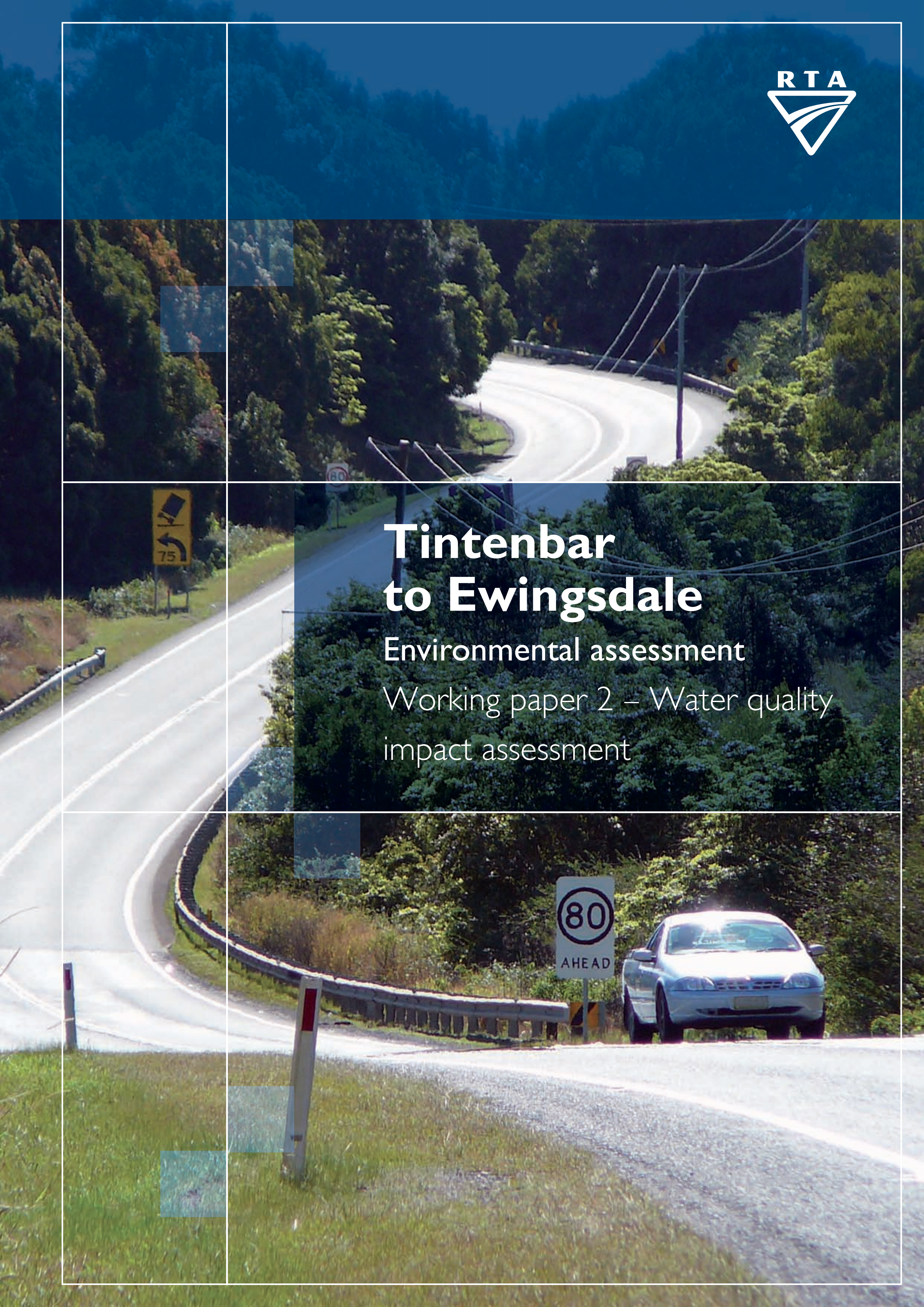
RTA



Tintenbar to Ewingsdale

Environmental assessment

Working paper 2 – Water quality impact assessment

Roads and Traffic Authority

Tintenbar to Ewingsdale Pacific Highway Upgrade

Working Paper 02 - Water Quality Impact Asssessment

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Glossary

Acute impacts - meaning an event that would happen infrequently but have a high event severity. For example the risk of spill of diesel from a tanker entering a neighbouring watercourse following a road traffic accident.

Best management practices - these are stormwater treatment techniques that can be put in place to retain pollutants and which are designed in accordance with best management practices.

Catchment – the area of land which collects excess rainfall (run-off) and directs it to a receiving water body.

Chronic impacts - an event that would occur frequently with a low event severity, for example increased sediment transport occurring in most runoff events may result in small incremental changes each time runoff is generated that over time could accumulate to have a high consequence.

Discharge – the rate of flow of water measured in terms of volume over time.

Event mean concentration - often abbreviated as EMC, it describes the average concentration of a pollutant throughout the whole duration of a storm event. EMCs are estimated by sampling and testing the water quality at even intervals through out the duration of a storm event. Many storm events are included in the sample to provide a meaningful estimate.

First flush - describes the first 10mm of runoff from a catchment and implies that most of the pollutants will be flushed off the catchment surface within the first 10mm. Is a term applied to hard impervious surfaces.

Multiple barriers approach - this is a risk management approach proscribed by the Australian Drinking Water Guidelines. This approach seeks to put in place numerous control points or barriers to pollution to ensure that drinking water is safe. An example of a multiple barriers approach is one which starts with catchment management, i.e. controlling activities on catchments to prevent pollution in the first instance, managing riparian corridors to create a stable ecosystem that is able to assimilate pollutants and finally putting in place a treatment plant to remove pollutants that filter through the other barriers. This approach differs radically from the traditional approach of relying on a single barrier, i.e. a water filtration plant.

MUSIC - the model for urban stormwater improvement conceptualisation (MUSIC), was developed by the Co-operative Research Centre for Catchment Hydrology to predict the effectiveness of various stormwater treatment techniques. It is ideally used to simulate the impact of a change in land use, such as the development of highway on rural land followed by an estimate of the performance of a stormwater treatment train put in place to retain pollutants. It is best used as a comparative assessment tool, i.e. to compare predevelopment with post development or to measure the effectiveness of treatment measures.

Treatment trains - describes a stormwater management technique which puts into place a hierarchy of treatment measures. A treatment train will involve the initial targeting of coarse pollutants followed by finer pollutants.

1 Introduction

The NSW Roads and Traffic Authority (RTA) have engaged Arup to undertake the environmental assessment and concept development for the proposed upgrade of the Pacific Highway between Tintenbar and Ewingsdale. This upgrade is part of the overall Pacific Highway Upgrade Program and will link the northern end of the approved Ballina bypass to the existing dual carriageway at Ewingsdale.

This Working Paper, prepared by Arup and Storm_Consulting, assesses the potential water quality impacts of run-off from the proposed upgrade on local surface water receiving environments, particularly the drinking water catchment areas of Emigrant Creek and Wilsons River that are traversed by the proposed alignment.

1.1 Project description

1.1.1 General

Below is a brief description of the proposed upgrade between Tintenbar and Ewingsdale.

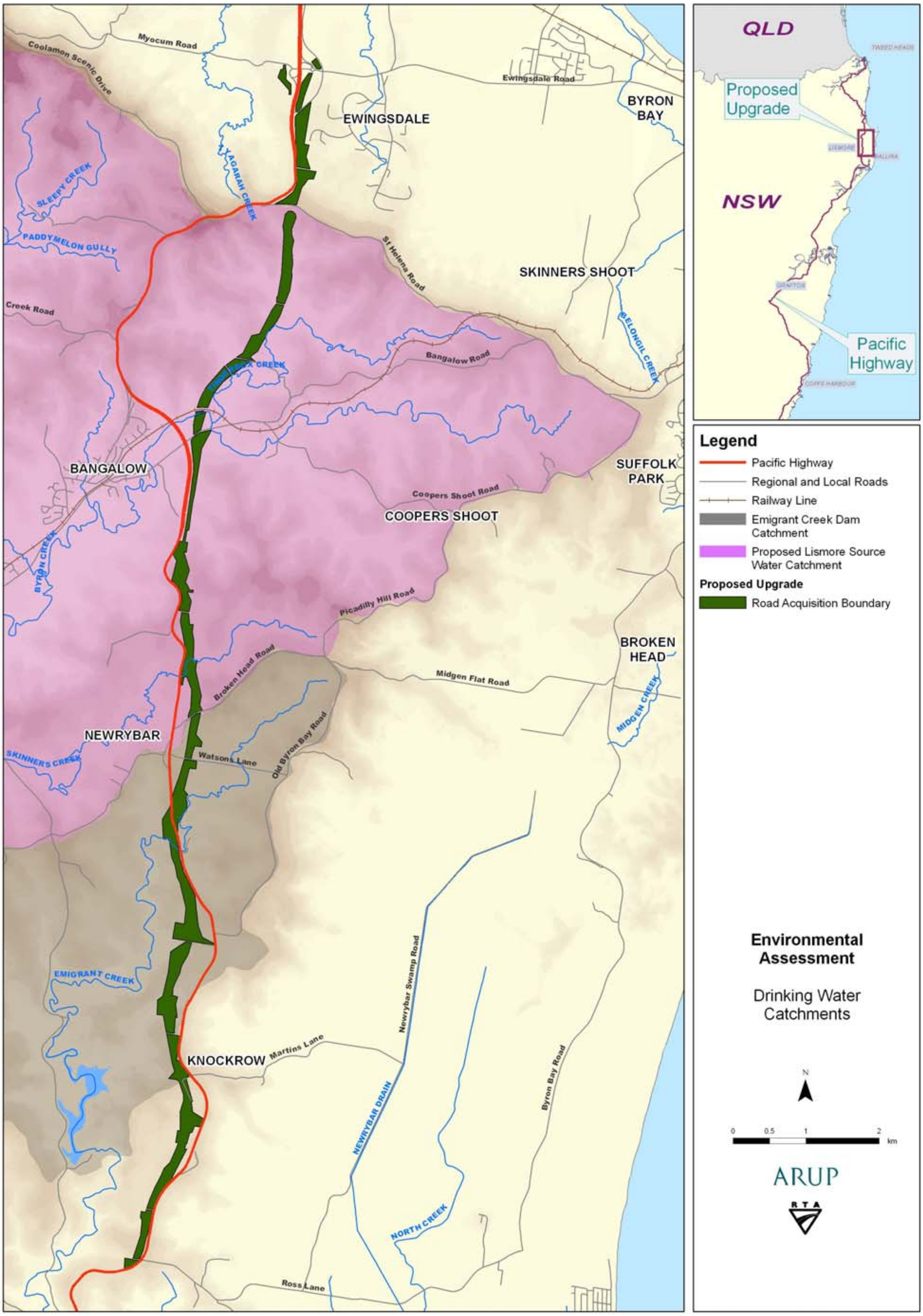
The proposed upgrade would be approximately 17 km starting at Ross Lane in Tintenbar and extending north to the existing Ewingsdale interchange, near the settlement of Ewingsdale. Generally the proposed upgrade would be in close proximity to the existing highway corridor from Ross Lane to the Bangalow bypass. From Bangalow the proposed upgrade would diverge to the northeast through Tinderbox Valley. From here the proposed upgrade would avoid the steep grades of St Helena Hill by way of a tunnel approximately 340 m long and 45 m below the ridge line. North of the tunnel the proposed upgrade alignment is located immediately to the east of the existing highway before tying into the Ewingsdale interchange.

Between Martins Lane at Knockrow and Broken Head Road at Newrybar the proposed upgrade passes through the drinking water catchment area for the Emigrant Creek dam for a distance of 5.2 km. Thereafter the proposed upgrade is in the drinking water catchment area for the Wilsons River until the alignment enters the tunnel under St Helena Hill, a distance of 7.2 km. The existing Pacific Highway passes through both of the drinking water catchments detailed above for distances of 4.8 km and 8.4 km respectively. The proposed upgrade route and drinking water catchment areas are shown in **Figure 1** over.

The general features of the proposed upgrade are as follows:

- Four-lane divided carriageways, two lanes in each direction, with a wide median allowing for the addition of a third lane in each direction.
- Modifications to the Ross Lane interchange. This interchange will be constructed as part of the Ballina bypass project.
- Modifications to the existing Ewingsdale interchange to provide full access between the modified local and regional road network and the highway.
- Class M standard highway with a 110km/h design speed and access control over the full length.
- A half interchange at Ivy Lane. North facing ramps provide access between the local road network and the proposed upgraded highway to the north.
- A half interchange at Bangalow. South facing ramps provide access between the local road network and the proposed upgrade to the south. This arrangement replicates the arrangement with the existing Bangalow bypass.
- Six twin bridges and four underpasses allowing roads and creeks to pass underneath the proposed upgrade. These would include twin bridges above Byron Creek and the existing Casino – Murwillumbah railway on the north side of Byron Creek.

