into the canopy (vines, epiphytes, etc.) to create a community above the forest floor. The microclimate and consequent forest structure provides habitat for many birds, mammals, reptiles, insects and other invertebrates which are specifically adapted to these conditions.

Essentially, the canopy provides a 'seal' over the forest, which, once broken, causes many subsequent effects. 'Linear' clearing of the canopy, such as is required when roads are constructed, usually results in the forest 'sealing' the vertical forest edges next to the road as trees, vines and shrubs respond to the higher light environment at the new edge. The cleared, or 'disturbed', area is a harsh and alien environment for most rainforest-adapted species which are often unable to survive beyond the thick vegetation of the forest edge. The suite of consequences resulting from the vertical forest edge abutting a disturbed area (e.g. road, other linear clearing or farmland) are described as 'edge effects.' These impacts are generally negative and result in change to the local populations of plants and animals. It is important to recognise that, for many species, a linear clearing will create two divided (disjunct) populations and reduce the movements of individuals across the clearing. Movement across the landscape is often necessary for daily or seasonal animal behaviour⁴ (e.g. seeking a mate), access to essential resources (food, denning sites), cross-pollination or seed dispersal, and to allow young animals to disperse and find new areas in which to live.

Seasonal High Rainfall and Soil Instability

By their nature, rainforests in Queensland generally occur in moist climates. A majority of the annual rainfall is recorded between December and April with a large proportion occurring on consecutive days when the monsoon trough is nearly stationary in the region. High intensity rainfall events are amongst the highest in the world⁵, with six-

minute totals equivalent to 250mm an hour in some northeastern catchments. Due to impervious soils, steep topography and high rainfall events, watercourses can overflow their banks and flood surrounding low lying areas. Direct comparisons with other humid tropical areas show that Queensland rainforests have high runoff co-efficients (percentage of mean annual rainfall that becomes runoff from the land) of 58-90%, whereas Malaysia has 9-14% and the Amazon basin 19-57%.



Rock-filled gabions act to retain cuts and fills, allowing steeper slopes, and hence less width of corridor disturbance (Photo: WTMA).

Climate change (enhanced 'greenhouse effect') is expected to produce more variability and greater extremes in droughts and rainfall events. Gradual sea level rise may also exacerbate problems of local inundation on roads near the coast. Roads within Queensland's rainforests are subject to damage from flooding events or excessive saturation of the road base and overloading of drainage structures, leading to high repair costs and hazardous driving conditions. These problems may increase with predicted climate change.

The steep topography and incidence of intense rainfall events make rainforest regions prone to landslides. The warm and wet environment is conducive to rapid rock weathering, creating a large bulk of unstable material, which can potentially slip given the right conditions. Removal of vegetation, changes to natural drainage and modification of slopes by infrastructure such as roads increase the susceptibility of the land to move under the force of gravity⁶. Intense rainfall events increase the weight of the soil and provide

⁴ See Sattler and Williams (1999) (Reference) in *Roads in Rainforest: Science behind the Guidelines*.

⁵ See Bonnell (1991) (Reference) in *Roads in Rainforest: Science behind the Guidelines*.

⁶ See Granger et al. (1999) (Reference) in *Roads in Rainforest: Science behind the Guidelines*.

lubrication to trigger landslides. Thus, planning for new roads must consider both the short and long term implications for cut-and-fill work, as well as the design of alternative structures that can reduce potential for landslides.

Conservation and Protection

Queensland has a system of National Parks, Conservation Parks, Resource Reserves and National Parks (Scientific) to protect natural values for the future. The Australian Government has contributed resources to the management of highly important areas listed as World Heritage (which includes some Queensland National Parks).

Protected Areas of Queensland.

Classification	No. Areas	Total Area (km ²)
Conservation Park	168	41,849
National Park	212	41,391
National Park (Scientific)	7	1,435
Resources Reserve	39	6,276

Rainforest occurs in many of the protected areas as well as in large areas of Crown Land, State Forests, and privately owned land occurring along, or east of, the Great Dividing Range. Careful application of appropriate planning and design principles to these rainforest areas is necessary to protect both the natural values and the investments in infrastructure.

Regional Ecosystems

Regional ecosystems have been defined as the vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil⁷. The status of each Regional Ecosystem is assessed on its size compared to its pre-clearing extent, and gazetted under Queensland's *Vegetation Management Act (1999)* as either 'endangered', 'of concern', or 'not of concern at present'. Assessment also takes into account threatening processes such as erosion or weed invasion, and the rarity of the vegetation community.

Areas (ha) of Wet Tropics Regional Ecosystems (REs) (by status). See Appendix 1 in *Roads in Rainforest: Science behind the Guidelines* for a list of the ecosystems.

Area	Endangered (ha)	Of Concern (ha)	Total area (ha)
Cooktown	3,684	14,791	96,625
Cairns	2,495	16,046	99,315
Ingham	16,110	93,169	645,451
Innisfail	24,775	59,467	633,618
Mossman	3,538	35,314	312,689
Total for Mapped REs	50,602	218,787	1,787,698
Total for Wet Tropics Bioregion			1,983,855
Total World Heritage Area			900,489

World Heritage listing protects approximately 900,000 ha of land in the Wet Tropics, but outside this area most of the endangered ecosystems are found in coastal or tableland agricultural and urban districts. These remnant forest patches, found throughout the lowland and tableland regions, contain important vegetation types that are often under-represented in the area.

Appendix 1 in *Roads in Rainforest: Science Behind the Guidelines* includes a list of the regional ecosystems of Queensland which are considered rainforest for the purposes of the guidelines. This should not be considered an exhaustive nor exclusive list; rather it gives an indication of the forest types considered as rainforest. Further information on regional ecosystems and their recent status can be found on the Queensland Herbarium website⁸.

10 ⁷ See Sattler and Williams (1999) in *Roads in Rainforest: Science behind the Guidelines*.

⁸ http://www.derm.qld.gov.au/wildlife-ecosystems/plants/queensland_herbarium/index.html

The Impacts of Roads on Rainforest Environments

Forest fragmentation, caused by clearing of land for agricultural production, plantation and urban purposes is recognised globally as one of the major threats to tropical rainforest fauna⁹. Fragmentation can also include 'internal fragmentation' of large tracts of rainforest by linear clearings such as roads, powerlines, railways and water pipelines. These clearings create gaps that subdivide natural habitats, cause new disturbance areas, and impact on wildlife populations by reducing the possibility of movement in the landscape and, in some cases, increasing mortality rates¹⁰.



The Kennedy Highway near Cairns was chosen as a site for animal road mortality research because it bisects rainforest habitat (Photo: Guy Chester).

Rainforests in Queensland occur mainly along the ranges near the coast, while other coastal lowland and tableland forests occur in a relatively disturbed landscape dominated by intensive agricultural and pastoral industries. Roads that cross the ranges or traverse lowland or tableland forests can interfere with landscape connectivity by severing forest corridors that may allow movement of animal populations.

The construction of roads through mountainous rainforest ranges involves the crossing of many gullies and ridges with consequent challenges for road engineering. This may result in cut-and-fill embankments, culverts and bridges.

Together, these result in a larger footprint of disturbance than the actual road surface itself, with the fragmentation of natural habitats and resulting edge effects increasing in severity as the road becomes wider¹¹. Edge effects of roads penetrate forests to different distances, with the effect of a road on adjacent habitat being far greater than the actual clearing. For example, in the Wet Tropics World Heritage Area, there are 1,610 ha of cleared forest in road corridors, but if floristic changes that can penetrate 25-50 metres are taken into account, up to twelve thousand hectares of habitat is potentially affected.

The death of wildlife is one of the most obvious impacts of roads in most habitats. The magnitude of rainforest road kill is rarely understood because Australian rainforests are home to relatively few animals large enough for victims to be obvious from a moving vehicle. High rates of road kill often occur at gullies and creeks and at the junctions between cut-and-fill embankments. This is because these places are often the easiest places for wildlife to cross roads when moving through the landscape. In addition, the presence of cut batters or steep slopes may prevent animals such as tree-kangaroos escaping impacts with vehicles¹².



Snakes are common road kills in forested areas (Photo: Nigel Weston).

⁹ See following References in *Roads in Rainforest: Science behind the Guidelines*: Laurance and Bierragaard (1997); Laurance *et al.* (1997); Laurance and Goosem (2008).

¹⁰ See Goosem (1997) (Reference) in *Roads in Rainforest: Science behind the Guidelines*.

¹¹ See Goosem 2000(a) and McKelvey *et al.* (2002) (References) in *Roads in Rainforest: Science behind the Guidelines*

¹² See Izumi (2001) (Reference) in *Roads in Rainforest: Science behind the Guidelines*

For further information on the impacts of roads on rainforest environments, including potential for landslips, erosion and changes to stream water quality, and disturbance of wildlife by traffic noise, streetlights, headlights and movements, as indicated by scientific studies see *Roads in Rainforest: Science behind the Guidelines* – Part B of these Guidelines.

1.5 Acknowledgements

These two documents – the *Best Practice Guidelines* and the *Science Behind the Guidelines* were written using information from a previous document together with updates from more recent road impact and mitigation studies.

The previous document (Chester, G., Goosem, M., Cowan, J., Harriss, C. and Tucker, N. (2006) *Roads in Tropical Forests, Best Practice Guidelines*. Report to Queensland Department of Main Roads, May 2006, Rainforest CRC, Cairns, Australia, 126 pp.) was compiled using joint funding from the then Queensland Department of Main Roads (QDMR) and the Rainforest CRC. The authors of this document summarised research undertaken in the field of road ecology within the Rainforest CRC and of research from elsewhere in Australia and the world, as well as reference to work undertaken by the authors prior to the creation of the Rainforest CRC. The initial guidelines document also drew on information and figures contained in the QDMR manual prepared jointly by the QDMR, Rainforest CRC and Gutteridge, Hoskins and Davies, entitled *Roads in the Wet Tropics: Planning, Design, Construction, Maintenance and Operation – Best Practice Manual* (December 1997).

We would like to acknowledge the funding obtained from the Queensland Department of Transport and Main Roads for the preparation of these Guidelines under the auspices of Ms Karen Oakley, and funding for salaries from the Australian Government's Marine and Tropical Sciences Research Facility (MTSRF), implemented in North Queensland by the Reef and Rainforest Research Centre Limited.

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1.6 References

See the References section in *Science Behind the Guidelines* – Part B of these Guidelines.

2. Principles

The principles described in the following pages are the key outcomes that promote the achievement of the objectives of Department of Transport and Main Roads' Best Practice Management of road building within the rainforest environments of Queensland. These principles are therefore statements of outcomes that include key definitions and sources of additional information on that topic. Further, the Guidelines are specific actions and supporting approaches that will allow the user to achieve the Principles.

It is important to read all principles for each section before reading a specific guideline – the principles form the basis for the guidelines in each section.

Although principles have been allocated to particular stages of a project as they may more generally apply to that stage, each principle will apply through all stages of planning, design and management.

When Using this Manual:

1. Read the Overview Chart to clarify the key issues for your project.
2. Read ALL Principles for ALL road infrastructure phases.
3. Refer to the Guidelines within the road infrastructure phase relevant to you.
4. Refer to additional material recommended within the Guidelines relevant to you.
5. Contact the project environmental officer if further clarification/advice is required.

Principles in each phase

Phase	Principles
Plan	R1) Preserve and Value Sensitive Ecosystems R2) Maintain Plant and Animal Populations R3) Ensure Catchment Integrity
Design	R4) Reduce Edge Effects R5) Promote Habitat Corridors R6) Provide Canopy Connectivity
Manage*	R7) Maintain Habitat Quality

* Manage = Construct, Maintain, Operate

R1 Preserve and Value Sensitive Ecosystems

The preservation of ecosystems, especially endangered or rare habitats, requires thorough research that is integrated across the planning, design, and management of road corridors.

Why?

The viability of any natural ecosystem can be reduced through disturbance and/or fragmentation caused by a new road or road upgrade. Thorough research that is integrated across the planning, design and management of road corridors is required to identify the most sensitive (i.e. endangered or 'of concern') habitats so that they can be avoided if possible. Habitat loss should be minimised in all natural rainforest areas through appropriate design and mitigation approaches. Significant features can be emphasised to the public through presentation.

Key Terms

In Queensland, **Regional Ecosystems** are broadly defined as a vegetation type and its conservation status (see below). Regional Ecosystem mapping is based on broad structural and floristic classes, the underlying geomorphology and bioregion, and by additional delineation by elevation and other relevant factors.

The system includes a determination of conservation significance which is given statutory effect by the *Vegetation Management Act 1999*:

- An 'endangered' Regional Ecosystem is one that has either:
 - (a) less than 10% of its pre-clearing extent remaining; or
 - (b) 10-30% of its pre-clearing extent remaining and covers less than 10,000 ha.
- An 'of concern' Regional Ecosystem is one that has either:
 - (a) 10-30% of its pre-clearing extent remaining and is greater than 10,000 ha; or
 - (b) more than 30% of its pre-clearing extent remaining and the remnant remaining vegetation is less than 10,000 ha.
- A 'not of concern' Regional Ecosystem is a regional ecosystem that has greater than 30% of its pre-clearing extent remaining and covers more than 10,000 ha.

Additionally, the Department of Environment and Resource Management has a Biodiversity Assessment and Mapping program. This is a non-statutory classification system, but it provides additional data for assessing natural values. The Australian Government also identifies the conservation status of ecological communities under the *Environment Protection and Biodiversity Conservation Act 1999*.

Rainforest ecosystems are especially sensitive to clearing due to the closed canopy maintaining the conditions of lower light, lower temperatures, higher humidity, etc., to which rainforest species are adapted.

Ecosystems and their individual species are also valued by the community for their aesthetic features and therefore appropriate presentation of key ecological components should be



The status of rainforest dominated by fan palms is 'Of concern', while the Biodiversity Status is 'Endangered' (Photo: Suzanne Long).

R1 – Preserve and Value Sensitive Ecosystems

investigated when identifying the overall significance of a corridor. Thus, road placement and design can be used to showcase the natural environment in a manner that allows for greater appreciation of natural features such as large trees, riverine habitats, outlooks, etc. (See Guideline P5 (page 39) for details).

Relevant Concepts

Disturbance

Any event that alters the existing structure and inherent processes of an ecosystem. The larger and more extensive the disturbance event/s, the longer the timeframe for the system to return to its prior state (if ever). For example, cutting a new road through a rainforest will increase light and wind penetration, altering the local environment, with associated changes to the plant and animal species present.

Fragmentation

The division of formerly intact habitats into disjunct fragments. This can include 'internal' fragmentation where the habitat is divided by a linear strip or clearing such as for a road or powerlines. Fragmentation of habitat creates 'barriers' to movement of plant and animal species and can cause additional 'non-native' species to invade the area.

Roads in Rainforest:

Science Behind the Guidelines

See Sections:

- 1.1 Habitat Loss and Changes in Quality
- 1.2 Habitat Fragmentation and Barriers to Movement
- 1.3 Edge Effects and Disturbance

R2 Maintain Plant and Animal Populations

The maintenance of threatened and endemic species is an integral part of the planning, design and management of road corridors.

Why?

Populations of 'threatened' or locally endemic species can be impacted by a new road or road upgrade. It is necessary to first identify the most sensitive species so that measures can be taken firstly to avoid, then to minimise and mitigate, any significant impacts, including minimising barriers to population movement and reducing road kills.

Key Terms

Threatened Species

There are both State and Commonwealth processes for determining the status of a 'threatened' species, which have official protection under the respective Acts:

The **Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999** lists threatened species under Categories:

1. Extinct;
2. Critically endangered;
3. Endangered;
4. Vulnerable; and
5. Conservation dependent.

The Department of the Environment, Water, Heritage and the Arts administers the *EPBC Act 1999*.

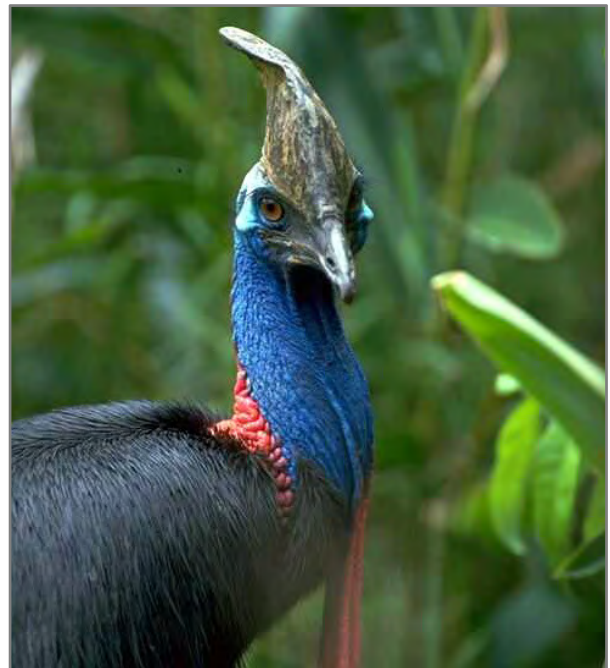
Queensland lists threatened species under the *Nature Conservation Act (NCA) 1992* within the categories of:

1. Extinct in the wild;
2. Endangered;
3. Vulnerable;
4. Near threatened; and
5. Least concern (common).

The *NCA 1992* is administered by the Department of Environment and Resource Management.

Locally Endemic Species

'Endemic' means that the species is only found within that area, and nowhere else. Although they may not be listed as *threatened*, their populations have a limited distribution and therefore any disturbance or loss of habitat can potentially impact on their survival. Many endemic species are found within World Heritage Areas and have specific conservation values relating to this type of protected area.



The endangered Southern Cassowary is threatened by road mortality, habitat fragmentation and habitat loss (Photo: WTMA).

R2 – Maintain Plant and Animal Populations

Relevant Concepts

Barriers to movement

Roads and their verges can be barriers to species movement, including daily or seasonal migrations. This is of particular importance to animals, but plants can be impacted as well if the gap is wide enough (many plants need animals to pollinate their flowers or distribute seeds). Consequently, individuals may not be able to access needed resources, resulting in reduced reproductive success. These short-term consequences can lead to reduced vigour in small or isolated populations, and possibly to eventual population decline. Also, if a local population is divided, then genetic flow within the population may be reduced, with in-breeding a potential long-term result.

Road kill

Animals that do attempt to cross a road may be killed. If mortality caused by vehicle impacts is high for a local population, then the species may be locally threatened with extinction over the long-term. Even if the population is large enough to survive some mortality, the age structure may be impacted. For example, younger animals may be killed more frequently than older animals which can lead to limited reproductive capacity due to the aging population.

Roads in Rainforest:

Science Behind the Guidelines

See Sections:

- 1.2 Habitat Fragmentation and Barriers to Movement
- 1.3 Edge Effects and Disturbance
- 1.4 Roadkill and Construction Mortality



A small existing culvert has the potential for maintaining connectivity across roads for ground-dwelling terrestrial animals.

R3 Ensure Catchment Integrity

The maintenance of healthy catchments through which a road corridor is planned is a primary goal within planning, design and management phases.

Why?

The maintenance of catchment integrity is important at various spatial scales, from the small local creek to the larger river. Additionally, temporal scales must be assessed, ranging from immediate impacts due to soil erosion to longer-term influences of road use on water quality. These multiple impacts must be properly identified and assessed throughout all phases, but especially when determining an appropriate location for a road corridor.

Key Terms

Catchment

A specific geographic area in which rainfall is captured and directed into a series of gullies which flow into creeks that, in turn, flow into larger streams and eventually into a river.

Integrity

The long-term maintenance of natural system functioning, including in the case of catchments:

1. Seasonal variations in water flow;
2. The movements of aquatic animals;
3. The health of riverine plant communities; and
4. Water quality.

Riparian corridors

Riverine (or riparian) corridors include both the aquatic and terrestrial components of the 'waterway'. Riparian areas act as a habitat for both aquatic and land-based species. Aquatic species move along the waterway, whilst birds, mammals and other land-based species use the corridor as a 'route' to move across the landscape as there may be enhanced cover, food and water resources within the riparian corridor.



Existing bridges can, in some cases, maintain riparian habitat connectivity.



Rainforest streams provide habitat, as well as movement corridors, for fauna.

R3 – Ensure Catchment Integrity

Relevant Concepts

Riparian ‘funnels’

A high proportion of small mammals and frogs are killed on the road surface in the vicinity of creeks and gullies, as the riparian corridor acts as a ‘funnel’ for movements of these species. A similar trend for road kills of Lumholtz’s Tree Kangaroo has been found on the Atherton Tablelands, where animals are often seen and/or killed where creeks intersect with the road network. Additionally, there is an association of higher frog road kill in relation to ponded water near the road in road side drains.

Aquatic health

Waterways within rainforest environments are generally humid, low-light environments. If adjacent vegetation is removed, then the aquatic environment will shift to a less moist, high light situation that can subsequently increase water temperatures. Water temperature is an important aspect of maintaining a healthy aquatic system because increased heating may alter the oxygen balance and increase the prevalence of algae, which in turn can reduce the oxygen levels further, causing fish kills and altering the natural balance of the system. Eroded soil and pollutants from vehicles using a road may be carried into the stream, thereby reducing water quality. Changing the amount of water reaching a stream alters the streambed and habitats for aquatic species.

Roads in Rainforest:

Science Behind the Guidelines

See Sections:

- 1.1 Habitat Loss and Changes in Quality

R4 Reduce Edge Effects

The reduction of significant edge effects should be considered early in the planning phase, and emphasised throughout the design stage.

Why?

Through appropriate planning and design, edge effects can be greatly minimised, resulting in reduced impacts to the microclimate and subsequent maintenance of local rainforest ecosystem processes.

Key Terms

Edge effects

'Edge effects' are the diverse group of changes that occur at, and near, abrupt edges between natural habitat and clearings. Environmental factors that may alter include the microclimate, vegetation structure and plant composition. Tree death and increased densities of weeds near the edge are two common responses to a new edge created through clearing. Animal populations may respond to edge effects through avoidance or by reduced survival or reproduction at the edge (creating a 'negative' effect on the population). Alternatively, some species increase their use of the edge habitat due to an increase in the resources they need such as more light or more food plants. Such 'edge' species are usually very common and include weeds and pests, while forest specialists often decrease.

Microclimate

This is defined as the primary aspects of a 'local' climate, that is, within the forest itself, including the available light, humidity, air and soil temperatures, soil moisture and wind speed.



Edge effects and loss of canopy result in all linear clearings having an ongoing impact on the integrity of ecosystems in tropical forests. Canopy closure over a clearing will decrease the amount of edge-affected forest.

R4 – Reduce Edge Effects

Relevant Concepts

Edge-affected forest

Edge effects can penetrate the rainforest up to two hundred metres (or sometimes further) and thus the area of disturbed forest is much greater than simply the clearing footprint. Fauna species likely to suffer greater edge effects include those that are rainforest-dependent and those that have large home ranges (as they are more likely to encounter the edges). Canopy closure over the clearing will decrease the amount of edge-affected forest, while wider road clearings will increase it. The degree of edge effects and the extent they penetrate into the forest differs with species and depends on the factor being measured.

Mitigation of edge effects

The two most effective methods for mitigating edge effects caused by the clearing of forest for roads or other linear infrastructure is through retention of tree canopy cover over the road and by plantings, especially of species with high leaf densities, along cuttings. Re-establishment of vegetation can reduce the penetration distance for edge effects such as temperature, evaporative moisture loss, and litter moisture content. Further, revegetation can also assist in maintaining organic material in the soil, and in preventing the death of large trees by keeping a more constant microclimate and reducing wind speeds.

Roads in Rainforest:

Science Behind the Guidelines

See Sections:

1.3 Edge Effects and Disturbance

R5 Promote Habitat Corridors

Retaining corridors that allow faunal movement between areas of similar habitat should be considered an important element in the late planning phase and throughout the design phases.

Why?

Animal populations are dependent on a variety of resources that change seasonally across the landscape. Roads fragment the habitat of local populations, potentially leading to long-term impacts on their viability if a safe corridor for movement is not made available.

Key Terms

Habitat corridor

A habitat corridor may take the form of a strip of vegetation in the landscape that links two separated patches of habitat and provides sufficient cover for designated animal species to move safely between the areas. The width and length and 'cover' of the corridor are important determinants of whether the corridor is effective for a particular species. Corridors in rural and urban areas often comprise strips of vegetation along watercourses. Areas below bridges, underpasses below a road or overpasses above it all may form part of a corridor.

Population viability

The persistence (or viability) of a species' local population is dependent on several factors including:

1. Maintaining sufficient numbers (i.e. not having too few individuals);
2. Having access to important resources for breeding and refuge from predators; and
3. Having sufficient genetic diversity to maintain long-term responsiveness to changing environments.

The latter factor may become increasingly important as climate change impacts are already known to be impacting Queensland rainforest environments.

Relevant Concepts

Habitat connectivity

Habitat connectivity is of great importance in ensuring that contact between individuals of plant and animal species on either side of the road is maintained. This means that populations on either side can interbreed regularly, thus reducing the possibility of the negative impacts of population variability in the short-term and genetic drift in the long term. In the short term, connectivity also will allow animals or plants to recolonise an area if a catastrophic disturbance occurs that results in the loss of all individuals from one side of the road.

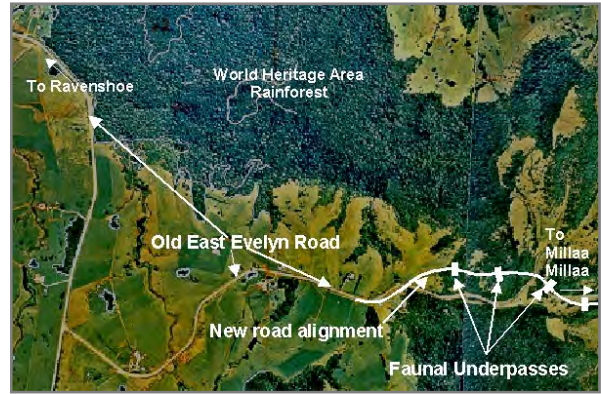
Bridges and Underpasses / Overpasses

Bridges which allow vegetation to grow underneath assist in maintaining habitat connectivity. If bridges are not feasible, underpasses (large tunnels designed for the use of fauna only) should be considered in areas where longer sections of road lack bridges. Vegetation cover at underpass mouths should include low-growing shrubs, whereas within an underpass refuges from predators can be provided in the form of rock piles, logs, brush, etc. Overpasses (land bridges) can be built over a road where the topography is suitable and the costs can be justified. Such structures, once revegetated, are particularly useful for providing routes for larger animals that are known to cross roads and are therefore a safety concern.