Figure 1 Drinking Water Catchment Areas



- Sedimentation basins to intercept carriageway run-off for treatment before discharging into the natural watercourses.
- Signage providing clear directions for traffic at Ross Lane, Ivy Lane, Bangalow and Ewingsdale interchanges.
- Twin parallel tunnels under St Helena ridge (one tunnel bore for each carriageway). The tunnel would be about 340 m long and about 45 m below St Helena Road.
- Safe median and outer verges, including safety barriers where required.
- The existing highway would be retained as a continuous road for local and regional traffic. It is further anticipated that between Ross Lane and Bangalow the existing highway would be handed over to the councils. Between Banagalow and Ewingsdale the existing highway would continue to function as a regional link between Lismore / Bangalow and the north and would be retained by the RTA.

1.1.2 Design guidelines

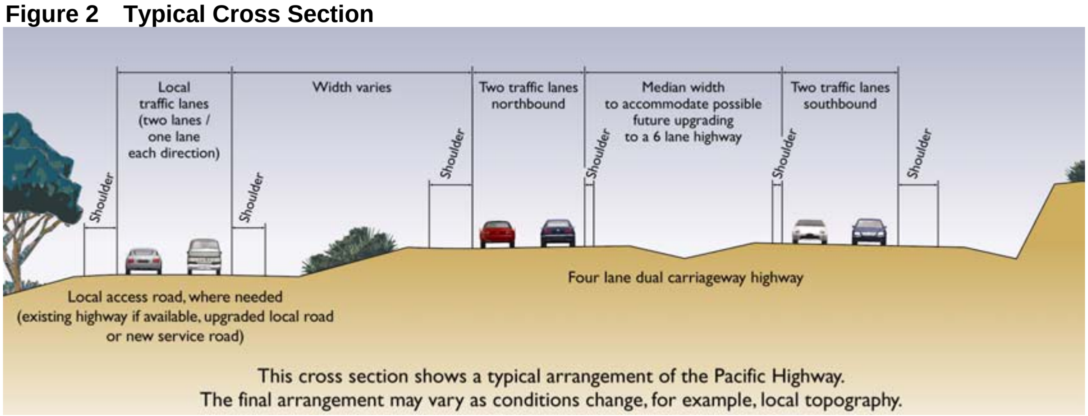
The Tintenbar to Ewingsdale upgrade will be designed as a ‘M Class’ upgrade as designated in the *Draft Pacific Highway Design Guidelines* (RTA 2005b). Key standards applying to this project are summarised in **Table 1** below and a typical cross-section for the upgraded highway is shown in **Figure 2** Typical Cross-Section over.

Table 1 Pacific Highway Design Guidelines

Feature	Upgraded Highway	Other Roads including Existing Pacific Highway
Design speed	110 km/h horizontal and 100 km/h vertical	100, 80 and 60 km/h dependent on function
Cross section	Dual carriageway with two 3.5 m wide lanes, inner shoulders 0.5 m, outer shoulders 2.5 m, minimum median width varies from 2.6 m to 12 m depending on median barrier type	Two lane single carriageway with maximum 2 m shoulders dependent on road function
Vertical grades	Desirable maximum grade 4.5% Absolute maximum grade 6% (desirable maximum length 500 m) Climbing lanes may be required depending on length of sustained grades above 4.5%	Not specified, refer Road Design Guide (RTA 1996)
Surface Drainage	Must be provided where the works intercept runoff, floodplains, watercourses, depressions or drainage lines All outlets must incorporate energy dissipation, erosion and sediment control Batter catch drains must be provided upslope of all cut batters	No change to existing conditions unless realigned as part of the upgrade works
Flood immunity	1 in 100 year desirable or 1 in 20 year absolute minimum across floodplain. Effects of Probable Maximum Flood to be assessed	No change to existing conditions
Intersections	Grade separated, no at-grade intersections permitted	At-grade
Landscape design	Urban and landscape design and treatments to be in accordance with objectives of the Pacific Highway Urban Design Framework	No change to existing conditions unless realigned as part of the upgrade works

Feature	Upgraded Highway	Other Roads including Existing Pacific Highway
Access to highway	Restricted	Unrestricted
Local access	Alternative routes to be provided	Service roads or local arterial road networks to provide alternative routes for local traffic
Clearances above highway	5.3 m for the full road width including shoulders (5.3 m for any pedestrian bridges), 7.5 m above railway	5.3 m desirable, 4.6 m minimum

Figure 2 Typical Cross Section



1.2 Director General's requirements

In relation to the water management issues associated with the environmental assessment of the proposed Tintenbar to Ewingsdale Pacific Highway upgrade, the relevant section of the Director-General's requirements (DGRs) is as follows:

Surface and Ground Water – including but not limited to:

- water quality impacts to the catchments of Emigrant Creek and Wilson River, in consultation with Rous Water, taking into account impacts from both accidents and runoff (i.e. acute and chronic impacts) and considering relevant public health and environmental water quality criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000.*

1.3 Assessment methodology

The assessment of water quality impacts and the development of mitigation measures for the proposed upgrade involved:

- Review of existing conditions in Emigrant Creek and Wilson River catchments areas.
- Assessment of existing highway water quality and ecological impacts.
- Stakeholder consultation with Rous Water and local community members.
- Hydrological analysis to determine run-off flows from the proposed upgrade.
- Literature review of potential impacts on water quality associated with highway drainage.
- Defining the proposed treatment approach to be used for the separate catchment areas.

- Development of construction water quality treatment measures based on guidelines in *Managing Urban Stormwater – Soils and Construction 4th Edition* published by Landcom (2004) also referred to as the "Blue Book" and the draft DECC document – *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction*.
- Development of operational water quality treatment measures based on guidelines in *AP-R232 – Guidelines for treatment of stormwater runoff from the road infrastructure* published by Austroads (2003), RTA document – *Procedure for selecting treatment strategies to control road runoff* (2003), and more generally from best-practice measures.
- Development of a MUSIC water quality model to assess the performance of proposed operational treatment measures using representative rainfall data provided by the Australian Government - Bureau of Meteorology.
- Review and discuss potential chronic and acute pollution impacts and performance of treatment measures proposed for Pacific Highway upgrade.

2 Background and context

2.1 Overview

Section 2 of this working paper details the existing conditions of the Emigrant Creek and Wilsons River drinking water catchments in relation to the proposed Tintenbar to Ewingsdale Pacific Highway upgrade. The section describes in detail the following aspects:

- Drinking water supply arrangements for the local government areas.
- The Emigrant Creek dam and its surrounding catchment area.
- The operational features of the Emigrant Creek water treatment plant.
- Existing water quality in the Emigrant Creek dam catchment.
- The Wilsons River catchment and the Lismore Source water extraction facility.
- Existing water quality in the Wilsons River catchment
- Aquatic ecology in Emigrant Creek, Byron Creek, Skinners Creeks, and Tinderbox Creek, a tributary of Byron Creek.
- Alignment and operation of existing Pacific Highway.

2.2 Drinking water supply

Rous Water is a single purpose County Council with a primary responsibility to supply water in bulk to the local government areas of Lismore, Byron, Ballina and Richmond Valley.

Water presently comes from two main sources, being Rocky Creek dam and Emigrant Creek dam. Other minor sources include plateau bores and Woodburn bores.

Rocky Creek dam was constructed in 1953 and has a capacity of 14,000 ML and a safe yield of about 11,600 ML per annum. Emigrant Creek Dam was constructed in 1967-68 to provide a water supply to Lennox Head and Ballina and is currently used to supplement the supply from Rocky Creek dam. Its capacity is 820 ML with a safe yield of about 2,600 ML/annum although this will fall to 1,600 ML/annum in the future due to environmental flow requirements downstream of the Emigrant Creek dam.

The Rous Water *Regional Water Management Strategy* which was adopted in 1995 (and was amended in 2004) presented a range of options to meet water requirements. Rous Water adopted four actions from the strategy:

- Investigate and develop alternative water sources such as reuse, where appropriate.
- Implement demand management measures.
- Develop the Lismore Source.
- Develop Dunoon dam.

Rous Water has also been undertaking demand management to reduce the demand for water however, with the growth in population in the area, the existing supplies are considered not adequate to meet Rous Water's future needs. They are therefore proceeding with the augmentation of the supply by the development of a new water source at Lismore.

The new water source at Lismore is referred to as the Lismore Source and will consist of a pump station abstracting up to 30 ML/day of water from the upper reaches of a tidal pool in the Wilson River about 5km upstream of Lismore (Howard's Grass).

Rous Water also maintains an active interest in catchment management in order to promote healthy catchment areas producing good, clean drinking water. Particular emphasis in the Emigrant Creek dam catchment has been on the provision of healthy buffer zones that can be actively managed for water quality purposes through riparian restoration.

2.3 Existing environment

2.3.1 Emigrant Creek catchment and Emigrant Creek dam

Emigrant Creek dam is an existing water supply reservoir with a new, advanced water treatment plant located on the south-western side of the reservoir, and near to the dam wall.

Emigrant Creek drains a catchment consisting of a variety of land uses including grazing and horticulture (mainly macadamia plantations), which together comprise over 77% of the total area. Other landuses include residential, nurseries and other horticulture including orchards and plantations of banana, coffee and stone fruit. Only a small percentage (7.7%) of the catchment is bushland which predominantly surrounds the bottom half of Emigrant Creek Dam (Rous Water, 2004 in SKM 2005).

Aerial photos of the catchment clearly show the extent of various land uses, the catchment boundaries and the existing highway. The key details of the catchment are shown in **Figure 3** over including the preferred route corridor. The dam, water filtration plant and its intake are located at the downstream end of the catchment.

Key catchment data

- Area of catchment: 1960 Ha (19.6km^2).
- Area of reservoir: 26.16 Ha.
- Acquisition of land by the RTA for the upgrading of the highway within Emigrant Creek catchment: 81.6 Ha (~4% of catchment area).
- Area of new carriageway constructed as part of the proposed upgrade: 12.45 Ha (~ 0.6% of the catchment area).
- Length of Pacific Highway upgrade in catchment: 5.2km.
- Distance of Pacific Highway upgrade from Emigrant Creek dam: 850m to 1250m.

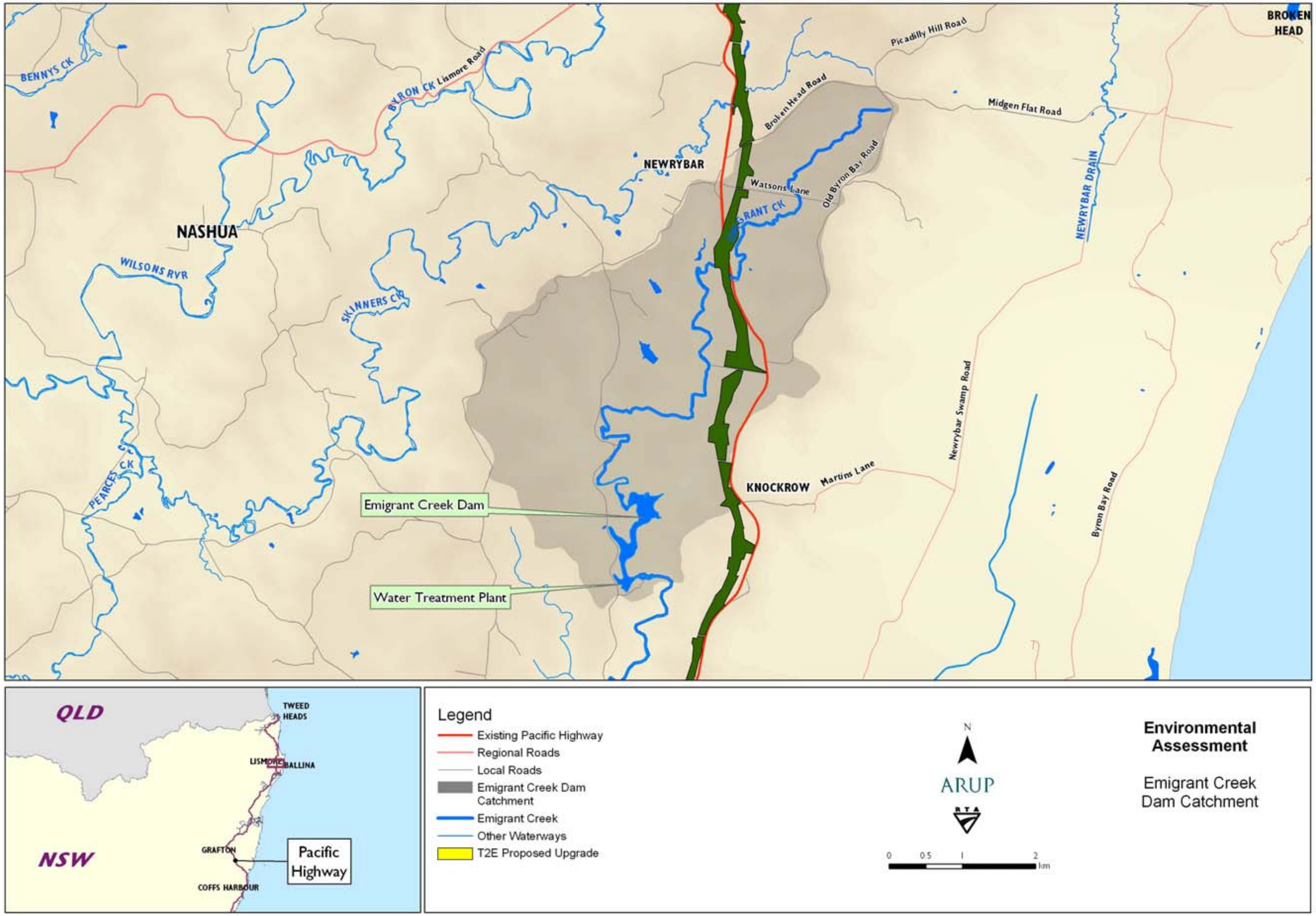
The land uses impacted by the proposed highway route have been assessed by Arup and are summarised in **Table 2** below. The table shows that the land use most affected by the construction of the highway is mature macadamia farms followed by grazing land.