R5 – Promote Habitat Corridors



Despite impact mitigation of the fauna culvert, roads generally cause a net loss of habitat and fauna connectivity. Revegetation will reduce this habitat loss over time (Photo: Jonathan Munro).



An aerial photograph showing the two sections of the Wet Tropics World Heritage Area divided by the East Evelyn Road. Upgrading this road through sensitive upland rainforest required extensive revegetation which provided an overall increase in habitat and connectivity.

Roads in Rainforest: Science Behind the Guidelines

See Sections:

- 2. Mitigation Strategies
- 2.2 Bridges
- 2.3 Faunal Underpasses

R6 Provide Canopy Connectivity

The retention of canopy connectivity over the road is a priority in the late planning phase and throughout design and management phases.

Why?

Canopy cover is an important element of the rainforest environment that maintains the local microclimate, disperses rainfall and allows tree-dwelling species such as arboreal marsupials to move through the landscape, as well as encouraging movement by ground-dwellers. Without the retention of an adequate amount of canopy, edge effects become more pronounced, weeds and alien fauna may colonise the roadside, and local populations may be negatively impacted by the road.

Key Terms

Canopy connectivity

The canopy of the rainforest maintains a natural connectivity by trees' branches reaching across to fill the light gaps caused by treefalls. Connectivity of the canopy across a road can be encouraged by maintaining a density of overlapping branches that are strong enough to support larger-sized arboreal marsupials.

Arboreal marsupials

Tree-dwelling (arboreal) species of mammals are commonly found in the mid to upper canopy of rainforests and some adjacent forest types. In Queensland, these include fourteen species of possums and gliders, and two species of tree kangaroos.



Maintaining canopy connectivity over a road has multiple benefits (Photo: Greg Dawe).

Relevant Concepts

Canopy cover

The maintenance of canopy cover over roads will assist in ensuring continued ecological integrity of the forest. A rainforest is generally a moist, low-light environment that is dramatically altered by a new clearing or a new road, as the environment suddenly changes to a drier, higher-light-intensity zone where rainfall is directly impacting on the ground rather than dissipating down through layers of the canopy. Retaining canopy cover over a road can therefore reduce the light intensity along the edges of the forest, decrease negative edge effects, prevent colonization by weeds and alien fauna, provide movement corridors, and lower the potential for rainfall to cause local erosion.

Canopy bridges

Providing canopy connectivity for arboreal marsupials and other tree-dwelling animals is particularly important where sensitive species occur such as in higher altitude areas (>300m) of the Wet Tropics where several species will not move at ground level. It is also important where many arboreal animals are likely to be killed by vehicles. If there is no possibility of maintaining touching tree canopies in these situations (e.g. where the road is very wide), it is recommended that the less

R6 – Provide Canopy Connectivity

preferable option of ‘canopy crossing’ devices be used. Rope bridges and other structures can provide a physical link between the canopies on either side of the road, providing a safer movement pathway for most tree-dwelling species.

Roads in Rainforest:

Science Behind the Guidelines

See Sections:

- 2. Mitigation Strategies
- 2.1 Canopy Closure
- 2.5 Canopy Bridges

R7 Maintain Habitat Quality

Maintaining habitat quality is a priority activity in the late design phase, and throughout all aspects of road construction and management.

Why?

Habitat quality can be retained through appropriate and simple practices such as reducing local cleared areas, managing topsoil, and preventing the spread of weeds, pests and diseases.

Key Terms

Habitat quality

The ability of a habitat to support native species can be described by its 'quality'. Therefore habitat quality is often used to describe a single species' environmental needs at a local scale or to broadly refer to the more general capacity of the environment to maintain ecological processes for a suite of local, native species.

Key threatening process

Phytophthora cinnamomi is a fungus-like root-rotting pathogen with an extremely broad host plant range. It is soil-borne, and can release vast numbers of swimming spores into the soil which are then readily spread by surface or sub-surface water movement as well as by soil transport on machinery, vehicles and footwear. *P. cinnamomi* has the ability to cause dieback patches in forests by killing a number of different tree species. It represents a significant threat to many native ecosystems across wetter parts of the continent and has been listed as a Key Threatening Process under the *EPBC Act 1999*.

Relevant Concepts

Pests, weeds and disease

A road may alter the habitat quality of the local area by altering the physical structure and ecological functioning of the environment. Road verges which are maintained as grasslands or low, shrubby swathes can allow the penetration of weeds, pests and alien fauna into the surrounding forest habitat. Human disturbance such as clearing of dead trees can facilitate the weed invasion process by eliminating or reducing the cover and/or vigour of native competitors. Additionally, pests such as cane toads, feral mice and rats, and mynah birds may survive better in 'edge habitats' such as grassy verges. Areas of disturbance may also contribute to disease propagation, especially in formerly intact habitat.

Topsoil management

Methods for protecting and managing the soil should be initiated as part of the design phase of a road project. Topsoil should not be removed until appropriate measures are introduced for control of erosion. Topsoil removal should only occur in areas ready for commencement of earthworks and the soil should be minimally handled and stored for as short a time as possible near the site where it will be replaced to maintain native seed viability. Topsoil management needs to consider the risk of spread of weeds and soil-borne diseases.

R7 – Maintain Habitat Quality



Results of revegetation using hydromulch stabilisation that included native grass and acacia seed (Photo: Nigel Tucker).



Some species of frog, including this endangered species *Litoria rheocola*, are affected by road noise – some are stimulated to chorus and as a result there may be a subtle effect on the energy balance of male frogs near roads, while others avoid road edges altogether (Photo: WTMA).

Roads in Rainforest: Science Behind the Guidelines

See Sections:

- 1.6 Invasion by Weeds, Diseases and Feral Animals
- 1.7 Chemical Pollutants
- 1.8 Vehicular Disturbance

3. Guidelines

These Guidelines support the overall principles identified previously, by highlighting a specific issue, its importance and how the issue should be approached. Each section should be read as a whole, while also consulting relevant guidelines in the other sections.

Each Guideline has the following format:

- A title describes the main focus of the guideline.
- A brief statement describes the action to be taken.
- A 'Why?' statement provides a context for this action.
- A 'Key Issues' statement gives detail about the issue/s.
- A 'How?' section provides specific steps to be taken.
- A 'Science Background' provides a basis for understanding the key issues with additional background/examples for each issue.

Guidelines within each phase

Phase	Guideline
Plan	P1) Understand Ecological Values of Corridor P2) Balance Transport and Environmental Objectives P3) Minimise Impacts to Environmental Values P4) Mitigate and Offset Significant Impacts P5) Showcase Natural Values
Design	D1) Assess Safety and Environmental Impact Trade-offs D2) Reduce Vegetation Loss and Minimise Edge Effects D3) Ensure Habitat Connectivity for Fauna Movement D4) Install Canopy Crossing Devices D5) Maintain Stream Integrity and Ensure Fish Passage
Manage	M1) Reduce Erosion and Manage Sediment M2) Minimise Pollutants M3) Manage Disturbance to Prevent Spread of Diseases, Pests and Weeds M4) Manage Topsoil M5) Revegetate Disturbed Sites M6) Maintain and Monitor Ecological Works and Devices

P1 Understand Ecological Values of Road Corridor

Investigate the ecological values of a planned road corridor to maximise the opportunity for ensuring the protection of sensitive areas and species.

Why?

By clarifying the ecological values of any planned road corridor before the design stage, any potential impacts to areas of sensitive native forest and endangered and/or endemic species can be described and analysed by appropriate environmental specialists. Avoiding sensitive areas early in the planning process can produce savings in both cost and environmental impacts.

Key Issues

Ecological values include all the habitats and species that are found within the road corridor. A great diversity of rainforest types continue to exist in Queensland, which means that rainforest systems in different areas can be quite distinct in terms of species. Throughout Queensland, 58% of rainforest Regional Ecosystems are listed as threatened. Even if a rainforest type is more common throughout the state, it may be locally uncommon due to reductions in its former area. Therefore, its regional significance should be assessed in addition to its State and Commonwealth conservation status.



Ringtail possums have been shown to react to noise (Photo: Robyn Wilson).

Further, local populations of rainforest flora and fauna that may be endangered, rare or endemic to the area must be considered as key ecological values. These may include relatively unstudied species with poorly known distributions or habitat requirements and more common species that may have a restricted distribution in the immediate area (e.g. white Lemuroid possums in the Wet Tropics).

How?

- ✓ Consult the Appendix in *Science Behind the Guidelines* – Part B of these Guidelines – for a list of the Regional Ecosystems of Queensland which are considered *rainforest* (note, updated lists should also be sought).
- ✓ Consult mapped Regional Ecosystems (DERM website*).
- ✓ Consult biodiversity classes (DERM website**).
- ✓ Ensure the potential species of conservation concern have been identified for each ecosystem type (DERM** and Commonwealth[#] websites).
- ✓ Consult Species Recovery Plans for identified species, where available.
- ✓ Consult key experts on the habitat / species to gain local information.
- ✓ Consult or develop documents such as the Review of Environmental Factors^Ω for the project area.
- ✓ Talk with your project environmental officer for assistance.

* http://www.derm.qld.gov.au/wildlife-ecosystems/biodiversity/regional_ecosystems/index.php

** <http://www.derm.qld.gov.au/>

[#] <http://www.environment.gov.au/epbc/protect/species-communities.html>

^Ω See Road Project Environmental Processes Manual at

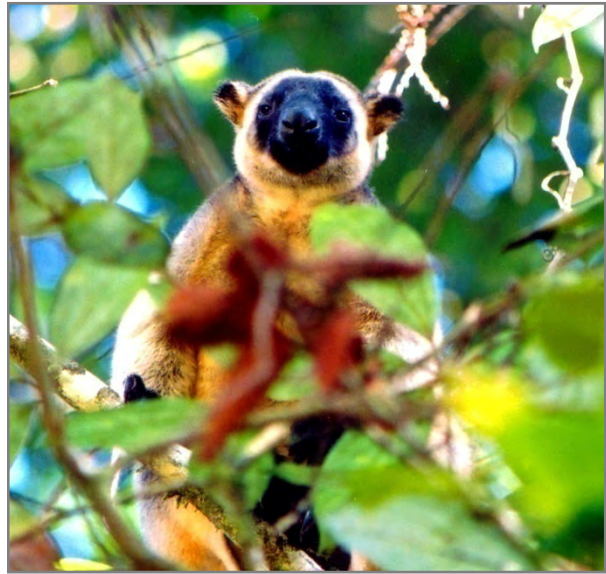
<http://www.mainroads.qld.gov.au/en/business-and-industry/road-builders/technical-publications>

P1 – Understand Ecological Values of Road Corridor

Science Background

As an example, the habitats of the Wet Tropics Bioregion contain 1,850,000 ha and 185 Regional Ecosystems (REs). Further, 18 REs (10%) are classified as 'Endangered' and 134 (72%) are 'Of concern'. Some REs are within the World Heritage Area while others have no protection or are only partially protected (Source: Wet Tropics Management Authority 2009).

Within the Wet Tropics Bioregion consideration must also be given to 28 endangered, 54 vulnerable and 14 presumed extinct plant species, and 3 critically endangered, 20 endangered, 14 vulnerable and 1 presumed extinct vertebrate animal species under the *EPBC Act 1999*. Consider also that 44 endangered, 59 vulnerable, 278 rare and 15 presumed extinct plant species, and 23 endangered, 27 vulnerable and 56 rare vertebrate animal species listed under Queensland's *Nature Conservation Act 1992* are found within the Wet Tropics Bioregion (Source: Wet Tropics Management Authority 2009).



The Lumholtz's tree kangaroo is considered to be threatened by road mortalities
(Photo: Jonathon Munro).

Roads in Rainforest:

Science Behind the Guidelines

See:

Section 1. The Impacts of Roads

Appendix 1. Rainforest Regional Ecosystems

P2 Balance Transport and Environmental Objectives

Assess road function in relation to environmental principles and reassess to achieve minimal impacts, particularly in sensitive areas.

Why?

By identifying alternative corridor routes early in the planning process that meet the major transport objectives and also reduce environmental impacts, the design and implementation stages can then be used more efficiently to refine the dual objectives, rather than trying to counter significant environmental problems later in the process.

Key Issues

In planning roads, the purpose of the road will influence its placement and required design elements. Optimal road planning processes should maximise specific transport objectives, while minimising significant environmental impacts.

For example, in scenic rainforest areas a road may have a mixed function of being both a major connecting route and a tourist road. This is likely to occur in areas of outstanding natural beauty and environmental sensitivity, such as in coastal areas and forested mountain ranges. While a high design speed may be ideal for a particular function, the consequent need for a wide road and wide cleared verges increases the linear barrier effect, leading to fragmentation and isolation of animal populations on either side of the road. In this case, it would be important to choose a road corridor placement that has scenic appeal, reduced speed, and lowered impacts on sensitive habitats and species.

How?

- ✓ Avoid areas of endangered habitats and species where possible.
- ✓ Consider whether the road may increase the threat (or be a threatening process) for a sensitive habitat or an endangered or endemic species.
- ✓ If significant impacts are indicated on a habitat and/or species, then alternative routes should be considered.
- ✓ Develop alternative options that may be assessed against both transport and environmental objectives.
- ✓ Consult Guideline D1 (page 41) for related information.



The Captain Cook Highway corridor placement achieves the transport purpose of a major connecting route while providing outstanding scenic vistas for tourists and reducing environmental impact with a lower speed limit (Photo: WTMA).



Traffic calming devices, such as coloured road edges and signage (pictured here in the Mission Beach area) indicate that drivers are moving through a sensitive conservation area and encourage reduced travel speeds.

P2 – Balance Transport and Environmental Objectives

Science Background

The El Arish-Mission Beach Road is an arterial road which passes through the Wet Tropics World Heritage Area and traverses an important habitat for the endangered Southern Cassowary. The major known cause of death of cassowaries in the Wet Tropics is collision with vehicles. Reducing the risk of vehicle accidents was a primary consideration in the road upgrade, but environmental concerns, particularly cassowary conservation, were equally important. This led to a design philosophy of increased safety for road users and cassowaries by reducing the speed environment. Upgrading strategies comprised a combination of reduced speed limits, warning signage, rumble strips and the use of coarser and different coloured tarmac along the verges of road sections at Cassowary crossing points. Although speeds were initially reduced, local drivers seem to habituate, suggesting that additional measures, including speed zone enforcement, are warranted.



The importance of ensuring safety and maintaining an unstable hillslope necessitated the use of a well-designed stabilising wall that also minimised the road ‘footprint’ and prevented erosion and sediment loss, thus balancing both safety and environmental objectives (Photo: Bruce Jennison).

Roads in Rainforest:

Science Behind the Guidelines

See: Section 1 The Impacts of Roads

P3 Minimise Impacts to Environmental Values

Using 'net environmental benefit' as a guiding criteria, choose a road corridor that minimises impacts to sensitive habitats, core habitats for threatened or rare species and reduces threats to catchment integrity.

Why?

By locating a road corridor away from sensitive forest habitats and core areas of local threatened or rare species, the impacts to flora, fauna and natural system functioning may be avoided, or at least minimised over the long-term.

Key Issues

In Australia the policy of 'no net loss'* of native vegetation was initially based on the concept of providing compensatory habitat for an impacted area. 'Ecologically Sustainable Development' has since been defined in regional planning processes as including a commitment to no net loss of environmental values.

The principle of no net loss has evolved from a simple 'replace losses on an area-for-area basis' (which possibly may be appropriate for habitats such as wetlands where values are reasonably uniformly distributed) into a 'no net loss of values', which implies recognition of variation in quality and overall function of environmental resources. This concept can be applied to all components of a landscape, with specific indicators developed to represent the most important elements.



Roads that traverse prime cassowary habitat increase the likelihood of birds dying on the road.

How?

- ✓ Consider the potential adverse impacts of alternative road corridor alignments/design on selected indicators for sensitive habitats, plant and wildlife populations, and catchment integrity (see Principles R1 to R3 (pages 15 and 19), these Guidelines).
- ✓ Obtain advice from environmental scientists and other experts regarding the potential trade-offs in overall and cumulative environmental impacts.
- ✓ Detail the predicted key impacts for each indicator for the different road corridor alternatives and re-assess through stakeholder input.
- ✓ Compare indicators for alternative corridors (and, if upgrading a road, with the existing road). Choose the alternative that achieves a net environmental benefit.
- ✓ Consult Guideline D2 (page 43) for related information.

* This is a legal requirement only in some instances, such as the Wet Tropics World Heritage Area.

P3 – Minimise Impacts to Environmental Values

Science Background

For the proposed Kuranda Range Road upgrade in far northern Queensland, seven indicators were chosen for their importance and/or ease of measurement. The indicators met the criteria of: simple, measurable, accessible, relevant and timely (SMART). Each indicator was independent from the others and included the amount of habitat disturbance, connectivity (canopy, ground and aquatic/riparian), catchment impacts and edge effects. Measurements of indicators along the existing road were compared to estimates made from detailed plans of the proposal. Overall, the upgrade had improved scores over those of the current road on the majority of these indicators.

Roads in Rainforest:

Science Behind the Guidelines

See:

- Section 1. The Impacts of Roads
- Section 2. Mitigation Strategies

P4 Mitigate and Offset Significant Impacts

Produce a comprehensive mitigation plan for all significant impacts of the road corridor that cannot be avoided, including compensation/offsets for habitat and species loss that cannot be mitigated.

Why?

Fragmentation and loss of habitat are the major causes of species decline. It is therefore necessary to provide a full account of significant impacts so that appropriate mitigation strategies and offsets can be provided as a means of maintaining important environmental values.

Key Issues

Mitigation is the last approach to be used on-site when avoidance and minimisation are not sufficient to reduce the significance of an impact. There are many alternatives to mitigating a potential impact, including short and long-term solutions, which often require substantial monitoring to ensure their effectiveness.

Offsetting should only be considered when the impacts cannot be avoided, minimised or mitigated and in areas where offsetting is a legal requirement. Primary offsetting replaces impacted values through either the provision of equivalent or greater areas of habitat (through off-site restoration or acquisition) or increased protection and ongoing management of existing habitat, preferably located in the same area, or at least the same catchment as the road corridor. The concept of providing primary offsets is somewhat related to no net loss* as it assumes that there is a net loss of habitat due to development/clearing and that habitat protection or creation should be provided to offset the loss. Secondary offsets are those that contribute to environmental benefit but may not replace the values directly, such as funding for research.

This concept of mitigation is particularly applicable to new roads. In relation to the upgrading of a route, the first principle is to attempt to have no net adverse impacts resulting from the upgrade, when compared to the existing road. As such, compensatory habitat and/or the application of primary offsetting would only come into effect once it has been determined that there has been a net loss. One important factor to consider here is that this compensatory habitat may be for one particular habitat type, species, community or population, rather than an overall assessment.

How?

- ✓ Impact avoidance, minimisation and mitigation should be thoroughly investigated before recommending offsetting (compensatory habitat protection and/or creation).
- ✓ Any area selected for primary offsets should preferably be within the same catchment although it does not need to be adjacent the road corridor.
- ✓ Refer to the Queensland Government 'Environment Offsets Policy' and the Department of Environment and Resource Management's 'Policy for Vegetation Management Offsets'**.

Science Background

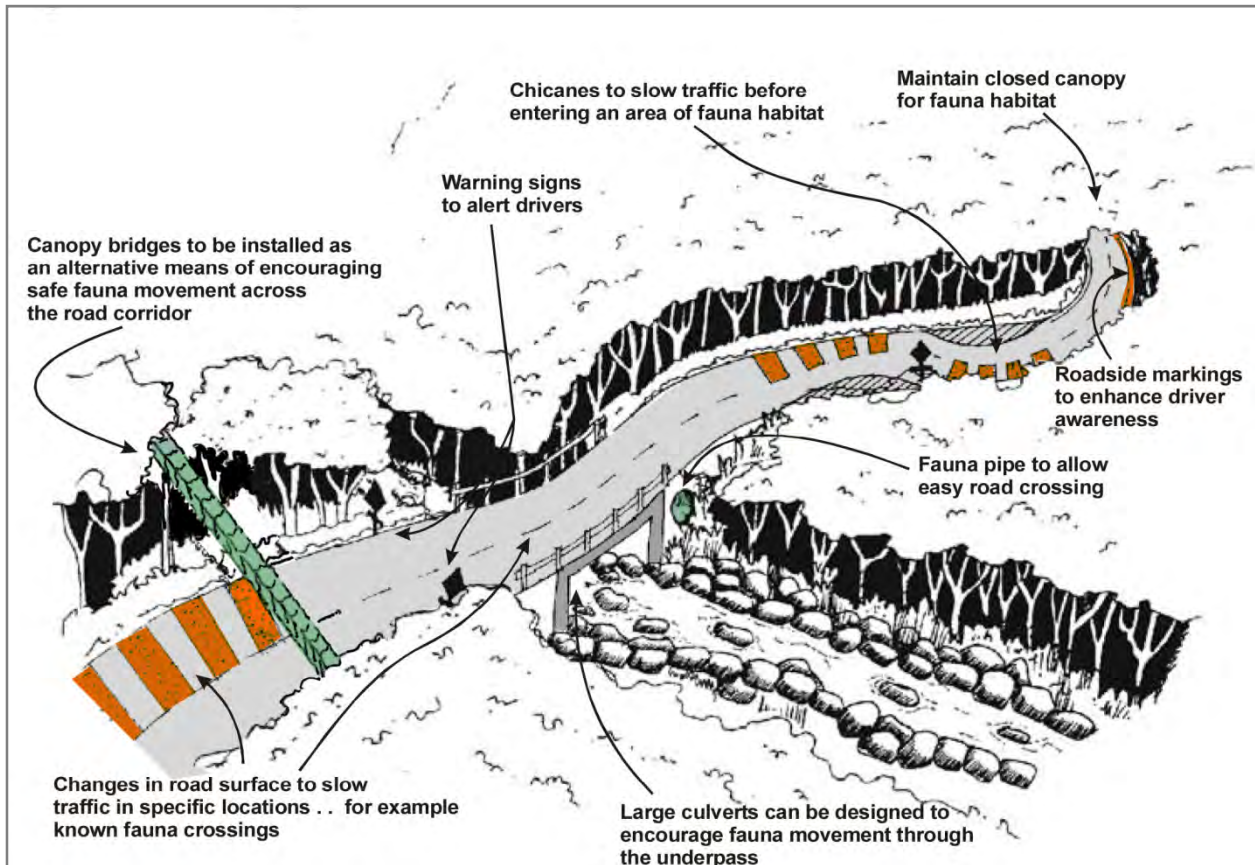
One offset method is the purchase and protection of an equivalent or greater area of habitat not currently under protected tenure. Another method involves revegetation of equivalent or greater areas of existing degraded sites such as currently unused corridors. However, there is insufficient scientific evidence to indicate the length of time and appropriate maintenance requirements for a restored rainforest to function equivalently to a native plot of the same habitat type. Studies comparing restored sites to native forest have indicated that some values, such as bird diversity,

* No net loss is a legal requirement only in some instances, such as the Wet Tropics World Heritage Area.

** http://www.derm.qld.gov.au/services_resources/item_details.php?item_id=202749

P4– Mitigate and Offset Significant Impacts

increase through time in restored sites over time scales of a few decades, but that many other aspects of ecosystem structure and function may take many decades or more to establish (Catterall *et al.* 2004). Alternatively, mitigation for impacts to a small area of habitat might be provided by structures that enhance the habitat for native species.



Examples of mitigation for the negative impacts of a road corridor on fauna.

Roads in Rainforest: Science Behind the Guidelines

See:

- Section 1. The Impacts of Roads
- Section 2. Mitigation Strategies

P5 Showcase Natural Values

Consider the scenic integrity of the area as a key value that is showcased through appropriate visual interpretation and education opportunities.

Why?

Placement of a road corridor can enhance or detract from the driver's experience of the natural values of the area. Careful planning and design can reduce the visual dominance of a road and increase the area's scenic integrity, which may lead to greater appreciation of the rainforest environment.

Key Issues

Roads can create contrasting images along landscapes by becoming visually dominant in areas of otherwise high scenic quality. Changes to the landscape can alter the visual amenity of an area through the interaction of the following factors.

Visual dominance

The degree to which the road and structures can be seen and thus detract from the scenic amenity of the natural landscape.

Scenic Integrity

The scenic integrity of the natural landscape, which can be reduced when road infrastructure (or alteration) dominates the scene and detracts from the scenic amenity of the natural landscape.

Public Sensitivity

Whether a dominant scenic alteration is actually seen by the public (e.g. from a lookout, or from a well-traveled road).

It is important to recognise that visual dominance has an effect on humans only; it does not in itself affect ecosystem integrity. As such, a visually dominant road in an isolated area, where the public is unlikely to look upon the road (i.e. low public sensitivity) would not have high scenic impact. Similarly, even in areas of high public sensitivity, if a visually dominant road is placed in an area where previous vegetation clearing reduces the scenic integrity (e.g. near a powerline clearing or cuttings along a railway line), the road may be considered to have lower impact on visual amenity than if it were in a pristine landscape.

Interpretation and Education

By providing a design placement that incorporates key ecological features of local or regional importance, the corridor can serve to enhance drivers' appreciation of the natural environment. In particular, pull-outs, educational signage, and the protection of special features (such as fencing around a large tree next to a pull-out) should be integrated into most rainforest road corridors.