Table 2 Land use by percentage impacted by proposed highway

Land Use	Percentage	Land Use	Percentage
Access Roads	8	Rural Residential	0
		Sheds	1
Coffee Immature	4	Timber	1
Grazing	27	Timber Plantation	1
House Block	1	Vegetables	3
Macadamias Immature	2	Water Course Cleared	4
Macadamias Mature	35	Water Course Timbered	1
Nursery	8	Water Supply	0
Other Fruit	4	Total	100%

As stated in Section 2.1 Rous Water are working with landowners in the Emigrant Creek catchment area to promote a healthy catchment through riparian restoration in buffer zones around the creek line. The RTA would also undertake riparian zone restoration along creek lines where land is acquired as part of the proposed upgrade that is not required for road works.

Figure 3 Emigrant Creek Catchment



2.3.1.1 Emigrant Creek water treatment plant

Emigrant Creek water treatment plant (WTP) is a state of the art treatment plant located close to the dam wall. The main function of the water treatment plant is to treat raw water to drinking water standards for the protection of human health. A process flowchart of the Emigrant Creek WTP is shown in **Figure 4** below.

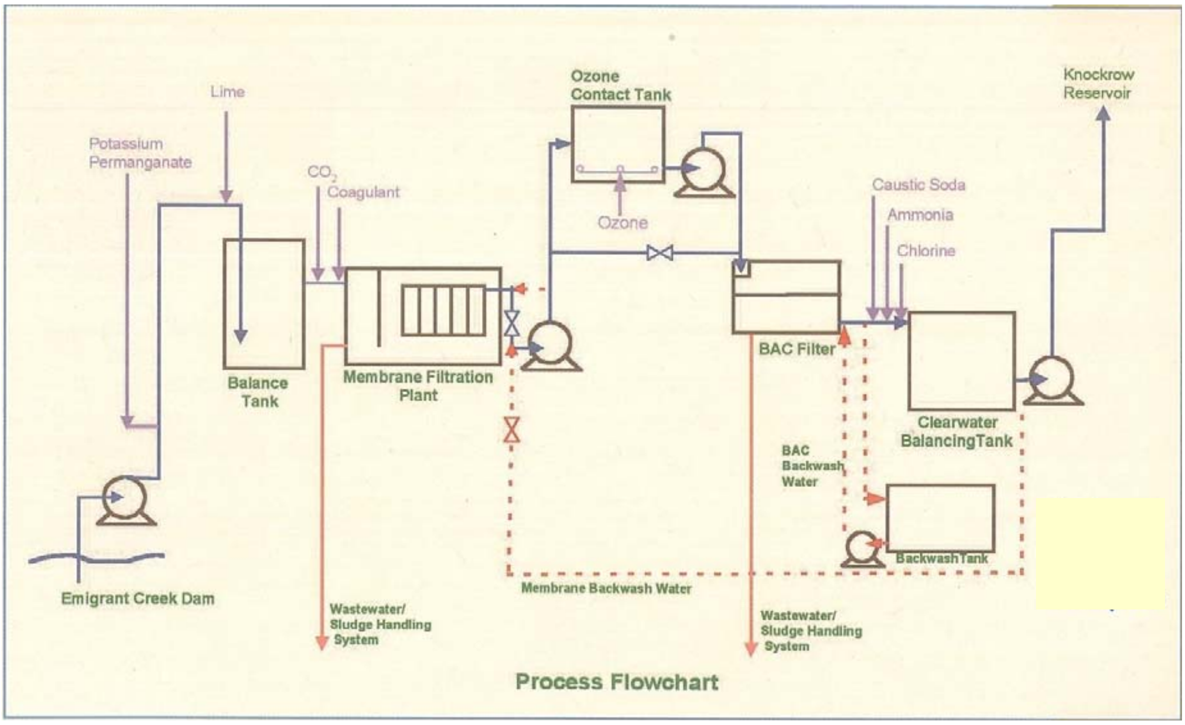
The WTP consists of membrane microfiltration followed by ozonation and carbon filtration. Membranes would be particularly susceptible to fouling should significant hydrocarbons be present in the raw water intake.

Key features of the treatment plant include

- The WTP has dual level off take (depths not advised).
- 7.5 ML/day plant with supply to Ballina and Lennox Head.
- The plant is monitored remotely and is manned. The plant may be turned off remotely.
- An auto-sampling device is located at the intake to monitor raw water quality parameters such as turbidity and pH. Heavy metals are monitored quarterly by grab sampling

Rous Water has been proactive in implementing a multiple barriers approach to its water supply operations in this catchment. Amongst many activities this has included the construction of the water filtration plant, de-stratification near the WTP off take and extensive work in the dam and catchment such as the riparian restoration program.

Figure 4 Emigrant Creek WTP Process



2.3.1.2 Existing water quality in the Emigrant Creek dam catchment

Egis Consulting conducted a Drinking Water Quality Risk Managment Review (2001) which identified the following major risks associated with various land uses in the Emigrant Creek dam catchment:

- Septic tank/infiltration systems – water quality results do not indicate excessive export of coliforms however this remains a risk.
- Macadamia Castle tourist development (due to its small zoo, high level of use and proximity to a small watercourse that drains into Emigrant Creek).

- Creek systems used for cattle watering – water quality indicates higher levels of turbidity outside the creek and lower levels inside the creek.
- Microbiological contamination and turbidity – see above.
- Pathogens from dairy farm – coliform levels found are within the expected range of rural runoff.
- Pesticide spills from farms.
- Contamination from dip sites.

A workshop conducted by Egis for the purpose of the risk management review identified that:

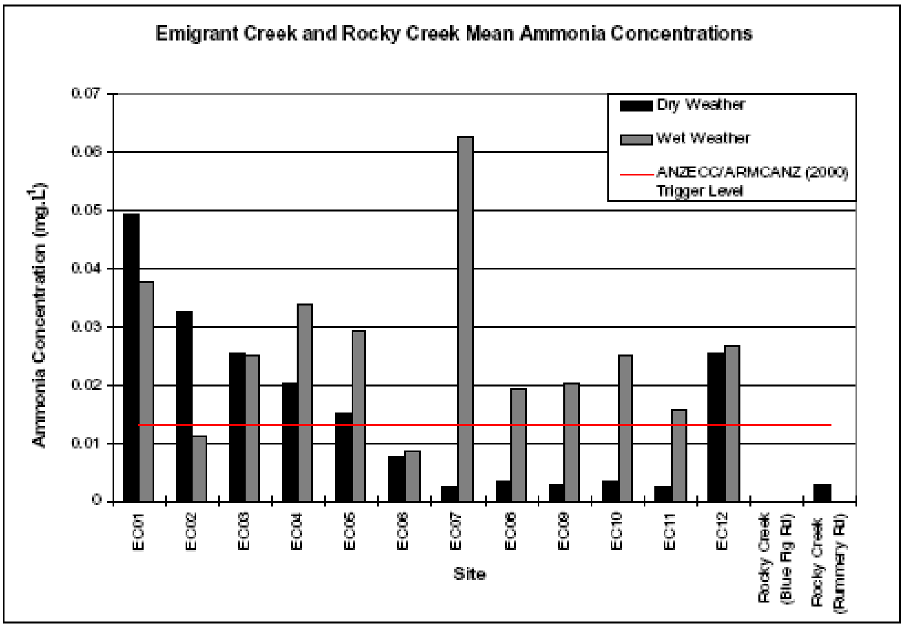
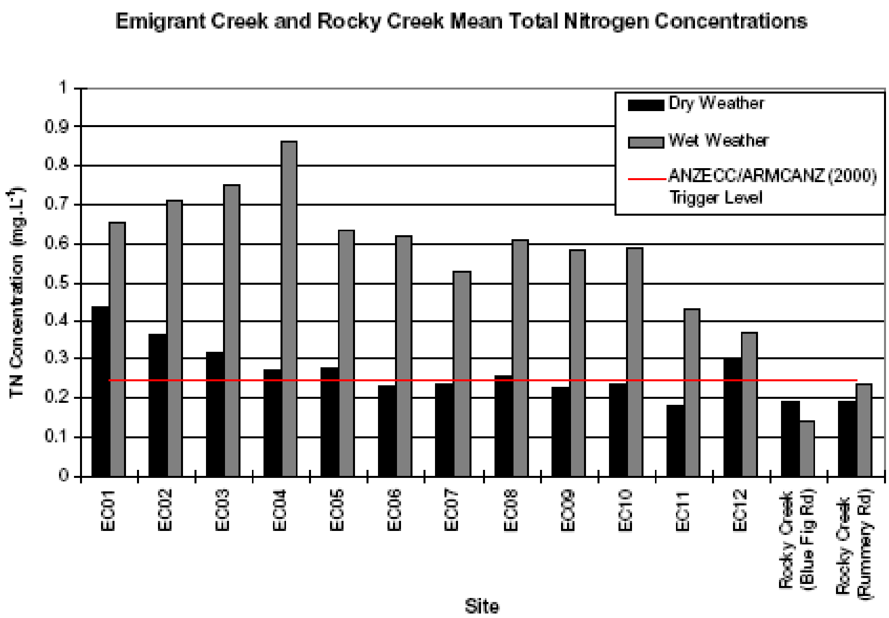
"There is a major highway crossing Emigrant Creek at which there have been three recorded accidents. Along the entire road system within the catchment there were fourteen accidents of which two involved light trucks. Hence, there is a significant risk of spillage of fuels and industrial chemicals into the creek system which, given the small size of Emigrant Creek dam (870 ML) could be relatively undiluted when it reaches the outlet of the dam."

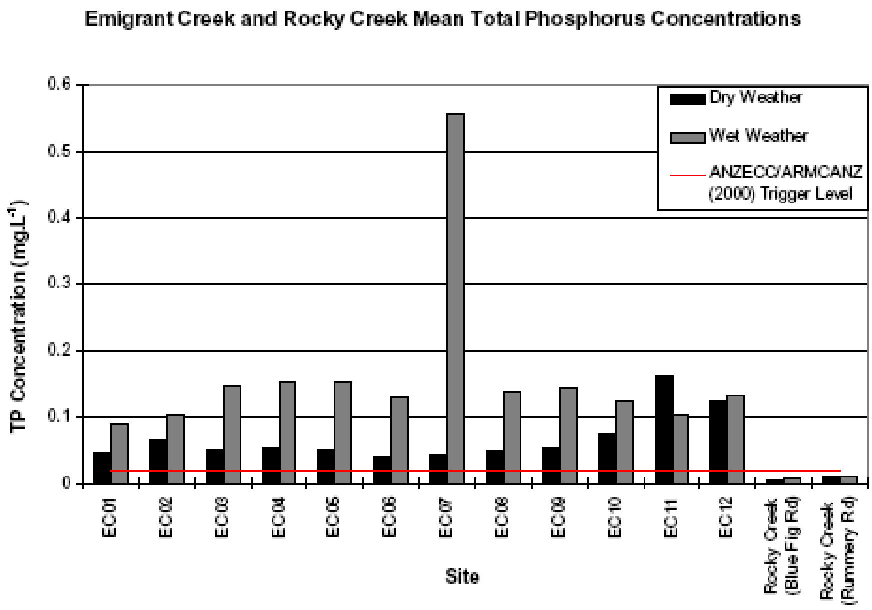
The period during which the accidents detailed above were recorded however, is not detailed in the Egis report. Furthermore no mention was made of any actual spill event having occurred.

Rous Water commissioned SKM Consulting to undertake a review of existing water quality data in Emigrant Creek (SKM, 2005). **Table 3** over below summarises the water quality review by SKM.

The study was based on the collection of water quality samples from 12 sites within the Emigrant Creek Dam catchment. The water quality was measured during both wet and dry events between 2003 and 2005 and 14 samples were tested from each site. Rocky Creek was also sampled to provide a reference site.

Table 3 Existing Water Quality in Emigrant Creek

Pollutant	Assessed Quality
Ammonia	Dry weather flows have generally lower concentrations while wet weather flows had values in the order of 0.01 to 0.06 mg/L. Highest recorded level occurred within the dam itself suggesting that nutrients potentially leading to algal blooms may be a concern. The results show that all sites in the lower portion of the catchment exceed the ANZECC guideline default trigger value while the upper catchment has good dry weather values but poor wet weather values. 
Total Nitrogen (TN)	Dry weather concentrations were relatively low while wet weather concentrations had values exceeding 0.5 mg/L in the lower part of the catchment. The results show that all sites in the lower portion of the catchment exceed the ANZECC guideline default trigger value while the upper catchment has good dry weather values but poor wet weather values. 