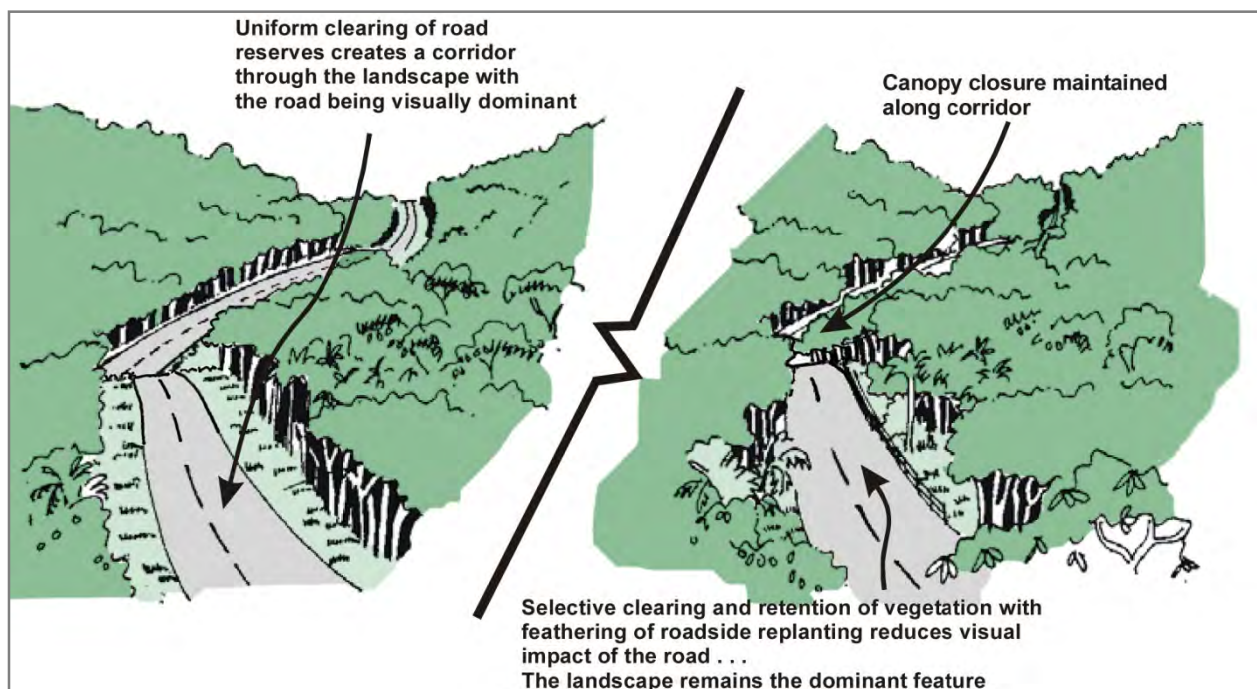
P5– Showcase Natural Values

How?

- ✓ Align roads through existing disturbed areas or those with minimal to moderate vegetation cover.
- ✓ Minimise the potential for the road to cause a linear contrast across the landscape (e.g. by following existing ridgelines and by batter revegetation).
- ✓ Use design speeds which are appropriate and designs that blend with the landscape rather than creating straight sections that cut across the landscape (e.g. use a curvilinear design).
- ✓ Locate unique features (large trees, rivers, outlooks) and design the corridor to allow for educational opportunities.
- ✓ Use appropriate signage for interpretation and warning (if certain features are sensitive to human damage).

Science Background

A recent review of the success of active revegetation and natural regeneration on cut batters found that disturbed habitat can be visually noticeable five to twenty years after their construction. Whilst new design approaches and rehabilitation techniques can reduce these impacts, it is important to note that scenic impact assessments should consider both short- and long-term effects (after revegetation of cuts and fill batters).



Poor (*left*) and best practice (*right*) road corridor design.

Roads in Rainforest:

Science Behind the Guidelines

See:

- Section 1. The Impacts of Roads
- Section 2. Mitigation Strategies

D1 Assess Safety and Environmental Impact Trade-offs

Develop a comprehensive review of trade-offs between the achievement of safety objectives and the reduction of environmental impacts, including fauna road kill and edge and barrier effects.

Why?

As a safe and efficient road corridor may be achieved under varying placement and design alternatives, it is important to select a corridor that minimises environmental impacts without compromising essential safety criteria.

Key Issues

Road safety is a central issue in the planning and design of road corridors but road safety issues can conflict with other interests such as the ecological values of areas. Three key factors may interact to influence the trade-offs between safety and environmental impacts:

1. Speed;
2. Road width; and
3. Location.

For the former, road design speeds may need to be reduced in environmentally sensitive areas to reduce the need for clearing of vegetation and to reduce potential road kill impacts. Wider roads result in less road kill but much greater barrier effects for wildlife, so these trade-offs should be considered by consulting an environmental professional. Further, the location of the corridor needs to consider the total impacts to catchment and environmental integrity, including sensitive habitats, plants and animals of the region.

How?

- ✓ At potential road kill locations and wildlife crossing points (e.g. at stream crossings and ridges) provide for reduced speed zones.
- ✓ Locate intersections and overtaking lanes in areas that are less environmentally sensitive.
- ✓ Use flexible wire rope type barriers (e.g. Briffen) wherever possible to minimise road clearing widths.
- ✓ Where possible, provide stopping sight distance to cut/fill transition zones (for safe fauna crossing).
- ✓ If a wider road is required for safety reasons, then additional underpasses or other devices may be needed to reduce significant disruption to fauna movement patterns.



Coloured (red) road verges create a narrower pavement which encourages slower vehicle speeds, while a Briffen wire fence provides a safety barrier.



Steep cuttings can trap wildlife on the road – in this location a tree kangaroo was killed by a vehicle because it could not escape.

D1– Assess Safety and Environmental Impact Design Trade-offs

Science Background

The Captain Cook Highway north of Cairns traverses an area with exceptional conservation values created by the two contrasting natural World Heritage Areas – the Wet Tropics and the Great Barrier Reef. The use of flexible wire rope type barriers on the Highway was preferred, and specially designed foundations were developed to hold the barrier posts. This has resulted in minimal disturbance outside the existing road footprint whereas the usual barrier system requires up to one metre of extra embankment to provide support for the posts. Options investigated include paving right to the edge of cut embankments and using concrete drains that minimise the amount of disturbance in steep sidelong country. The above measures were a best practice attempt at meeting environmental expectations while improving safety requirements for an important road corridor.

Roads in Rainforest:

Science Behind the Guidelines

See:

- Section 1. The Impacts of Roads
- Section 2. Mitigation Strategies

D2 Reduce Vegetation Loss and Minimise Edge Effects

Design the corridor to minimise vegetation loss and maintain habitat connectivity by incorporating narrower roads and reduced verges, by revegetating hillslopes and utilising existing disturbed areas.

Why?

The single most important factor impacting the rainforest environment is the fragmentation and loss of habitat. Therefore, by reducing the footprint of the road corridor in intact habitats, the impacts to vegetation, flora and fauna and the overall environmental integrity of the rainforest are greatly reduced.

Key Issues

By restricting corridor clearing to the minimum width required and undertaking rehabilitation, habitat loss in sensitive environments can be reduced. Minimising width also reduces linear barrier effects.

In addition, retention of canopy cover over the road will simultaneously reduce erosion, limit edge and linear barrier effects, and discourage weeds and feral animals. Maintaining the connectivity of the rainforest canopy will also allow for the safe movement of arboreal species. For the majority of narrow roads with low use (e.g. for tourist drives), keeping clearing widths to a minimum would represent a net improvement in adverse impacts.

How?

- ✓ Minimise road footprint and disturbance to vegetation.
- ✓ Maintain rainforest habitat as close to road as possible to minimise clearing width.
- ✓ Maintain canopy closure if possible, or at least some degree of canopy connectivity to reduce edge and barrier effects and restrict weed and pest invasions.
- ✓ Consider the trade-off between increased edge effects and reduced barrier effects when designing split carriageways for higher volume traffic in preference to four undivided lanes, especially where arboreal species are present.
- ✓ Identify mechanisms to reduce clearing (such as the use of barriers, e.g. wire rope, rather than clearing for the necessary recovery width).
- ✓ Design corridors to enable the revegetation and regeneration of native plants, especially those that will enable 'sealing' of rainforest edges.
- ✓ Visit the project site with your environmental officer.

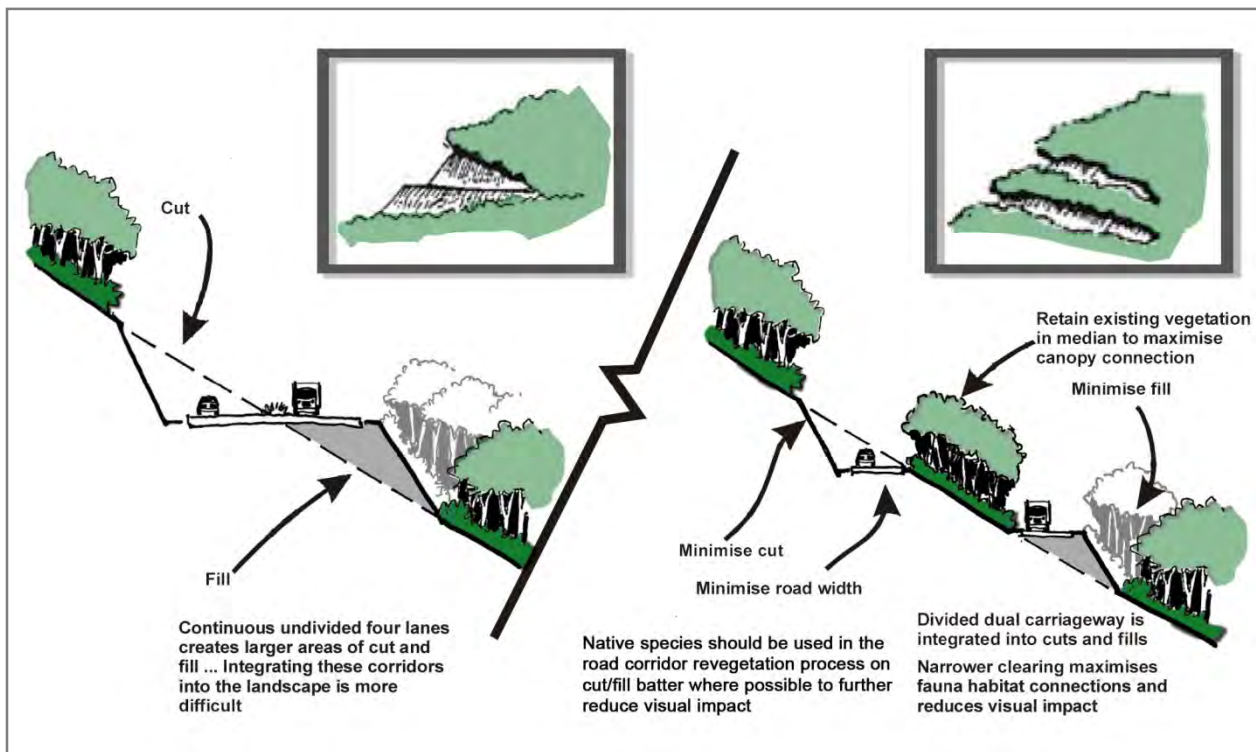
Science Background

The Lacey Creek section of the El Arish–Mission Beach Road was the first project in the Peninsula District to be constructed under permit from the Wet Tropics Management Authority. Gabions were chosen for retaining walls as they assist in reducing the width of the road clearing, and hence the barrier impacts on the forest. The fills were generally low (less than three metres) and steep with some isolated higher areas. The retaining wall was designed so it was directly under the shoulder of the road instead of outside the shoulder as originally designed. The use of gabions was successful in minimising the footprint of the project and minimising environmental impact.

Studies have shown that maintaining canopy over a road will reduce the distance that edge effects (alterations in the microclimate, vegetation and fauna) penetrate into the rainforest. Additionally, many animals including ground- and tree-dwelling species do not experience the same degree of barrier effects, moving across the road more readily when canopies touch over the road. Light-loving

D2– Reduce Vegetation Loss and Minimise Edge Effects

weeds find it harder to establish along the road verge when rainforest canopy limits the light available. Without a weedy verge, pest animals are also discouraged. Canopy can also lessen the erosive power of heavy rainfall, which is diverted down tree trunks and away from the road.



Undivided four-lane corridors (*left*) can create large barrier effects, whereas split carriageways (*right*) can improve habitat connectivity, although the trade-off with greater edge effects must be considered.

Roads in Rainforest: Science Behind the Guidelines

See:

Section 1. The Impacts of Roads

Section 1.2 Mitigation Strategies – Canopy Closure and Minimising Clearing Width

D3 Ensure Habitat Connectivity for Fauna Movement

At key crossing areas such as streams and gullies, design large zones of habitat connectivity using bridges that span over the rainforest canopy. Include purpose-built fauna underpasses in other road sections.

Why?

Allowing a safe 'zone' for movement of fauna will ensure that populations on either side of the road do not become isolated. Also, if such zones are a common design feature along the corridor, some species may regularly utilise these areas, thus reducing potential road kill.