Pollutant	Assessed Quality
Total Phosphorus (TP)	Dry and wet weather concentrations were found to be high, with wet weather considerably higher than dry weather values. Values of 0.1 mg/L were experienced in the lower part of the catchment near the dam. The results show that at all sites the ANZECC guideline default trigger value is exceeded for both wet and dry weather events. This is to be expected in a catchment with predominately rural land uses. 
Coliforms	Coliforms had values typical of rural stormwater runoff.
Turbidity	Turbidity in the creek was found to comply with ANZECC guidelines and generally to be low, though reference sites away from the creek indicated higher values associated with rural land uses.

An extract of the conclusions from the SKM (2005) report is included below:

"The monitoring of reference sites in Rocky Creek Dam highlights the fact the Emigrant Creek suffers from poor water quality, which further deteriorates during and following wet weather. The Rocky Creek sites generally complied with the relevant ANZECC/ARMCANZ (2000) guidelines for all water quality indicators during both dry and wet weather conditions. The catchment is heavily forested and therefore receives and maintains better water quality than Emigrant Creek. Emigrant Creek by comparison is subject to the cumulative impacts of poor landuse management in places and poor coverage of riparian vegetation, providing little protection to water quality. The main water quality indicators of concern are nutrients which result in the eutrophication of Emigrant Creek dam and blooms of toxigenic cyanobacteria and the high number of E.coli most likely derived from cattle grazing."

The key points in this conclusion are that Emigrant Creek generally suffers from poor water quality that does not comply with the relevant ANZECC guideline trigger values and that the main water quality indicators of concern are nutrients which result in the eutrophication of Emigrant Creek dam. Nutrients must therefore be a key target of any water quality modelling and any specific management measures to be put in place on the proposed highway.

As part of the Tintenbar to Ewingsdale project further water quality sampling was undertaken by The Ecology Lab Pty (refer to Pacific Highway Upgrading, Tintenbar to Ewingsdale, Aquatic Ecology Working Paper 05, February 2008). Though based on less robust data, The Ecology Lab formed similar conclusions to SKM in respect of the prevailing water quality.

An extract of the executive summary from Working Paper 05 is included below:

"Previous studies of water quality within the Emigrant Creek catchment indicated that land uses including agriculture and grazing had deleterious impacts on water quality, with many parameters exceeding guidelines for the protection of aquatic ecosystems. Results of water quality sampled in-situ in the investigation area indicated similar trends, although sampling was done at each site once only, after periods of dry weather. Water quality results for all watercourses were typical of aquatic ecosystems that have been historically highly disturbed by agricultural and grazing practices. There were no detectable organochlorine pesticides or oil and grease residues found in any watercourse. Levels of total phosphorous and total nitrogen exceeded ANZECC guideline trigger values for protection of aquatic ecosystems in Byron, Skinners and Emigrant creeks. Low levels of chromium were present in those waterways but all levels of heavy metals were below guidelines with the exception of copper at one location in Emigrant Creek."

Working Paper 05 found similarly poor water quality in both Emigrant Creek Dam and Wilsons River catchments (Byron and Skinners Creek are located within the Wilsons River catchment). Also of note was that heavy metals were found to be low (except for Copper at one location in Emigrant Creek).

2.3.2 Wilsons River catchment

The Wilsons River lies within the Richmond River catchment and the catchment area for the Wilsons River at Lismore is approximately 1,400 square kilometres. The catchment includes the steep and dissected plateau of the Nightcap and Koonyum Ranges, near the coast, running west to the Lofts Pinnacles.

The proposed new water source at Lismore is referred to as the Lismore Source and will consist of a pump station abstracting up to 30 ML/day of water from the upper reaches of a tidal pool in the Wilson River about 5km upstream of Lismore (Howard's Grass).

The abstraction point would be approximately 61km downstream of the proposed highway and aspects of the Lismore Source proposal are currently being finalised.

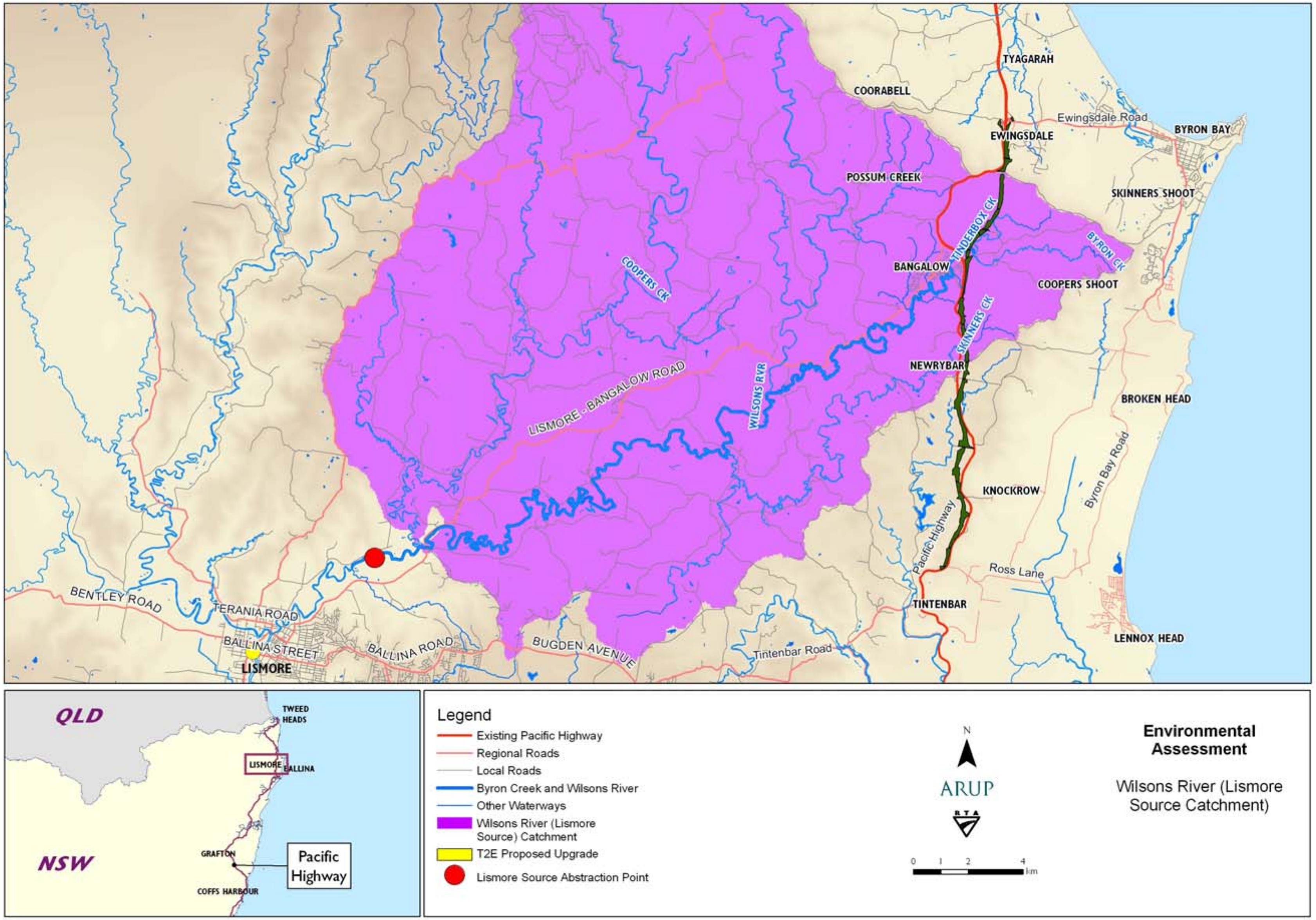
The catchment area is significantly larger than the Emigrant Creek dam catchment and it is characterised by rural land uses with a number of settlements and urban areas.

Key catchment data:

- Area of catchment – 48,110 Ha (481 km^2).
- Acquisition of land by the RTA for the upgrading of the highway within Wilsons River catchment: 91 Ha (~0.2% of catchment area).
- Area of new carriageway constructed as part of the proposed upgrade: 16.4 Ha (~ 0.03% of the catchment area).
- Length of Pacific Highway upgrade in catchment – 7.2 km
- Length of existing Pacific Highway in catchment – 8.4 km
- Distance of Pacific Highway upgrade from proposed extraction point – ~61 km
- Length of other major roads in catchment - ~60 km
- Length of local / access roads in catchment - ~560 km
- Approx area of settlements and urban areas - ~790 Ha

The key details of the catchment are shown in **Figure 5** including the proposed upgrade.

Figure 5 Wilsons River Catchment



2.3.3 Existing water quality in the Wilsons River catchment

As mentioned in section 2.3.1.2 The Ecology Lab undertook some water quality sampling on Byron and Skinners creeks which form part of the Wilsons River catchment.

The Environmental Impact Statement for The Lismore Source (Parsons Brinkerhoff, February 2006) indicates that a water quality monitoring program was undertaken by Rous Water in the Wilsons River tidal pool from 2002 to 2005. Samples were taken at approximately monthly intervals, and the total number of samples taken was 39.

The results of the sampling are shown in **Table 4** below:

Table 4 Wilsons River (Lismore Source) Water Quality Data

Water Quality Constituent	Range (dry weather) N = 39	Median (dry weather) N = 39	Median (first flush) N = 8	Drinking Water Guidelines[2]	Irrigation Water Guidelines Values[3]	Aquatic Ecosystem Guidelines[3]
Alkalinity (as CaCO3), mg/L	21 to 56	30	26.5			
Aluminium (dissolved), mg/L	0.06 to 0.92	0.16	0.625	0.2	5	
Arsenic, mg/L	0	0	0	0.007	0.1	
Cadmium, mg/L	0	0	0	0.002	0.01	
Apparent Colour, Hazen	23 to 105	50	222.5			
Copper, mg/L	0 to 0.01	0	0	2	0.2	
E.Coli cfu/100mL	2 - 154	35	137	0		
Electrical Conductivity uS/cm	93 - 144	111	108		1400 - 1700	200 – 300
Gross Alpha radiation mBq/L	0 -38	0	0	500	500	
Hardness (as CaCO3), mg/L	19 - 36	24	18	200	60	
Iron (dissolved), mg/L	0.12 – 0.95	0.48	0.60	0.3	0.2	
Manganese (dissolved), mg/L	0 – 0.04	0	0	0.5	0.2	
pH	6.78 – 7.87	7.21	6.82	6.5 – 8.5	6 - 9	6.5 – 8.5
Soluble P, mg/L	0 – 0.11	0.03	0.045			0.02
Total Coliforms, CFU/100mL	55 – 4010	817	2653			
Total Dissolved Solids, mg/L	53 – 98	70	69	500		
Total Nitrogen, mg/L	0.10 – 0.25	0.15	0.42		5	0.3
Total Organic Carbon, mg/L	1 – 10	2	7.5			
Total Phosphorus, mg/L	0.01 – 0.12	0.08	0.18		0.05	0.05
True Colour, Pt-Co or Hazen	12 – 62	25	65.5	15		
Turbidity, NTU	1.2 – 9.5	3.8	49.5	5		6 - 50
Zinc, mg/L	0	0	0	3	2	

Notes:

1. guideline values are objectives expressed as recommended maximum values or desirable ranges;
2. National Health and Medical Research Council (2004), Australian Drinking Water Guidelines, NHMRC;

3. ANZECC / ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy, Paper No. 4, Volume 1, October 2000; Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of New Zealand;
4. N = number of samples taken.

Based on the water quality data provided in **Table 4** the EIS stated that generally, the water quality at the Lismore Source is acceptable as a raw source of drinking water.

The levels of zinc were measured as 0 (presumably below detection limits) which would appear to indicate that stormwater runoff from the sections of highway within the catchment has negligible impact on the overall water quality levels.

In addition Rous Water engaged the NSW Department of Commerce to carry out an assessment of the water quality risks in supplying their customers with drinking water pumped from the Wilsons River at the Lismore Source and treated at Nightcap water treatment plant.

Their report *Wilsons River Risk Assessment – Risk Assessment and Mitigation Measures Report* (Department of Commerce, 2005) identified that the highest risk events that could affect water quality were:

- Runoff from storms could wash potentially harmful micro-organisms from sewerage systems into the river.
- Storms washing soils and phosphorus from farmland into the river.
- Pollutants moving upstream with the tide to the abstraction point.
- Low river flow and high nutrient concentrations leading to high algal concentrations, and consequently toxicity, taste and odour problems.

Other events that were considered to have high consequences, but were assessed as having a low overall risk included:

- Terrorist attack.
- Chemical spills from traffic accidents.

These low risk events were considered to be best managed through an Emergency Response Plan rather than as part of normal operational procedures.

2.4 Aquatic ecology

Working Paper 5 – Aquatic Ecology documented the aquatic ecology of Emigrant, Byron and Skinners creeks. These are the three major waterways affected by the proposed upgrade.