Key Issues

In rainforest environments, habitat connectivity can be improved especially by building bridges, but also by providing underpasses on wider roads and highways to ensure safe 'movement' zones for animals. Bridges over rivers, creeks and gullies built at heights that allow rainforest trees to remain under the bridge will allow movements of fauna at all forest levels: canopy, understorey and ground-dwelling fauna can all move under the road. Therefore, designing bridges that span above the canopy could reduce both linear barrier and road mortality impacts.

Purpose-built underpasses provide an alternate method for mitigating against the barrier effect caused by roads for understorey and ground-dwelling fauna, although may not be used by as many species as high bridges. Such underpasses are usually large tunnels designed for the use of fauna only and should be considered in areas where longer sections of road lack bridges. It is important to ensure that there is sufficient vegetation adjacent to underpass openings, as well as suitable cover (i.e. brush, rock piles, logs) within the tunnel to ensure safe passage for animals. 'Land bridges' (ecoduct overpasses) are constructed, vegetated bridges over the road for fauna and provide another alternative means of providing connectivity for fauna.

How?

- ✓ Design high bridges above the canopy at watercourse crossings.
- ✓ Provide weep holes in (or preferably pipes under) bridges that disperse treated runoff to

supply moisture to plants underneath.

- ✓ Ensure sufficient light will remain under the bridge to maintain the natural environment.
- ✓ Construct bridges through top-down approaches that minimise disturbance and maintain continuous habitat, rather than attempting to revegetate later.
- ✓ Where bridges are not feasible and ground-dwelling fauna of conservation significance exist, an underpass or land bridge (ecoduct overpass) should be utilised.
- ✓ For areas where fauna are likely to cross the road, consider placing fences strategically to 'funnel' the animals towards underpasses.
- ✓ Use 'furniture' (i.e. rocks, large branches, ropes) in underpasses to allow for different sized animals to find refuge from predators.
- ✓ If a dual-purpose (fauna and drainage) culvert is used, ledges for dry passage should be provided throughout the length of the tunnel.
- ✓ Regular monitoring of all crossing structures is necessary to assess their use by target species.
- ✓ Consult the 'Wildlife Corridors' section of the TMR Fauna Sensitive Road Design Manual, Volume 1*.

Science Background

Researchers modelled the available light under bridges for the Kuranda Range upgrade for specific plants of conservation significance and more generally for canopy survival and faunal connectivity. In order to retain ecosystem function and canopy connectivity, key design features of high bridges (where the canopy can be maintained underneath) included having a gap between dual carriageway bridges of at least five metres to allow light for rainforest growth underneath. Bridge runoff after rain was treated to remove pollutants and spread under the bridge to maintain moisture.

The large underpasses on the Atherton Tablelands have been found to be effective for many species of rainforest fauna, and even for some rainforest specialists. Monitoring of

* <http://www.mainroads.qld.gov.au/en/business-and-industry/road-builders/technical-publications>

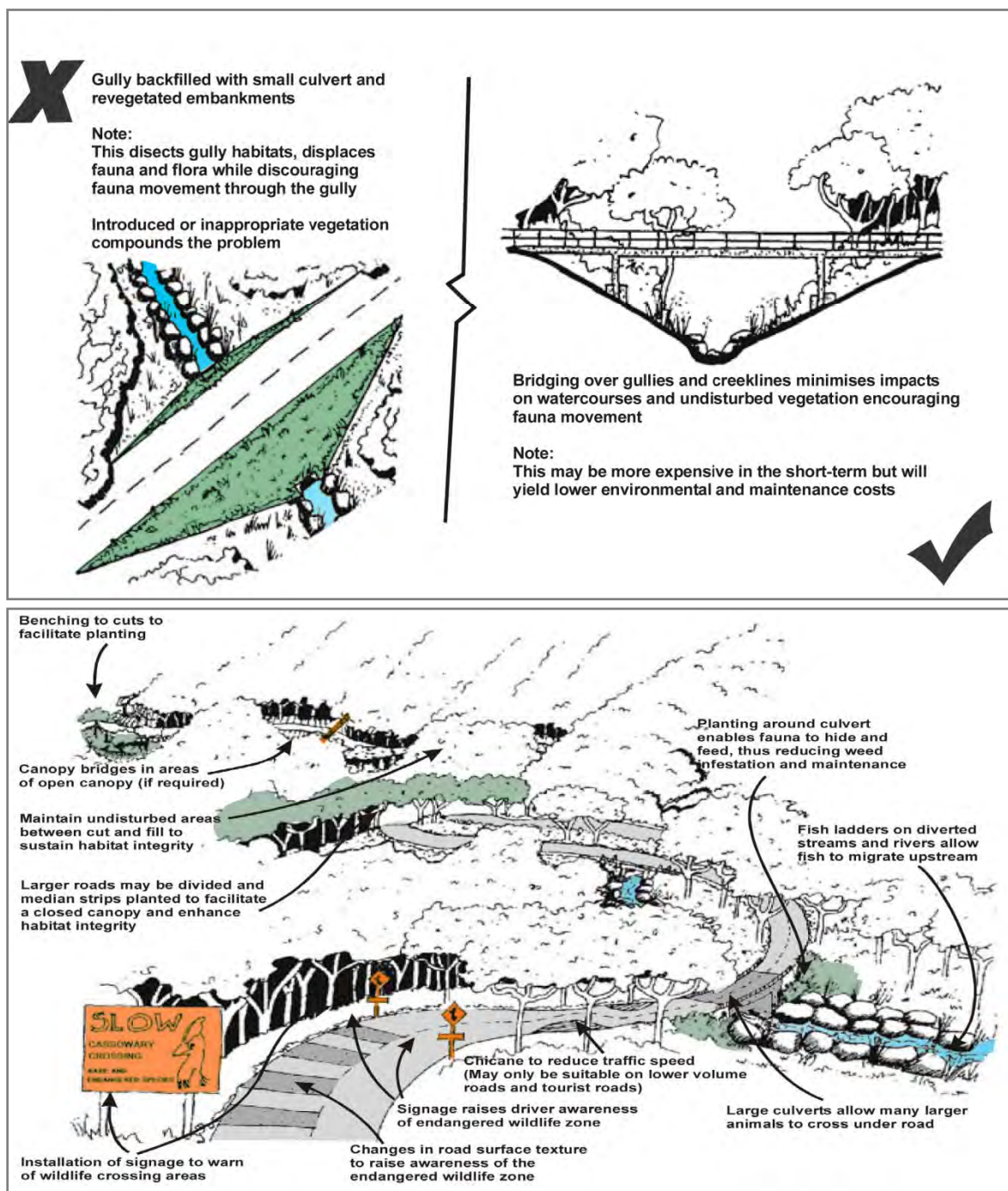
D3– Ensure Habitat Connectivity for Fauna Movement

roadkill and remote photography of animals in the underpasses show movements of many animals and reductions in roadkill, although not all animals living in the area have been observed, showing that high bridges are the best alternative. A few species (e.g. cassowaries) require bridges for movement through the landscape and are unlikely to commonly use the closed-in spaces of underpasses.

Roads in Rainforest: Science Behind the Guidelines

See:

- Section 1. The Impacts of Roads
- Section 2.2 Bridges
- Section 2.3 Faunal Underpasses
- Section 2.4 Fencing



(Top) Faunal movement is inhibited by embankments (shown in the graphic on the left) and enhanced by bridges (shown on the right). (Bottom) Designing for safe faunal movement across roads can be done using multiple approaches.

D4 Install Canopy Crossing Devices

If canopy connectivity is not possible for arboreal fauna of conservation concern, then install canopy crossing devices (such as rope canopy bridges) at appropriate locations.

Why?

Arboreal species such as possums prefer to move through the canopy and if they are forced to go to the ground they are at high risk of road mortality. Therefore, providing artificial crossing points may facilitate their safe movement across a road.

Key Issues

Although canopy connections (i.e. the branches touching or overlapping) are the preferred crossing points used by rainforest arboreal species such as the ringtail possums, rope tunnel or ladder overpasses may also facilitate movements for some species when such connectivity is lacking. Some of these species are strictly tree dwelling and thus will not venture to the ground, with many suffering extreme barrier effects from roads. Canopy crossing devices (sometimes called canopy bridges) have proved successful for tree-dwelling species in Australia and overseas. They are made from simple materials such as rope, poles, wire and cables to create a bridge over the road.



Herbert River ringtail possum using a rope bridge crossing (Photo: wildaboutaustralia.com.au).

How?

- ✓ Maintain canopy connectivity by tree branches touching wherever possible.
- ✓ If canopy connectivity is not feasible, then select several suitable crossing points (smaller spans near large trees are the best locations).
- ✓ The separation distance between adjacent canopy bridges should be determined by the distance that target species usually move around the forest.
- ✓ Consider planting trees on the roadsides to improve the natural connectivity.
- ✓ Locate canopy crossing bridges six to seven metres above the road.
- ✓ Establish regular monitoring of the bridges to assess their use by target species.

Science Background

At least four species of possums in the Wet Tropics are considered sensitive to the barrier effect of roads due to their reluctance to come to the ground. Relatively inexpensive crossing devices were used on the Atherton Tablelands in areas above three hundred metres elevation where canopy connectivity was weak or non-existent. Complex rope tunnel structures had been used successfully by a number of species of possum and so this design was trialled. Additionally, a simple rope ladder across a fifteen-metre wide canopy gap was also successful, with all targeted possums known to use it, and many different individuals using it regularly. Whether such structures are effective over wider canopy gaps associated with highways is currently being assessed with canopy bridges installed and monitored over a wide highway. Thirty months after installation they are occasionally used by some possum species, but a longer time may be required for animals to become habituated.

D4– Install Canopy Crossing Devices

Canopy crossing bridges are not as important for tree kangaroos because they may readily move on the ground. However, they have been seen venturing at least a short distance onto a rope ladder overpass. Although roadkills are a major concern for Tree Kangaroos, underpasses may be a more preferable option for this larger-bodied species.



Simplified canopy bridge – a rope ladder erected over the Old Palmerston Road
(Photo: Nigel Weston).



More complex rope canopy bridges erected on the Atherton Tablelands.

Roads in Rainforest: Science Behind the Guidelines

See:

- Section 1.5 Modification of Animal Behaviour
- Section 2.1 Canopy Closure and Minimising Clearing Width
- Section 2.5 Canopy Bridges

D5 Maintain Stream Integrity and Ensure Fish Passage

The initial design of drainage and stormwater structures should consider combining drainage function with the requirement of maintaining stream integrity and safe passage for aquatic fauna including fish.

Why?

Drainage structures can cause barrier effects and alter downstream habitats. Minimal impacts on fish and aquatic habitat can be achieved by maintaining an intact streambed and by placing road bridges above the canopy. However, where drainage structures must be used, good design and the use of appropriate materials should enable movement of all aquatic species for most of the year.

Key Issues

Drainage design should consider environmental factors such as fish passage, water quality and stream habitat connectivity for aquatic life. The goal for fish passage at these crossings is to adopt appropriate waterway design and, where necessary, provide dedicated fishways that create suitable flow conditions for passage of particular species over a range of stream discharges. Pipe and box culverts and pipe causeways create several problems for fish passage. They reduce the width of the stream and therefore increase the water velocity which prevents slow-swimming Australian fish from moving upstream to grow or breed. Further, these structures tend to scour the downstream side creating a drop in the usual water level and a barrier that most aquatic fauna cannot climb. Finally, they are generally dark and less inviting for fish to pass through and thus should only be used for intermittent gullies and drains without permanent water.

The rock ramp fishway is suitable for overcoming water surface drops and provides a good fish passage solution for small-bodied species. Rock ramps simulate the natural stream environment of riffles, pools and rapids with a gentle slope similar to the natural stream that replicates its depth, velocity and turbulence.

How?

- ✓ Avoid changing the flow velocity and normal streambed characteristics by building bridges, rather than installing culverts.
- ✓ When crossing streams maintain the streambed by using erosion prevention approaches during construction activities.
- ✓ If streambed disturbance must occur, then for fish passage use rock ramp fishway designs, and include large ridge rocks, intermediate pools and upstream and downstream aprons.
- ✓ Use a meandering alignment and an earth bed channel that follows the natural stream pathway.
- ✓ During the wet season, avoid construction in streams that provide fish habitat.
- ✓ Design roadside ditches and drains so that water does not pond and therefore attract frogs (which then may be killed on the nearby road).
- ✓ Consult the Department of Transport and Main Roads 'Road Drainage Design Manual.'
- ✓ Consult with specialists in the Queensland Department of Primary Industries and Fisheries.

D5– Maintain Stream Integrity and Ensure Fish Passage

Science Background

Road crossings of waterways are often designed with little consideration of the requirements for aquatic life. Of approximately two thousand road crossings in the Mackay district, seventy percent are considered an obstruction to fish passage. The majority of Australian fish species need to move upstream for at least one part of their life cycle. They tend to be slow swimmers so cannot swim against the fast flow rates found in drainage structures that concentrate the water flow. They also cannot 'jump' up gaps in the water flow caused by scouring at the downstream side of culverts. Research shows well-designed fishways can allow fish passage.



Partial width rock ramp fishway on University Creek, Townsville (Photo: Ross Kapitzke).