The working paper found that upper reaches of Emigrant Creek and its tributaries are graded Class 2, 3 and 4 fish habitat. The main channel of Emigrant Creek includes moderate fish habitat with varied features such as pools and riffles. The dam and upstream reach are classified as Class 1 major fish habitat when the dam is full and operating.

Surveys in Emigrant, Skinners and Byron creeks found no presence of any protected species.

Seven fish species were found across four sampling sites of Emigrant Creek including freshwater catfish, prawns, yabbies, crayfish, empire, flathead and striped gudgeon, gambusia, shrimp, long finned eels and turtles.

Aquatic surveys in Skinners Creek found four species including Duboulayi’s rainbow fish, long finned eel, gudgeon and olive perchlet.

Surveys of Byron Creek found six species of fish and freshwater crustaceans and turtles. Byron Creek provides both good fish habitat and Class 3 and 4 habitats.

Surveys of Tinderbox Creek found six species of fish.

The Ecology Lab found numerous barriers to fish passage in the study area including Emigrant Creek Dam, the existing highway and local crossings (causeways and culverts).

2.5 Existing highway conditions

2.5.1 Description of existing highway

With the exception of the Bangalow bypass and the Ewingsdale interchange, the Pacific Highway between Tintenbar and Ewingsdale is single carriageway, generally with one lane in each direction. Overtaking lanes are provided at intermittent locations along the length.

The existing posted speed limit on this section of the highway is 100 km/h with the exception of the following sections:

- Tintenbar Hill to just north of Ross Lane (80km/h).
- Skinners Creek to the southern end of the Bangalow bypass (80km/h).
- St Helena Hill (60km/h).

A significant length of the highway within the study area has sub-standard geometry and many advisory signs are posted along its length. An assessment of the existing alignment geometry with regard to compliance to both the RTA's minimum and desirable design standards for the project identified that over 50% of the existing highway alignment does not comply with at least one minimum design standard.

Other examples of poor geometry are evident on the existing highway. These include insufficient sight distances, particularly at the numerous at-grade intersections and property driveways with direct access to the highway.

Historical accident data for the 5-year period 1 May 2002 to 30 April 2007 indicates that the following accidents occurred on the existing Pacific Highway as it passes through the drinking water catchment areas

Table 5 Accident figures for existing Pacific Highway (1 May 2002 to 30 April 2007)

Accident Severity	Emigrant Creek Dam Catchment	Wilsons River Catchment
Fatal	1	2
Injury	5	35
Vehicle towaway	9	51

Incident record data collected by the RTA Ballina works depot indicates that in the past 5 years there have been 3 accidents where a spill was recorded on the Pacific Highway between Ross Lane and Ewingsdale interchange. All the spills were minor in nature i.e. small amounts of oil, grease and petrol however, the exact volume of the spills were not quantified in the incident reports. None of the spills occurred in the Emigrant Creek dam catchment area however 2 of the incidents occurred within the Wilsons River catchment area.

2.5.2 Existing highway water quality and ecological impacts

Using the data available the following water quality/ecological impacts can be concluded:

- The road geometry contributes to the relatively high number of accidents on the existing highway. The accident rate for the 5 year period 2002 to 2007 of 36 accidents per 100 million vehicle kilometres travelled (MVKT) is above the state-wide accident rate for a rural 2-lane undivided road of 32.8 accidents per 100 MVKT. The accident rate differs considerably however, if the highway is examined into two sections; Ross Lane to Bangalow, and Bangalow to Ewingsdale. These rates are 23 accidents per 100 MVKT and 56 accidents per 100 MVKT respectively. The reported accident rates means that there is a potential risk of an accidental spill on the highway and no measures are currently in place to prevent any such spill entering a receiving watercourse.
- The Ecology Lab in the Aquatic Ecology Working Paper 05 (February 2008) found no exceedence of heavy metals (exceed for copper at one location in Emigrant Creek) in the receiving waters. It should be noted that the study undertook only one dry weather sample of water quality at several locations in the Emigrant Creek Dam and Wilsons River catchments.
- The work by SKM (2005) did undertake sampling of 7 wet and 7 dry events and importantly had sampling sites immediately upstream of the existing highway (site EC09) and downstream of the highway (site EC08). A review of the SKM results found no perceptible decline in water quality downstream of the highway. Typical water quality parameters were measured such as nutrients, suspended solids, pH, coliforms and DO. An examination of the presence of metals in either dissolved form or present in the sediments was not undertaken as part of this study.
- The existing highway does impede fish passage in some locations (Aquatic Ecology Working Paper 05 February 2008).
- Rous Water has noted that it considers that the existing highway poses an unacceptable risk to the water quality in the drinking water catchments due to the fact that there are no existing water quality treatment measures in place. SKM (2005) suggests that the existing highway has a minimal impact in terms of the water quality parameters measured.
- The proximity of the proposed upgrade to the Emigrant Creek dam and the dam off take means that the potential impact of the highway on the water quality in the Emigrant Creek catchment area is of higher consequence than in the Wilsons River catchment. Mitigation measures proposed for the section of the proposed upgrade within the Emigrant Creek catchment should reflect the greater potential impacts.
- The proposed upgrade should include facilities to capture accidental spills during both construction and operation.

2.6 Conclusion

The water quality sampling undertaken on creeks adjacent to the proposed upgrade indicated that the water quality in these creeks reflects the rural nature of the catchment and in general the creeks suffer from poor water quality.

Within the Emigrant Creek dam catchment the proposed upgrade will provide a high quality alternative route for the majority of traffic to the existing Pacific Highway, which also passes through the catchment. The proposed upgrade however, will run in close proximity to the dam (between 850 m and 1250 m to the east) and accordingly it will present potential impacts to the water quality in the dam.

Rous Water maintains an active interest in catchment management in order to promote healthy catchment areas producing good, clean drinking water particularly in the Emigrant Creek dam catchment area. Through the provision of healthy buffer zones that can be actively managed for water quality purposes through riparian restoration Rous Water are aiming to improve the ambient water quality in the catchment. It should be noted however, that the secure yield provided by Emigrant Creek dam is less than 10% of the total secure yield of the Rous Water regional water supply and this yield will be reduced in the future as plans to increase the secure water supply are all focused around Lismore, with the Lismore Source and the Dunoon dam.

Notwithstanding the proposed reduction in the yield from the Emigrant Creek dam it is clear that the dam plays an important part in the regional water supply and the healthy catchment management activities are a reflection of the importance attached to the dam by the concerned stakeholders.

In the Wilsons River catchment area the proposed upgrade is approximately 61 km from the Lismore Source off take. Additionally the area of the proposed upgrade as part of the whole catchment area is relatively small and there is a significant length of other roads, number of settlements and urban areas within the catchment.

It can therefore be concluded that the potential impact of the highway upgrade on the water quality in the Emigrant Creek catchment area is of higher consequence than in the Wilsons River catchment. Mitigation measures proposed for the section of the proposed upgrade within the Emigrant Creek catchment should reflect the greater potential impacts and accordingly the assessment of water quality impacts should be more detailed.

It should be noted that proposed upgrade should include facilities to capture accidental spills during both construction and operation for its entire length.

3 Consultation

3.1 Overview

A comprehensive community and stakeholder involvement program has been undertaken for the proposed upgrade.

The principal objective of the community consultation process has been to keep people well informed and to involve them in the proposed upgrade during each stage of its development. The program commenced from early in the development of the proposed upgrade and has continued into the preparation of the environmental assessment.

In addition to community consultation, extensive stakeholder consultation was undertaken throughout the duration of the project starting during the inception stages. Stakeholder consultation is still an ongoing process and to date has played an important role in delivering the proposed upgrade with minimal impacts. Stakeholders involved in the consultation process have included a range of organisations such as local and state authorities, local schools, fire brigade and the water authority.

There has been a high level of community and stakeholder interest and involvement in the potential water quality impacts of the proposed upgrade, particularly in respect of the Emigrant Creek Dam and its catchment area.

3.2 Stakeholder workshops

Throughout the duration of the project the RTA and Arup have conducted a number of workshop sessions in order to ensure that the interests of all the project stakeholders are correctly defined and addressed appropriately.

The workshop sessions conducted as part of the Tintenbar to Ewingsdale project are:

- Planning Focus Meeting No.1
  16 November 2004, Byron Bay
- Planning Focus Meeting No.2
  15 February 2005, Ballina
- Corridor Assessment Workshop
  2/3 August 2005, Ballina
- Value Management Workshop
  14/15 December 2005, Ballina
- Planning Focus Meeting (Part 3A Application)
  16 April 2007, Ballina

As a key stakeholder to the project Rous Water were invited to attend all of the above workshop sessions. The invitation to attend Planning Focus Meeting No.1 was declined however representatives of Rous Water attended all of the subsequent workshop sessions.

In addition, the RTA and Arup met with representatives of Rous Water prior to the Value Management Workshop sessions in order to review their key issues and concerns.

3.3 Rous Water workshops and meetings

Further to the above mentioned stakeholder workshops there has been significant additional consultation with Rous Water representatives in respect of the potential water quality impacts arising from the proposed upgrade.

As a result of concerns raised by Rous Water following the Value Management Workshop further meetings and workshops were arranged in order that key issues regarding the potential impacts on the drinking water catchment areas are adequately addressed in the development of the project proposals.

The meetings and workshops were supplemented by regular exchange of correspondence with Rous Water. Throughout this process the primary emphasis of Rous Water concerns has been on the potential impacts of the proposed upgrade on the Emigrant Creek Dam and its catchment area

The key meetings and workshops arising from this consultation process are detailed below:

- Meeting with Rous Water
  May 2006, Lismore
  Meeting to present Storm_Consulting to Rous Water and outline proposed water quality modelling work to be undertaken prior to finalisation of preferred route.
- Meeting with Rous Water
  June 2006, Lismore
  Presentation given by Arup and Storm_Consulting detailing the examination of chronic water quality risks associated with proposed upgrade and potential management strategies. Agreement to undertake a water quality impacts risk assessment to include acute risks.
- Meeting with Rous Water
  October 2006, Lismore
  Meeting to discuss findings of water quality impacts assessment. Agreement to hold risk workshop in December 2006.
- Visit to Emigrant Creek Dam Water Treatment Plant
  November 2006, Emigrant Creek Dam
  Visit by Arup and Storm_Consulting to WTP to assist in understanding and defining the water supply operation and the potential risks of the proposed highway upgrade.
- Risk Workshop
  December 2006, Ballina
  Risk workshop, independently facilitated by Urbis JHD, to develop a joint risk register for water quality impact risks arising from the proposed highway upgrade. Workshop attended by representatives from Rous Water, RTA, Arup, Storm_Consulting and Sydney Catchment Authority.
- Meeting with Rous Water
  July 2007, Ballina
  Workshop / meeting to present and discuss results of further assessment works of water quality impacts from the proposed upgrade at Emigrant Creek. Review of 21 Management Strategies recommended by Rous Water in their submission of 20 April 2007.
- Meeting with Rous Water
  November 2007, Lismore
  Meeting with Rous Water to provide update on key issues detailed in Rous Water submissions of 20 April 2007 and 24 October 2007. Review of status of chronic and acute water quality impact assessment work undertaken by Arup and Storm_Consulting.
- Meeting with Rous Water
  March 2008, Lismore
  Meeting with Rous Water to provide update on status of environmental assessment of proposed upgrade and program for lodging project proposal with NSW Department of Planning. Review of work undertaken and proposed mitigation for proposed upgrade in Emigrant Creek dam and Wilsons River catchments.

3.3.1 Peer review

In response to feedback from Rous Water, the RTA agreed that a peer review of the water quality assessment work detailed in this working paper be conducted.

The review was undertaken by David Stefani, an independent stormwater engineer and water quality modelling expert, who consulted with representatives of Rous Water in preparing his comments on the methodology and analysis undertaken.

3.4 Community consultation

A number of representations have been made by members of the community during the environmental assessment and concept design phase of the project in relation to the potential impact of the proposed upgrade on water quality.

The submissions have focused on the route selection process and the consideration given to the potential impact of the route options on Emigrant Creek Dam and its surrounding catchment area.

A summary of the key issues detailed in the community submissions is provided below.

- The risk of the shutdown of water supply for 30,000 people for an indefinite period is too great.
- Rous Water's policies and representations regarding the pollution threat to Emigrant Creek Water Catchment have been disregarded.
- Climate change and its potential impacts have not been given proper consideration and in fact have been disregarded
- The efforts of the community to rehabilitate the Emigrant Creek Water Catchment through the Watercatchers Rescue Project have been disregarded.

4 Potential effects of road runoff

4.1 Overview

Section 4 of this working paper details potential water quality impacts associated with stormwater runoff from roads. A literature review was undertaken to examine the range of pollutants that are likely to be present in the highway drainage and their probable levels.

Pollutants from roads were found to be propagated in two different forms; runoff in stormwater and direct deposition of airborne particles. Typical pollutants found in road runoff include: sediments, hydrocarbons, nutrients, metals, microbials and others.

It was found that there is a correlation between the volume of traffic on a road and the pollutant load generated from that road. The higher the traffic volumes the greater the pollutant loads.

For the purposes of modelling road runoff, it is possible to derive event mean concentrations for total suspended solids, total nitrogen and total phosphorus. The event mean concentrations for these pollutants developed by Fletcher et al (2004) would be appropriate for water quality modelling on this project.

It was found that there is a correlation between the reduction of total suspended solids and the reduction of other pollutants such as metals and microbials.

This section also examines the effect of other pollutants in stormwater runoff and concludes that potential treatment approaches should focus on the 'first flush' impacts and specifically the removal of suspended solids (to eliminate bound heavy metals), zinc and copper.

4.2 Effects of traffic loading

Driscoll *et al* (1990) found that there is a correlation between pollutant loads and traffic volumes. The greater the traffic volume, the greater the pollutant load. Highways with traffic loads less than 30,000 vehicles per day generated less than 50% of the pollutant loads generated by highways with greater than 30,000 vehicles per day. The traffic volumes predicted for the highway range from about 16,500 in 2012 growing to about 29,000 in 2042. This volume of traffic would result in the highway falling in the lower of the two distinct groups found and would therefore be associated with lower volumes of pollutant export than highways with daily traffic movements of above 30,000.

It should be noted however, that Drapper *et al* (2000) found a weak correlation between road traffic volume and exported pollutants from roads in South-East Queensland. The roads investigated by Drapper *et al* included the Pacific Motorway and Bruxner Highways.

4.3 Pollutants present in road runoff

The Construction Industry Research and Information Association report on Control of Pollution from Highway drainage discharges (Luker and Montague, 1994), lists the pollutants that are likely to be present in highway drainage as follows:

- Sediments;
- Hydrocarbon;
- Metals;
- Microbials; and
- Others.

An extensive list (refer Appendix B) of highway pollutants and their expected concentrations has been documented by the Highways Agency in the UK in its Design Manual for Roads and Bridges (Volume 11, Section 3). This list is based on UK experience and although load rates may be indicative of Australian conditions, it should be noted there are a number of marked differences between the UK and Australia including the frequency and intensity of rainfall events, the vehicle fleet, tyre composition and the use of de-icing agents in winter.

There is no discussion on the source of the data, i.e. sample locations and whether the water quality was affected by any treatment or not. Additionally there is no distinction in the data between chronic and acute events and this makes use of the maximum recorded levels of pollutants inappropriate. The list does, however, provide an extensive review of likely highway pollutants and their expected concentrations.

In 2003, South-East Queensland's Healthy Waterways Commission commissioned a study to provide a quantitative assessment of the pollutant export characteristics of sub-urban Brisbane roads under representative and quantifiable rainfall conditions.

This study (Barry *et al*, 2004) used MUSIC water quality modelling to estimate the relative contribution of pollutant loads from suburban roads. It found the presence of a first flush of pollutants and that the majority of the pollutant load occurs from frequent small storm events as opposed to large infrequent events. Pollutants such as nutrients, heavy metals, suspended solids and hydrocarbons were measured. The study found that roads in heavily urbanised catchments do make a significant contribution to the total pollutant load in that environment (it should be noted that this is not the same context as a rural environment). Roads were found to contribute 30% of the suspended solids and nutrients load and 40% of the petroleum hydrocarbon and heavy metal load.

Event mean concentrations derived by Barry *et al* are repeated below, they include heavy metals and total petroleum hydrocarbons (TPH):

Pollutant	EMC	Pollutant	EMC
TSS (mg/L)	180	Cu (μg/L)	31
TP (mg/L)	0.47	Ni (μg/L)	4.0
TN (mg/L)	3.2	Pb (μg/L)	75
Cd (μg/L)	0.50	Zn (μg/L)	320
Cr (μg/L)	3.1	TPH (μg/L)	1200

Source: Barry *et al* (2004)

This study however, did not consider stormwater contributions arising from roof runoff (which is often directly connected to road gutters) as a major source of pollutants. The widespread use of lead, copper and zinc on Australian roofs and in plumbing may be a significant source of heavy metals. The stormwater runoff from the proposed upgrade to the Pacific Highway would not receive any pollutant loading from roofs or any sources other than the pavement itself.

Drapper *et al* (2000) also derived EMCs for a number of major roads in South-East Queensland, including the Pacific Motorway and Bruxner Highway, and compared these findings against research undertaken in the United States by Driscoll. An extract from this report is provided over.

TABLE 4. Median Results Comparison with U.S. Data (mg/L)

Pollutant (1)	Southeast Queensland (2)	Driscoll et al. (1990)[a] (3)	Barrett et al. (1993)[b] (4)	Barrett et al. (1995a) (5)
TSS	60–1,350	142	45–798	19–131
TP	0.19–1.8	0.4[c]	0.113–0.998	0.1–0.33
TKN	1.7–11	1.83	0.335–55	0.28–1.03[d]
Cu	0.03–0.34	0.05	0.022–7.033	0.007–0.034
Pb	0.08–0.62	0.40	0.073–1.78	0.007–0.05
Zn	0.15–1.85	0.33	0.056–0.929	0.022–0.208

[a]AADT > 30,000.
[b]Average values.
[c]PO_4.
[d]NO_3-N.

Source: Drapper *et al* (2000).

Drapper *et al* (2000) found that the nutrient load washed off roads is largely the result of atmospheric deposition. Both the highway runoff quality and actual rainfall quality was measured to establish if the rainfall was the source of the nutrient loading on the roads. Drapper *et al* (2000) also found that heavy metal loadings were highest at exit points on major roads where heavy breaking occurred. This fact may enable a more focussed treatment approach for the proposed upgrade.

Fletcher *et al* (2004) were commissioned by the NSW DECC to review the literature to find suitable event mean concentration values for total nitrogen, total phosphorus and total suspended solids for water quality modelling in NSW. These values would be appropriate for water quality modelling on this project.

The event mean concentration values proposed by Fletcher *et al* (2004) are consistent with the range of values found by Drapper *et al* (2000), Driscol *et al* (1990), Barry *et al* (2004) and the UK Highways Agency Design Manual.

In the document "*Guidelines for Treatment of Stormwater Runoff from the Road Infrastructure*" (Austroads report AP-R232), Wong advises that to effectively reduce nutrients, metals and other toxins that may be found in road runoff, targeting the removal of very small particles must be undertaken. In other words, the suspended solids load is physically bound to most of the other pollutants, especially heavy metals, found in road runoff. Some forms of metals can, however, be present in a dissolved state, e.g. Copper. The bioavailability of most metals is related to the relative hardness of the water. As the hardness increases, the dissolved metals become less bioavailable lowering the toxicity of the pollutant (ANZECC, 2000).

4.3.1 Hydrocarbons and BTEX

Benzene and toluene are usually grouped with ethylbenzene and xylene (BTEX). They are a group of known carcinogens used in petrol as anti-knocking agents to replace lead. Their presence in exhaust gases occurs as particulate matter which may settle on the road surface or be precipitated by rainfall resulting in entrainment in runoff.

Total petroleum hydrocarbons (TPH) are a term that describes several hundred petroleum compounds that originate from crude oil. Examples are petrol, motor oils, diesel and grease.

Barry *et al* (2004) derived EMCs for TPH and these are 1.2 mg/L.

Bruckner (2006) and Kumar *et al* (2002) attempted to characterize Benzene and Toluene concentrations in road runoff. Bruckner found either insignificant levels or levels below detection limits of BTEX and TPH in the 12 samples of Pacific Highway runoff he collected. Bruckner did note that manual sampling was undertaken and that the first flush of rainfall was not included in the tested water quality samples.

Kumar *et al* (2002) found the presence of BTEX and TPH in the first flush of road runoff from a simulated rainfall event. Kumar *et al* (2002) failed to detect any TPH or BTEX in the runoff that occurred after the first flush. Barry et al (2004) together with Kumar et al (2002) and Bruckner (2006) suggest that TPH would be present in the first flush but quickly decay to undetectable levels with low persistence associated with volatility or high detection limits.

Like Barry *et al* (2004) Kumar *et al* conclude that targeting of the first flush should be a stormwater management strategy for the control of hydrocarbons and BTEX.

4.3.2 Eco-toxicity of road runoff

Kumar *et al* (2002) undertook a detailed eco-toxicological assessment of road runoff on behalf of Transport SA in Adelaide. This study reported the following:

- Undiluted stormwater first flush samples from roads are toxic to waterfleas (macro-invertebrates) but not to rainbow fish.
- Stormwater following the first flush is less toxic to waterfleas and not toxic to rainbow fish. Note that this study is directly relevant to T2E because rainbow fish are present in the receiving waters.
- Dissolved Zinc and Copper are the most likely cause of toxicity of the first flush of stormwater runoff.
- LC50 values for Zinc, Lead and Copper based on bioassays of waterfleas are repeated below:

Table 4. 48-hour LC_{50} values for copper, lead and zinc from acute bioassays with *C. dubia*. Numbers in parentheses are 95% confidence intervals.

Metal	LC50 (µg/L)
Copper	18.7 (15.3-22.7)
Lead	176 (132-236)
Zinc	255 (195-332)

Source: Kumar *et al* (2002)

- concluded that the first flush of undiluted road runoff would result in concentrations of Zinc and Copper that exceeded the LC50 values for waterflea – *C. dubia*. This was based on 48 hour bioassays. Lead levels did not exceed the LC50 value at any sites.

This study is considered to be a milestone for Australia and is a valuable reference document however, the following factors should be noted:

- The study undertook testing the toxicity of stormwater using undiluted samples. In reality highway runoff is likely to be only one component of the total flow entering a waterway. Highway stormwater drainage is normally diluted with cross drainage flows that it discharges into. This fact is recognised by the Highways Agency in the UK which specifies an environmental assessment method for road runoff impacts based on the copper and zinc concentrations coming off a road after allowing for dilution by cross flows. This is a critical aspect of interpreting a laboratory bioassay in a real world occurrence.
- Barry *et al* (2004) prepared stormwater pollutographs (graphs of the concentration of pollutants in stormwater versus time) which showed that pollutants decay in stormwater by as much as 90% within 40 minutes from the start of a storm event. This would of course be affected by the intensity of the storm and preceding wash-off events. Testing of the first flush was done by immersing the waterflea in the first flush for up to 48 hours and then measuring mortality rates. This method did not recognise that the first flush is exactly that; a rapid, 3 to 5 minute duration, flush of pollutants within a catchment that is followed by much less polluted, less toxic runoff from the storm event.

- The study did not recognise that if runoff is toxic to the invertebrates (waterflea) at the bottom of the food chain that indirectly it will also become toxic to the species that predate the macro-invertebrates. Species higher up the food chain are affected in two possible ways, i.e. toxicity from ingestion, and less available food if their food source is present in less numbers.

ANZECC (2000) also present a detailed table of toxicant values (LC100- LC85) for a wide range of pollutants and these are included in Appendix B.

In conclusion the paper by Kumar *et al* provides a wealth of data on the actual eco-toxicological effects of highway runoff. Due to the significant differences between exposure conditions (both pathways and duration) for laboratory bioassays compared to *in-situ* conditions however, the work has significant limitations when trying to apply its findings to assessing the impact of highway runoff.

4.3.3 Pathogens / microbial pollution

Stormwater typically contains 4,000 colony forming units (cfu) (ANZECC, 1992). Stormwater mixed with leaky sewers is likely to contain significantly higher numbers of pathogens. Dunphy *et al* (2005) found that stormwater entering a sand bioinfiltration system at Kiama had levels of coliforms in excess of 150,000 cfu/100ml which is uncommon for a sewered catchment.

Sources of pathogens on roads may be derived from minor spillages during transport of animals and raw materials and from leaf litter occurring within the road corridor. On highways other potential sources of pathogens include rest stops (with or without toilets) and areas where food is consumed.

The rural nature both the Emigrant Creek Dam and Wilsons Rivers catchments make them likely sources of significant concentrations of pathogens (SKM, 2005) however, untreated stormwater runoff from the highway may also include levels of microorganisms of the order of 4,000 cfu.

4.4 Potential effects of airborne pollution on drinking water

One issue, sometimes raised as a concern near highway projects is the potential impact of airborne pollution on drinking water.

As part of the Tintenbar to Ewingsdale project a detailed analysis of air quality impacts was undertaken by Holmes Air Sciences (refer to Pacific Highway Upgrading, Tintenbar to Ewingsdale, Air Quality Impact Assessment Working Paper 12, February 2008). The assessment work undertaken detailed that airborne pollutants could potentially enter water systems either directly through deposition from the air or through runoff from soil contaminated with fallout. The levels of pollutants entering the water system associated with the highway however, would be low and the proposed upgrade is not predicted to result in any deterioration in air quality. Accordingly there would be no deterioration in drinking water as a result of airborne pollution arising from the proposed upgrade.

4.5 Conclusion

In conclusion road stormwater runoff is likely to be contaminated with nutrients, heavy metals, hydrocarbons, and suspended solids from the highway operations draining onto the road. Untreated and undiluted road runoff may result in acute toxicity in aquatic species. In the majority of cases road runoff will be diluted and toxic impacts will be reduced however, the literature review confirms the need to treat highway runoff to mitigate impacts, particularly in sensitive receiving environments.