Roads in Rainforest:

Science Behind the Guidelines

See:

- Section 1 Habitat Loss and Changes in Quality
- Section 2 Fish Passage Structures

M1 Reduce Erosion and Manage Sediment

Erosion control strategies should be integrated throughout road construction and maintenance activities to prevent significant amounts of sediment entering waterways and causing localised disturbance to ecosystems.

Why?

Sediment from erosion affects water quality which can impact fish, amphibians, and aquatic invertebrate diversity, as well as aquatic vegetation. Seasonal timing, appropriate use of temporary storage areas, rapid rehabilitation of disturbed areas and restricting soil disturbance during road maintenance will minimise sediment impacts on watercourses.

Key Issues

The seasonally high rainfall found throughout most rainforest areas of Queensland means that it is essential that careful attention be given to drainage, erosion and sediment control. The Erosivity Index (EI) indicates an area's vulnerability to erosion, with many regions having high indices in the November to May period. Earthworks should be appropriately timed to avoid the peak rainfall season.

Sites with highly erodible soils or areas of rugged terrain are particularly vulnerable to erosion during and after road construction and require appropriate strategies to minimise potential impacts. Steeper slope angles and lengths, as well as stronger rainfall intensity, can magnify erosion hazards and should be considered when developing a site-specific sediment and erosion control plan. Maintaining a canopy over the road verge can reduce erosion.

How?

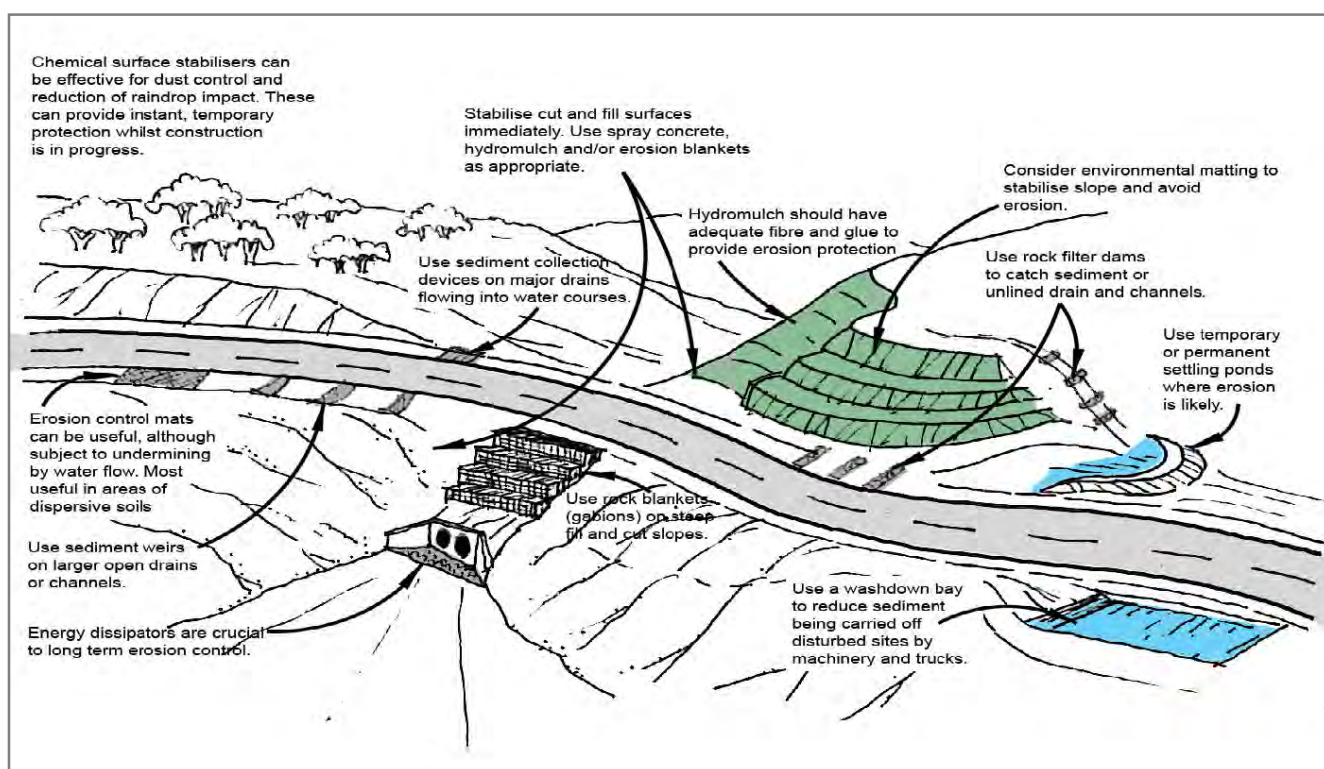
- ✓ Consult the Department of Transport and Main Roads' 'Road Drainage Design Manual' to develop a sediment and erosion control plan.
- ✓ Avoid construction during the wet season, especially December to April.
- ✓ Topsoil and vegetation should never be disturbed or removed until control measures are in place and approved (see TMR Technical Specifications for Environmental Management for specific actions to be taken).
- ✓ Disturbed areas should be rehabilitated (using hydromulching, jute mesh, etc.) immediately after cessation of earthworks. (See also M4).
- ✓ Cleared vegetation should be placed on disturbed areas along contours to reduce erosion and provide habitat for fauna.
- ✓ Surface runoff should be directed to sediment control devices such as basins, silt fences, vegetated channels or erosion control mats.
- ✓ In sensitive environments and protected areas, sediment control devices should be situated within the road structure footprint to minimise habitat loss.
- ✓ Regularly check temporary sediment control devices for functionality.

M1– Reduce Erosion and Manage Sediment

Science Background

A study on unsealed roads in the Wet Tropics found less erosion and road damage occurred where canopy was maintained above the road surface and the verge. Erosion was probably reduced because rainfall was intercepted by the multi-layered canopy and most of the water was redirected away from the road down the branches and trunks.

Additionally, during a major road upgrade in a high rainfall area, construction work was halted over the wettest months of February and March and a large sediment basin was constructed in a previously cleared area. Nevertheless, several heavy rainfall events outside those wettest months resulted in overflows of the sediment basin and discharge of large amounts of sediment into streams. This emphasises the need to avoid construction activities over at least a five month period in high rainfall areas. Clearing for a large sediment basin would be inappropriate in vegetated areas – the basin would need to be situated within the road footprint or alternative sedimentation control methods used.



During construction, erosion can be prevented through proper planning and management.

Roads in Rainforest:

Science Behind the Guidelines

See:

Section 1.1 Habitat Loss and Changes in Habitat Quality

Further reading:

Transport and Main Roads Road Drainage Design Manual

Transport and Main Roads Technical Standards

<http://www.mainroads.qld.gov.au/en/business-and-industry/road-builders/technical-publications>

M2 Minimise Pollutants

To ensure that pollutants from vehicles do not accumulate in the soil or waterways and that noise levels remain below ambient measurements, the inclusion of appropriate pollution control mechanisms should be included in the design and construction phases.

Why?

Water, soil and air pollution can cumulatively and negatively impact on local fauna and flora. Studies of the long-term consequences of exposure to contaminants indicates that effects may flow through an ecosystem from the soil, plants and invertebrates to vertebrates such as fish and mammals.

Key Issues

Road transport produces a number of pollutants that may enter the rainforest environment, causing either acute or chronic impacts. These include noise, gaseous emissions, heavy metals, hydrocarbons (oils) and rubber particles. Although the level of noise pollution varies with the amount of traffic, it has been shown to penetrate to distances of more than two hundred metres through the rainforest from the road edge. Light from streetlights and vehicle headlights can penetrate distances of fifty metres into rainforest and is also likely to disturb fauna.



Temporary bunding can help to minimise the impact of road works (Photo: Guy Chester).

The degree of localised contamination of either soil or water depends upon the amount of traffic, local climatic variables, the amount of organic material, other metal ions and the level of pH. Lead, copper, cadmium, zinc, manganese and nickel may accumulate in the topsoil of rainforest edges. These heavy metals have the potential to enter waterways or to be uptaken by local vegetation and subsequently accumulated in fauna that feed on the contaminated plants. Research results show heavy metals from vehicles can be found as contaminants of waterway sediments many kilometres downstream from the source road.

How?

- ✓ Surface runoff should be directed to sediment control devices such as basins, silt fences, vegetated channels or erosion control mats which may capture particulates and other waterborne pollutants.
- ✓ Where there are no cleared areas to site sediment control devices then utilise a pollutant trap which can capture heavy metals and organic pollutants.
- ✓ Ensure that all use of on-site chemicals adheres to TMR Technical Specifications for Environmental Management*.
- ✓ Restrict the use of fertilisers, pesticides, herbicides and surfactants along road verges.
- ✓ Use only non-residual herbicides and those without surfactants near watercourses.
- ✓ Use solid barriers such as bunds or solid fences in areas where headlights and noise may penetrate sensitive habitat (i.e. creeks).

* <http://www.mainroads.qld.gov.au/en/business-and-industry/road-builders/technical-publications>

M2– Minimise Pollutants

Science Background

Directing runoff through vegetated channels allows sediments and particulates (and attached pollutants) to settle, which greatly reduces heavy metal concentrations. Vegetation also improves the infiltration properties of soil and provides habitat for a diversity of life forms and is generally a better alternative to expensive detention ponds and drainage structures. However, as it would be inappropriate to introduce grassy vegetation into natural rainforest environments, a better alternative is to use native wetland vegetation for filtering of runoff in sediment ponds or channels.

Certain bird and frog species were less abundant near a rainforest highway in north Queensland, an edge effect that may relate to traffic noise. Other birds and frogs may alter the pitch of their calls near the road to attempt to communicate above traffic noise, which takes more energy than would otherwise be necessary and could reduce their ability to attract mates or discourage competitors.

Pollutant traps have been designed to capture pollutants from road runoff.



Installation of runoff water treatment system on rainforest highway, northeast Queensland (Photo: Bernd Lottermoser).

Roads in Rainforest:

Science Behind the Guidelines

See:

Section 1.7 Chemical Pollutants

M3 Manage Disturbance to Prevent Spread of Diseases, Pests and Weeds

Minimise the impacts of disturbance caused by construction and maintenance activities through application of appropriate hygiene and other practices that reduce the spread of diseases, pests and weeds.

Why?

During construction and maintenance, keeping vehicles clean can discourage the dispersal of weeds and diseases that are carried on vehicles. Additionally, rapid rehabilitation of disturbed areas along forest edges and waterways will minimise the establishment of non-rainforest habitat and reduce the prevalence of animal pest species.

Key Issues

During construction of new road corridors or widening of existing roads, the newly created forest edge is vulnerable to the invasion of non-native vegetation (weeds). Disturbance from earthworks facilitates the weed invasion process through vegetation clearing and by the importation of seeds and plant parts carried on the vehicle. Vehicles can also carry diseases such as *Phytophthora*, which spread to native rainforest trees, causing death. Chytrid fungus, a pathogen that kills frogs, is also likely to be transported by vehicles.

Similarly, road building materials brought onto a site need to be free of contamination from weeds and plant pathogens. Crushed rock from quarries is unlikely to contain contaminants, but material occurring in natural gravel deposits may be contaminated.



Seeds of the Japanese sunflower, an environmental weed in Queensland, can be transported along roads by vehicles, increasing the chances of the species invading and establishing in new areas (Photo: Dan Metcalfe).



Vehicles can be washed down to prevent the spread of weeds (Photo: WTMA).

M3– Manage Disturbance to Prevent the Spread of Diseases, Pests and Weeds

How?

- ✓ Consult TMR Technical Specifications for Landscape and Revegetation Works*.
- ✓ Design roads without grassy or low shrubby verges and maintain rainforest close to the road edge, including overhanging canopy cover.
- ✓ Retain topsoil and respread in the original locations.
- ✓ Wash down all plant and equipment entering from other sites in an approved facility.
- ✓ Develop disposal points for material cleared out of the sediment traps and revegetate as soon as possible.
- ✓ Ensure road-building materials are free of contamination by weeds and pathogens.
- ✓ Use weed-free sediment traps (e.g. avoid hay bales).
- ✓ Consult the guidelines for management of Phytophthora (Worboys 2006).
- ✓ Consider efficient new technologies such as Weed Seed Blowers on tractor slashers.

Science Background

Phytophthora cinnamomi, a soil and water-borne disease that causes rotting of the roots and death of many native plants, was first found in northern Queensland's tropical rainforests in 1975 and is particularly associated with upland areas on granite or rhyolite soils. Research has shown that many dieback patches occur close to roads, implying that road use or maintenance activities may be implicated in the spread of dieback. Best practice guidelines for minimising the spread of *Phytophthora* have been developed for the Wet Tropics Bioregion: these guidelines are also suitable for all rainforests areas in Queensland. Similar attention to hygiene of both vehicles and workers' boots will help prevent the spread of chytrid fungus, which is known in Tasmania to be associated with roads.

Research has shown that maintaining rainforest close to the road with canopy overhanging the verge (and road itself if possible) can help to reduce weed invasions by limiting the light available to light-loving weeds. This, in turn, restricts invasions by non-native fauna including feral pests.