The literature review of roadside pollutants undertaken did not find any studies that did broad scale sampling without pre-determining the parameters to sample for however, Appendix B presents a detailed list of pollutants likely to be found in highway runoff and this is supplemented with further information above.

Untreated road runoff is likely to have negative eco-toxicological effects and if these are to be minimised then treatment needs to focus on the first flush and specifically on the removal of suspended solids (to eliminate bound heavy metals), zinc and copper.

The review also identified that the Event Mean Concentration values for total nitrogen, total phosphorus and total suspended solids proposed by Fletcher *et al* (2004) should be adopted for the water quality modelling work undertaken.

5 Water quality guidelines

5.1 Overview

There are several water quality criteria routinely applied in NSW and more broadly in Australia and overseas. In order to assess the potential water quality impacts associated with the proposed Tintenbar to Ewingsdale Pacific Highway upgrade the following water quality performance targets have been considered:

- ANZECC Guidelines for Fresh and Marine Water Quality (2000).
- Australian Drinking Water Guidelines.
- NSW Department of Environment and Climate Change (DECC) stormwater quality guidelines – current and proposed.
- Sydney Catchment Authority, State Environmental Planning Policy 58 (SEPP 58).
- Richmond River Water Quality Objectives in conjunction with "Using the ANZECC Guidelines and Water Quality Objectives in NSW" (DEC, undated).
- UK Highways Agency, Design Manual for Roads and Bridges, Volume 11, Section 3 Environmental Assessment Techniques, HA 216/06 Road Drainage and the Water Environment.

The purpose of the review was to ensure that the criteria adopted for environmental assessment of the proposed Pacific Highway upgrade are appropriate and informed by the relevant issues associated with each of the various assessment methods.

As required by the DGRs the ANZECC Guidelines for Fresh and Marine Water Quality have been considered as part of this review however it was found that there direct application to the project is not appropriate given their need to consider the contribution of other land uses to the overall water quality.

The guidelines provided by NSW DECC requiring specific pollutant retention targets were identified as being appropriate criteria to apply to potential water quality impacts from the proposed upgrade in the Emigrant Creek catchment via the modelling of potential treatment options.

For the remaining sections of the proposed upgrade, including the section in the Wilsons River catchment area, it is proposed that mitigation measures in accordance recommended minimum design standards for erosion and sediment control during the construction and operation of main roads.

5.2 ANZECC Guidelines for Fresh and Marine Water Quality

The main objective of the ANZECC Guidelines for Fresh and Marine Water Quality is:

> *to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values [uses] for natural and semi-natural water courses in Australia and New Zealand.*

The ANZECC guidelines provide a framework tool for catchment managers to assess and manage the ambient water quality in a particular resource.

The application of the guidelines commences with the determination of goals for water quality and the health of the ecosystems within the whole catchment. It is therefore, not appropriate or practical for one land owner in a catchment to determine goals for the ecosystems in that catchment in isolation of all the other landowners / users. The process of determining goals for the catchment needs to be undertaken on a "whole of catchment basis".

5.2.1 Guideline trigger values

The framework contains guideline trigger values, which are concentrations of a chemical or nutrient that, if exceeded, have the potential to cause a problem in the ecosystem and so trigger a management response. These values are not meant to be applied directly to stormwater quality unless the stormwater is regarded as having conservation value.

Although commonplace for both regulators and decision makers to do so, the simple adoption of the guideline trigger values included within the ANZECC guidelines for a single landuse within a catchment are only to be used as a last resort. ANZECC specifically makes this point and reinforces it a number of times.

Further the guideline trigger values are applicable to in-situ water quality and will therefore reflect ambient conditions. Ambient conditions within the Emigrant Creek Dam and Wilsons River catchments are very likely to exceed the guideline trigger values prior to development (SKM, 2005). This makes it inappropriate to assess the impact of the proposal against the guideline trigger values.

While it may be possible for runoff from the road to comply with the guideline trigger values, this would result in a significant cost to the community as well as sterilise large amounts of land in order to treat the water to such an extent. Such a requirement may be appropriate for a pristine catchment, however, for a less than pristine catchment this would need to be considered in the context of the entire catchment.

- As the proposed highway carriageway area would only affect around 4% of the Emigrant Creek dam catchment and less than 0.2% of the Wilsons River catchment, the assessment of the proposed upgrade together with the rest of the catchment would result in the impact of the proposed highway upgrade becoming indistinguishable. It should be noted that for the proposed upgrade as a whole the area of highway pavement (main alignment, interchange ramps, local access roads etc) is less that 20% of the acquisition area. The majority of the acquisition area being required for the earthworks associated with the proposed upgrade, nominal clearance of the road footprint to the road boundary and water quality devices.

There are also statistical reasons why the guideline trigger values should not be used to assess the proposed upgrade. The guideline trigger values reference the 50^{th} flow percentile however, in a creek or river which has a permanent flow the 50^{th} flow percentile value is a agglomeration of both wet and dry weather flows. Wet weather flow is typically of poorer water quality than dry weather flow and the 50^{th} flow percentile is accordingly a statistical measure that smooths out the fluxes in water quality values. The proposed upgrade will not have any dry weather flows (by virtue of the impervious nature of the road) and therefore the use of the 50^{th} flow percentile as an indicative measure of water quality is not appropriate to adopt because it will only reflect the poorer wet weather flow.

5.2.2 Lethal concentration values

ANZECC (2000) presents tables of concentrations for specific toxicants, exposure to which are associated with survival of 85% to 99% of organisms, i.e. LC_{85} to LC_{99} values.

ANZECC notes that there are complex issues associated with using these values and actual survival rates would depend on the period of exposure (of a single event if acute and of multiple events if chronic) and the frequency of exposure. Actual exposure depends on many factors but principally on the load/concentration that would be discharged from the treatment measures together with the degree of dilution that would occur at the point of discharge.

It is possible to undertake ecotoxicological studies on a single discharge point, such as from a sewage treatment plant where highly concentrated and polluted water is discharged. These studies involve complex three dimensional fluid dynamic investigations would require significant sources of data to be collected so that the fate and decay of pollutants can be modelled with due consideration of the effects of mixing and dilution of the receiving water. Pollutant plumes and pathways can be modelled which show the variance or decay of concentrations of a toxicant with distance downstream of the discharge point. Ecotoxicity is then established either by reference to available data, such as the ANZECC guidelines (which reflect chronic or continual exposure) or through bioassays which would need to reflect the actual exposure periods and patterns associated with the intermittent storm flows that would occur as a result of this proposal. These would need to be relatively short periods and take into the dilution that would occur as predicted by the pollutant decay modelling.

This approach is deemed to be appropriate for assessing the impact of a new sewage outfall however there are a number of restrictions which limit the applicability of such an approach on this project. These include:

- Numerous discharge points which all differ and each of which would require a separate model and separate bioassay.
- Models for each toxicant would need to be established as they all behave differently in a fluid environment.
- The data needed to create such a model would include significant stream flow records or synthesized stream flow for each discharge point. These stream flow records do not exist and synthesis of artificial stream flows would require rigorous hydrological calibration which could take over a year to develop.
- Significant biological background data, at each discharge point would need to be collected to be able to identify the current ecological state of the waterways e.g. macro-invertebrate surveys for each site. Collection of this background data may take a considerable period of time.
- Such an investigation is not considered to be justifiable for a project of this nature. It would be appropriate for a sewage treatment plant which has a continuous discharge and loading on the receiving water but not for assessing the impact of treated stormwater discharges which have an intermittent discharge and substantially reduced pollutant loading.
- Based on available information it is difficult to predict the decay of a range of toxicants in stormwater. Typical pollutants such as nutrients and suspended solids can be modelled but decay rates for other toxicants are not known. The best approach for the assessment of the impact other toxicants on receiving waters is to indicate the performance of the proposed treatment measures based on the results of monitoring of existing and similar treatment measures.

In conclusion assessment of toxicants for linear projects where multiple intermittent discharges occur can be assessed by inference of the performance of similar treatment devices. It is not appropriate to undertake detailed fate and decay assessments on highway projects especially when they affect less than 2% of a catchment area and as a result would contribute no more than 2% to 3% of the total pollutant load in the catchment.

5.3 Australian Drinking Water Guidelines

Guidance on what constitutes good quality drinking water is provided by the Australian Drinking Water Guidelines (NHMRC & ARMCANZ, 1996), a companion document of the National Water Quality Management Strategy of which the ANZECC guidelines form just one part.

The Australian Drinking Water Guidelines are intended to meet the needs of consumers and apply at the point of use; for example, at the tap. They are applicable to any water intended for drinking irrespective of its source or where it is used. They are not intended as guidelines for environmental water quality.

These guidelines are directly applicable to the polished and treated water quality after it leaves the water filtration plant and only indirectly applicable to the raw water entering the reservoir. In an ideal world, all raw water would comply with the guidelines and the need for treatment or filtration would not exist. It is important to appreciate that raw water quality or the water flowing in Emigrant Creek and the Wilsons River does not need to be compliant with the drinking water guidelines but it would ideally need to protect the ecosystems within the receiving waterway. By establishing environmental protection as the principle water quality objective public health, through protection of raw water quality, would also be protected.

The guiding principles listed in the Australian Drinking Water Guidelines however, were considered in respect of the project. **Table 6** below identifies the project response to each of these guiding principles.

Table 6 Response to guiding principles of the Australian Drinking Water Guidelines

Guiding Principle	Project Response
The greatest risks to consumers of drinking water are pathogenic micro-organisms. Protection of water sources and treatment are of paramount importance and must never be compromised.	The proposed upgrade would be a potential source of pathogens. The sediment removed as part of the proposed treatment train would play a major role in reducing the concentration of pathogens entering receiving waters.
The drinking water system must have, and continuously maintain, robust multiple barriers appropriate to the level of potential contamination facing the raw water supply.	The Rous Water treatment system contains multiple barriers. Additional barriers would be added as part of the treatment train for the proposed upgrade.
Any sudden or extreme change in water quality, flow or environmental conditions (e.g. extreme rainfall or flooding) should arouse suspicion that drinking water might be contaminated.	Sediment basins are proposed that would retain runoff from most storm events. Ongoing communication between Rous Water and the RTA would assist in identifying any contamination after extreme storm events.
System operators must be able to respond quickly and effectively to adverse monitoring signals.	The RTA would work closely with other stakeholders to prepare an emergency response plan for incidents occurring on the road network within the catchment area.
System operators must maintain a personal sense of responsibility and dedication to providing consumers with safe water, and should never ignore a consumer complaint about water quality.	The RTA acknowledges Rous Water's commitment to providing safe drinking water.
Ensuring drinking water safety and quality requires the application of a considered risk management approach.	The risks to drinking water quality (both acute and chronic) have been carefully considered in both the route selection and environmental assessment process.

5.4 NSW Department of Environment and Climate Change stormwater quality guidelines

The NSW DECC has water quality criteria that were introduced in their document *Managing Urban Stormwater, Council Handbook - Draft* (EPA, November 1997) and provide guidance for local government agencies to adopt into their stormwater management plans. The current guidelines are intended for application in urban residential areas under post development conditions however they could also be applied to major highway projects or industrial / commercial sites. The specific pollutant retention targets as shown in **Table 7** below:

Table 7 DECC current and proposed stormwater pollutant retention criteria

Pollutant	Current Guideline Minimum retention (%) of the average annual load	Draft Guideline Minimum retention (%) of the average annual load
Total Suspended Solids	80%	85%
Total Nitrogen	45%	45%
Total Phosphorus	45%	65%
Oil and Grease	None visible	None visible

The draft guidelines were issued for consultation in 2007. The changes in minimum retention values represent improvements in best management practices for the treatment of stormwater runoff and the values have subsequently been adopted by a number of NSW council areas in respect of their water quality management guidelines.

These targets are measured by comparing the proposed development without any treatment against the proposed development with treatment. Note that the chosen measure of performance is average annual load retention – it does not require wet or dry years to be analysed – only for average performance to be assessed.

They permit the development to be assessed in isolation of the rest of the catchment.

The DECC criteria have been developed to ensure that receiving waters are afforded suitable levels of protection without imposing a severe burden on developers. It is understood that these criteria have been widely tested by the NSW DECC and reflect the need to manage the critical water quality parameters of concern in NSW – i.e. sediments and nutrients. These criteria however have wider impacts because in the context of a stormwater treatment train, retention of soluble nutrients may also result in the retention of other pollutants typically found in stormwater.

5.5 The Richmond River water quality objectives

The Richmond River Water Quality Objectives in conjunction with "Using the ANZECC Guidelines and Water Quality Objectives in NSW" (DEC, undated) reflect ANZECC default guideline trigger values. For the reasons stated above with respect to ANZECC default guideline trigger values, this method is not a suitable way to measure the impact of the proposed highway upgrade.