A Weed of National Significance, *Lantana camara* is an invasive plant that in some cases prevents the regeneration of native vegetation along disturbed areas.



Cane toads are prolific breeders and feed on a variety of dead and living matter. They are an opportunistic species that can move along roads and weedy verges to invade new areas.

Roads in Rainforest: Science Behind the Guidelines

See:

Section 1.6 Invasion by Weeds, Diseases and Feral Animals

Section 1.8 Vehicular Disturbance

Further reading:

Worboys, S. (2006) Guide to monitoring *Phytophthora*-related dieback in the Wet Tropics of North Queensland. Cooperative Research Centre for Tropical Rainforest Ecology and Management (Rainforest CRC): (<http://www.jcu.edu.au/rainforest/reports.htm>)

M4 Manage Topsoil

During construction and maintenance activities, all topsoil from disturbed or cleared areas should be temporarily stored for rapid reuse in revegetation zones.

Why?

Topsoil is often the most important factor in successful rehabilitation, particularly where the objective is to restore a native ecosystem. Therefore, the proper maintenance and reuse of topsoil can greatly facilitate the successful revegetation of disturbed areas.

Key Issues

Topsoil contains many important materials that assist in natural regeneration of a site, including seeds and other plant propagules (such as rhizomes, lignotubers, roots etc.), soil microorganisms, organic matter and plant nutrients. Once removed, topsoil should be directly used in revegetation, rather than storing in stockpiles for later use. If stored for too long, stockpiles become anaerobic (without free oxygen), soil structure deteriorates, organic matter and nutrients may be lost, seeds deteriorate, other plant propagules die and populations of beneficial soil microorganisms are reduced.



Poor maintenance of geofabric can result in erosion problems, weed invasions and failure of revegetation (Photo: Bruce Jennison).

Soil testing should be undertaken on all imported topsoil used in revegetation programs. Soil ameliorants should be added, if necessary, to correct pH or soil structure. Any imported topsoil should be certified and proven weed free. Topsoil should be handled only when in a moist condition. Many types of topsoil lose their texture, structure and consistency if they are handled when too dry. Conversely, some soils will pug (set very hard in large clods) if they are too wet when handled.

How?

- ✓ Salvage topsoil and respread on original areas as soon as earthworks are complete.
- ✓ Remove the complete A1 soil horizon (the layer of mineral/organic material) or, where this is not obvious; remove the top 100-300mm.
- ✓ Soils should not be stripped or replaced when too wet or too dry.
- ✓ It is preferable to reuse topsoil immediately rather than storing it in stockpiles.
- ✓ If topsoil must be stockpiled then:
 1. Form long and low (preferably 1.5m or lower, or no more than 3m high) piles;
 2. On level surfaces; and
 3. Cover with papermix mulch if longer than a month's storage time.

M4– Manage Topsoil

Science Background

Research has shown that the density, growth-rate, and number of native plants are significantly increased when an area is rehabilitated with directly returned, fresh topsoil as compared to sites where stockpiled topsoil has been used. Ideally, topsoil should be re-spread in the reverse sequence to its removal so that the organic layer, containing any seed or vegetative parts, is returned to the surface.

Topsoil should be spread over a roughened surface to a compacted depth of about 40-60mm on lands where the slope exceeds 4(H):1(V), or to a depth of 75-100mm on lesser slopes. If possible, on moderate slopes, topsoil should be tapered from a thickness of 100mm at the top of the slope, to 75mm at the bottom to allow for downward creep of the soil.

Roads in Rainforest:

Science Behind the Guidelines

See:

Section 3 Revegetation Techniques

M5 Revegetate Disturbed Sites

Disturbed natural habitat should be promptly revegetated throughout construction and maintenance phases.

Why?

Effective, phased revegetation of disturbed areas, including road verges, will help prevent erosion, minimise edge and barrier effects, and improve the overall habitat quality of the impacted area.

Key Issues

Rapid revegetation of disturbed areas can decrease the risk of erosion and sedimentation. Construction sites, roadside drains, road batters, disused sites and other areas with exposed soil are all sources of sediment during rainfall events. Temporary erosion protection measures (such as cover crops or hydromulching) are useful in the short-term, but they have a limited effectiveness over longer time frames. Therefore, revegetation using local native plant species should commence early, to control erosion and prevent weeds from establishing in the area. The long-term effectiveness of erosion and sediment control may be improved by encouraging progressive revegetation of batters during construction using freshly stripped topsoil and mulch that has been chipped from site vegetation. Establishing native species on cleared verges will also reduce future maintenance costs as mowing and herbicide use will be minimised.

How?

- ✓ Involve revegetation contractors early in the planning phases to allow for seed collecting from local areas.
- ✓ Minimise the removal of existing vegetation.
- ✓ Fence areas to limit pedestrian and vehicular access.
- ✓ Progressively revegetate disturbed areas.
- ✓ Conform to specifications (materials, rates and methods of application) for seeding, fertilising and mulching (paper or sugar cane mulch).
- ✓ Revegetate verges to the table drain with low-growing native grasses or ground cover.
- ✓ Use erosion control blankets and other methods depending on the steepness of the slope and the soil type.



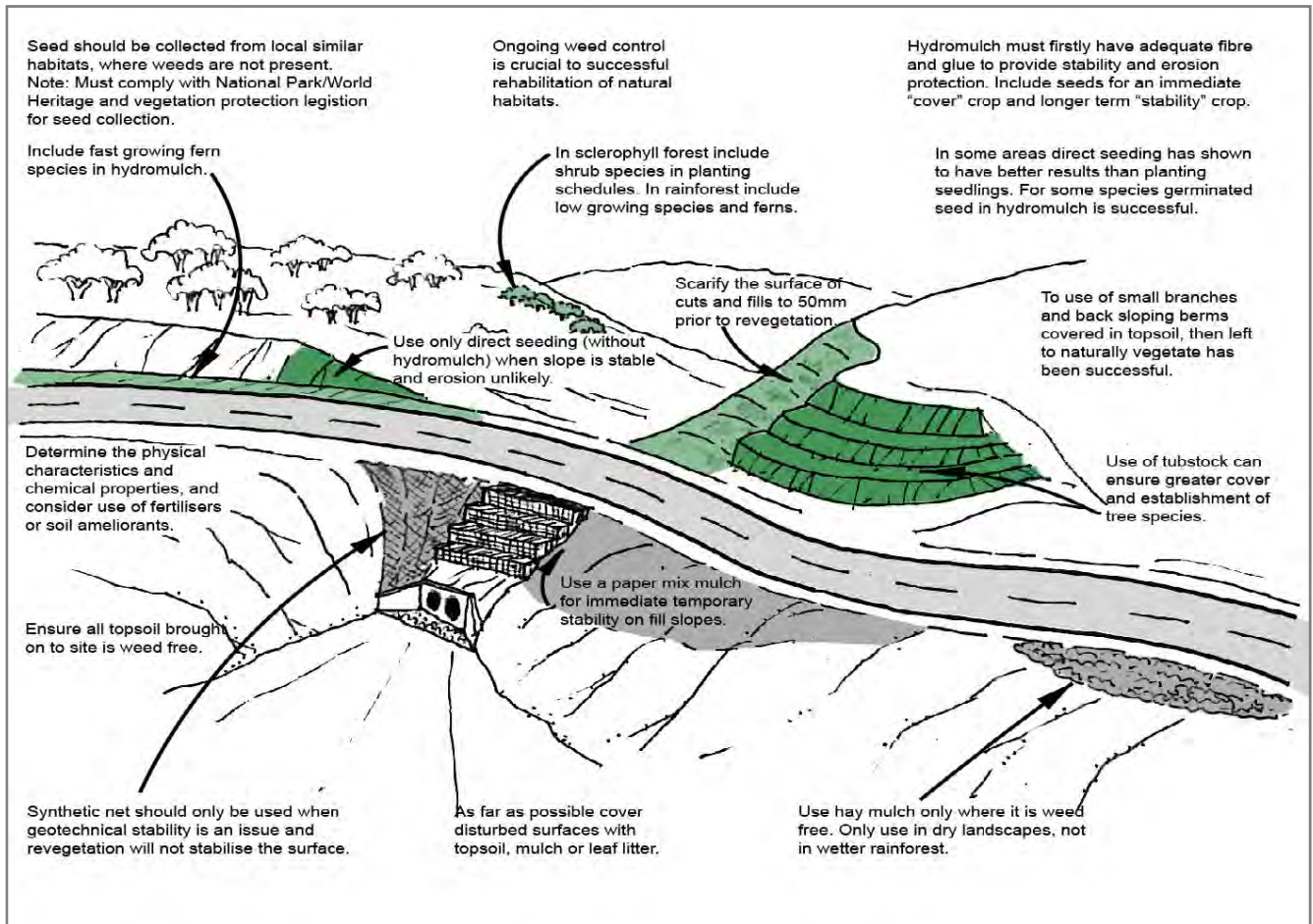
Effective revegetation of disturbed areas helps to prevent erosion, minimise edge and barrier effects and improves the overall habitat quality of the area.

Science Background

In the Wet Tropics region, research has been conducted on the revegetation success of roadside batters. In particular, slope aspect of steep cut batters was an important factor in the potential success of revegetation, with south facing slopes having lower revegetation success than west and north facing slopes. The slope gradient of cut batters does not appear to be a major factor in revegetation success, although on steeper slopes (>55 degrees) ferns, trees and shrubs were more abundant. Research also indicated that the main type of native species which naturally establish on

M5– Revegetate Disturbed Sites

cleared batters have wind-borne seeds, so having the site in close proximity to native forest will facilitate revegetation.



Benches should drain into lined structures which convey water to concrete-lined drains.



Terraced products are available commercially that allow stabilisation of cuttings and fill embankments. Care must be taken to ensure plants in these products have sufficient space for growth (Photo: David Rivett).

Roads in Rainforest: Science Behind the Guidelines

See:

Section 3 Revegetation Techniques

M6 Maintain and Monitor Ecological Works and Devices

A plan for maintenance and monitoring of revegetated areas, fish passages, sediment basins, culverts, underpasses, overpasses and canopy crossing devices must be included in the final implementation phase of road corridor works.

Why?

The functioning of restored areas and installed ecological devices is critical to ensuring a healthy local ecosystem. This requires a long-term commitment to monitoring and maintaining these features on a regular basis.

Key Issues

When a road corridor is being constructed or upgraded, it is important to ensure that included ecological works, such as revegetation, purpose-built fish culverts, sediment basins and animal movement devices are given appropriate attention and provided resources into the future. The most effective approach is to develop a plan that contains the following information for future implementation:

- Specific sites or devices with purpose specified (e.g. for fish passage, animal movement).
- Monitoring schedule (timetable) with specific tasks (e.g. monitor use of structure, examine blockages, monitor growth and survival of plants, etc.).
- Maintenance procedures that may be required and actions to be taken (e.g., removal of debris in culvert, replacement of natural items within and/or nearby, human trash removal).
- Follow-up with appropriate environmental managers when particular issues arise (e.g. poor water flow in culvert causing stagnant water).
- Resourcing (funds and personnel) for carrying out the plan.

The plan should be considered an ongoing project that will require intensive monitoring in the first several years, with reduced effort through time, depending on the nature of the works and devices. However maintenance of structures will be an ongoing requirement.



Early stages of revegetation of high fill batters on the East Evelyn Road upgrade: use of geofabric for initial stabilisation, terraces to allow access for maintenance and tube stock of species native to the area. These works must be maintained through weed control until canopy closure is established (Photo: Bruce Jennison).

How?

- ✓ Design a specific revegetation monitoring plan – this should be done at the same time as the revegetation design plan.
- ✓ Develop an environmental works and devices monitoring and maintenance plan for all other non-revegetation works.
- ✓ Consider other types of monitoring needed, including regular surveys for roadkills in likely 'hotspot' locations, and monitoring for use of crossing structures.
- ✓ Be realistic in allocating an adequate amount of time and funding for monitoring, especially in the first three years.

Science Background

In one large faunal underpass project, monitoring demonstrated use by many animal species. Long-term monitoring was required to determine whether rare, target species used the underpasses. Over time, some associated drainage works and underpass ‘furniture’ deteriorated, showing that funds required to maintain the structures should be included in an overall budget at time of construction.

Monitoring of rainforest road batters revegetated with trees and shrubs has demonstrated that, in areas which are not maintained until canopy closure is established, the trees and shrubs are often replaced by weeds and grasses. Similarly, research regarding revegetation projects show that post-planting maintenance is required for several years until canopy establishment or funds will be wasted.

Research shows that animals often take some time to habituate to underpasses, canopy bridges or other crossing structures. Monitoring for several years may be required to determine whether these structures are effective.

Further Reading

Transport and Main Roads Fauna Sensitive Road Design Volumes 1 and 2

<http://www.mainroads.qld.gov.au/en/business-and-industry/road-builders/technical-publications>



Site prepared for revegetation using hydromulching, Gillies Highway, January 2005 (Photo: Nigel Tucker).



Hydromulching results at the same cutting on Gillies Highway ~ January 2006 (Photo: Nigel Tucker).