5.6 Sydney Catchment Authority

Administered by the Sydney Catchment Authority, State Environment Planning Policy 58 (SEPP 58) was created to protect Sydney's drinking water catchments. The policy requires that all development within the catchment areas achieve a neutral or beneficial effect on the quality of stormwater runoff.

The application of this policy provides a balanced approach to assessing the impact of the proposed upgrade on water quality whereby preserving or improving the current situation is considered to be acceptable.

Through the consultation process, Rous Water have indicated that they do not believe that the current impacts of the existing highway on water quality are acceptable and therefore they believe that a comparative assessment using that approach to identify possible mitigation measures is inadequate.

Notwithstanding the comments from Rous Water it should be noted that the policy is applied elsewhere in NSW and there is significant merit in setting an objective that the combined existing and upgraded highway (and associated service roads) would have a beneficial effect on water quality compared to the existing situation.

5.7 UK Highways Agency

The environmental assessment methods used by the Highways Agency in the United Kingdom were also reviewed for applicability to this project.

Volume 11, Section 3 of the Design Manual for Roads and Bridges details the Environmental Assessment Techniques applicable to motorways and trunk roads in the UK. The document HA 216/06 Road Drainage and the Water Environment details a protocol for assessing the risk to water quality from highway runoff by assessing key indicator pollutants (Zinc and Copper). The protocol implicitly recognises that background concentrations need to be defined together with the predicted load of toxicants leaving the proposed highway. This method accounts for any dilution of road runoff to derive a prediction of in-situ water quality. The method is however limited in that it only serves as a decision making tool to determine if treatment needs to be put in place. Once it is resolved that treatment does need to occur, reliance on a best management practice approach is deemed to be an acceptable way to mitigate the impact.

In the context of this project there is no need to undertake the calculations because it has been accepted by all parties that a best management approach would be put in place in any event.

5.8 Recommendation

In conclusion, the ANZECC guidelines provide a tool for catchment managers to make decisions. The use of default trigger values contained within the ANZECC guidelines are not appropriate to assess a major road project in isolation and would therefore not be adopted for this water quality impact assessment.

The use of pollutant retention targets detailed in the NSW DECC criteria are considered to be an acceptable way to assess the impact of the proposal in the sensitive catchment area of Emigrant Creek dam and are adopted as the most appropriate water quality objectives against which the impact of this project can be assessed.

Taking into account the Director-General's requirement for consideration of public health, the protection of raw water quality would ensure that public health is protected. Due to the sensitivity of the Emigrant Creek dam catchment to the potential effects of stormwater runoff from the proposed upgrade the use of pollutant retention targets would ensure that raw water quality does not decline and that public health is protected.

For the remaining sections of the proposed upgrade, including the section in the Wilsons River catchment area, it is proposed that water quality impacts would be managed in accordance with recommended minimum design standards for erosion and sediment control during the construction and operation of main roads.

This approach reflects the lower potential effects of the proposed upgrade due to the relative small area of the proposed upgrade within the catchment, the distance from the proposed upgrade to the Lismore Source off take, the significantly longer length of other roads compared to the proposed upgrade and the areas of settlements and urban areas. A best management practice approach has been adopted for the development of the proposed stormwater treatment measures in the Wilsons River catchment.

6 Construction phase

The construction phase of the proposed upgrade has the potential to generate pollutants which could affect water quality. These could occur through chronic events, with low individual severity that could accumulate over time, or through acute events, which could occur infrequently but with high severity such as spills or leaks that could occur from accidents, negligence or even sabotage.

The primary potential impact on water quality during construction would be due to increased sediment loads from the conveyance of exposed soil to receiving waters during storm events. Increased sedimentation of watercourses can smother aquatic habitats and organisms, and can increase levels of nutrients, metals and other potential toxicants that attach to sediment particles. Other pollutants that could be expected to potentially impact on water quality during the construction period include:

- Hydrocarbons and chemicals as a result of spills and leakages from construction vehicles or fuel / chemical stores on construction sites.
- Litter and gross pollutants from construction material and activities.

Erosion and sedimentation control measures for the construction phase would be designed in accordance with the *Draft Pacific Highway Deisgn Guidelines* (RTA 2005b) to manage both chronic and acute events. These would include construction sediment basins designed in accordance with *Managing Urban Stormwater – Soils and Construction 4th Edition* published by Landcom (2004) and the draft DECC document – *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction*.

6.1 Chronic water quality impacts

The major construction phase mitigation measures are to consist of sediment basins constructed in accordance with the above guidelines and RTA drawing MD.R1.A10.A.

The requirements specified in the draft DECC document – *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction* for the size of construction sediment basins for non sensitive receiving environments where the duration of works is between 6 months and 3 years would be to contain all runoff expected from the 80th percentile, 5 day rainfall event.

Where space does not allow the use of basins designed for the 80th percentile, 5 day rainfall event then the option exists to provide sediment basins sized for the 75th percentile, 5 day rainfall event together with enhanced erosion controls.

For the Wilsons Rive catchment, and other areas of the proposed highway outside of the Emigrant Creek dam catchment the construction sediment basins would be sized to contain all runoff expected as follows:

- Sediment basins to contain all runoff expected from the 80th percentile, 5 day rainfall event.

As outlined in Section 2.6, the Emigrant Creek dam catchment is considered to be more sensitive to water quality impacts than the Wilsons River catchment. As such, the Emigrant Creek dam catchment has been afforded a higher level of protection as follows:

- Emigrant Creek dam catchment: Sediment basins to contain all runoff expected from the 85th percentile, 5 day rainfall event.

This meets the requirements specified in the draft DECC document – *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction* for the size of construction sediment basins for sensitive receiving environments where the duration of works is between 6 months and 3 years.

The sediment basin locations and their required capacities have been developed and optimised by Arup for the proposed upgrade and would be subject to refinement during the detailed design.

Where feasible, basins have been designed to accommodate an additional volume on top of the volume determined to be required for settlement and sediment storage zones. Sediment storage zones have been sized as 50% of the settling zone capacity. This method provides a conservative basin volume, which could be refined once soil erosion properties at each location are better defined.

The location of the basins and the associated basin detail are shown in Appendix A.

The design configuration of the proposed basins is such that aided flocculation of sediments within the wet basin is required prior to controlled manual release of the water. Provided flocculation and controlled release is undertaken in accordance with the relevant requirements and that best management construction practices are put in place during the construction phase, water quality should comply with the relevant standards and legislation. This would pose low risk to ecosystems and human health.

Other best practice erosion and sediment controls would also be adopted from the draft DECC document – *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction* comprising the following as examples:

- Top soil would be stockpiled and reused during vegetation. Stockpile heights would be minimised to limit wind erosion.
- Disturbed areas would be limited to only those areas which need to be worked on at that point in time and areas would be rehabilitated and sealed as soon as possible following construction.
- Batters slopes would be minimised to ensure that minimum possible area is disturbed.
- Clean run on water would be diverted around all works using diversion drains.
- Sediment basins to retain the 85th percentile 5 day rainfall event for the Emigrant Creek dam catchment. These basins would include the ability to retain an accidental spill that occurs during construction. The basins would comply with the requirements of the *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction*, i.e. provide sediment storage and settling zone and have a suitable spillway.
- Sediment basins to retain the 80th percentile 5 day rainfall event for the Wilsons River catchment. These basins would include the ability to retain an accidental spill that occurs during construction. The basins would comply with the requirements of the *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction*, i.e. provide a sediment storage and settling zone and have a suitable spillway
- The sediment basins would be operated to ensure that sediment is removed when the sediment storage zone has reached 80% of capacity.
- Sediment basins would be flocculated with appropriate, approved flocculants to enhance the settling of dispersible and small sediment particles.
- Best practice soil and water management would also put in place. This would include the use of sediment fences, check dams, level spreaders and other devices to mitigate the export of soil from the site.
- Trees would be mulched on site and the mulch used in the revegetation and stabilisation of the site.
- Top soil dressing and revegetation would take place as soon as possible.

- Revegetation would only use native endemic species.
- Temporary sterile grass covers would be used to seal areas whenever practical.
- The use of floating booms shall be made where major crossings and permanent pools are put at risk from construction activities.
- All storages of fuel and chemicals would be bunded and stored in approved storage containers.
- Steep batter slopes would be sealed using jute matt or mesh as appropriate or equivalent erosion control blankets would be employed. These shall be biodegradable.
- The preparation and implementation of an audited environmental management system and plan.
- The preparation of a construction phase best practice waste management plan.

During the development of the detail design a soil conservation consultant would be engaged to assist the design and implementation of best practice measures to ensure that water quality objectives for the project are achieved.

6.2 Acute water quality impacts

The sediment and erosion control strategy detailed above aims to direct runoff from all disturbed areas toward sediment basins. These basins are also appropriately sized to ensure that they can contain an accidental spill that may occur during construction operations.

Risks are primarily in relation to spills or leaks of fuels / oils and other machinery liquids such as radiator coolants which could arise from negligence, accident or deliberate sabotage.

The risks are best managed by application of *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction* guidelines that would act to divert and contain spilt product together with a comprehensive construction environmental management plan (CEMP) with appropriate incident response / management plans and procedures. Key aspects to the effectiveness of these measures are:

- Spill basins in place as soon as possible.
- Effective procedures for the recovery of spilt materials – pumps on site, earthmoving equipment, trucks etc to quickly remove pollutants positioned where they can be mobilised efficiently.

During the development of the detail design a specialist soil conservation consultant would be engaged by the RTA to assist in the development of the Erosion and Sediment Control Plan (ESCP). The ESCP is likely to be multi-part and will consist of a Primary ESCP, which will contain detailed background information, risk assessment and discussion, whilst a series of sub-ordinate Progressive ESCPs will provide up to date detail regarding location, installation and operation of control measures.

The Progressive ESCPs will typically develop as the project proceeds through design and construction as site conditions evolve and drainage flowpaths are changed. The ESCP will promote the design and implementation of best practice measures to ensure that water quality objectives for the project are achieved.

7 Operation phase

7.1 Overview

During the operation phase of the proposed upgrade impacts to water quality could occur through chronic events, with low individual severity that could accumulate over time, or through acute events, which could occur infrequently but with high severity such as spills or leaks from accidents. Both types of events need to be considered in developing mitigation measures.

Chronic water quality impacts would be managed through stormwater treatment measures. In accordance with the *Draft Pacific Highway Design Guidelines* (RTA 2005b) all carriageway runoff would be intercepted prior to discharge into receiving waters to minimise impacts on water quality during highway operation.

As outlined in Section 2.6, the Emigrant Creek dam catchment is more sensitive to the potential effects of stormwater runoff from the proposed upgrade than the Wilsons River catchment. Due to this the stormwater treatment measures for the Emigrant Creek dam catchment would be designed to provide a total pollutant load reduction within the catchment and would meet the DECC water quality criteria (Section 5.4).

In order to demonstrate that these criteria can be met preliminary treatment options have been developed and modelled for the Emigrant Creek dam catchment. The results of this modelling indicate that a bioretention basin using sand as a filter media would meet the above criteria.

As outlined in Section 2.6 the Wilsons River catchment has a lower sensitivity, compared with the Emigrant Creek dam catchment, to the potential effects of the proposed upgrade due to: the relative small area of the proposed upgrade within the catchment; the distance from the proposed upgrade to the Lismore Source off take; the significantly longer length of other roads compared to the proposed upgrade and the areas of settlements and urban areas. Due to the above, a best management practice approach has been adopted for the development of the proposed stormwater treatment measures in the Wilsons River catchment.

Stormwater treatment measures for the Wilsons River catchment would consist of the conversion of construction phase sediment basins described in Section 6.1 to permanent wet basins in accordance with RTA drawing MD.R1.A10.A.

Both of the options mentioned above would be appropriate for mitigating the acute risks within the Emigrant Creek dam and Wilsons River catchments.

In developing detailed design responses, further modelling and design refinement can occur to optimise performance and function. Through this process, other design solutions that also provide compliance with the load reduction and pollution criteria may be considered. If it can be demonstrated that alternative solutions can be developed which satisfy these criteria that can provide better value for money and/or are easier to maintain, then it would considered responsible to install these alternatives. Any process to identify and propose alternative measures should be undertaken in consultation with Rous Water.

7.2 Assessment methodology

7.2.1 Chronic water quality

Emigrant Creek catchment

The change of average annual pollutant load can be estimated through water quality modelling. The water quality model, Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was chosen because it is capable of modelling firstly the change in land use and then the level of mitigation provided by the proposed water quality treatment measures. The model is applicable to catchments up to 100 km^2 in size and is capable of modelling the change in land use of a rural catchment to a highway land use.

To model the predicted change in average annual pollutant loading both the existing highway together with the proposed highway needs to be assessed in isolation of the rest of the catchment. A pre-development model needs to be created to provide the base-line case followed by the construction of a post development model which reflects the change in land use from rural to highway. The model needs to include the mitigation effects of the proposed stormwater treatment measures.

Average annual loading is a term used to describe the expected average annual load. It is not a measure of the load to be expected in any year – every year will be better or worse than the average year and this measure reflects an "on average" approach. This requires careful selection of a suitable rainfall data set with which to simulate average annual performance.

In relation to a development proposal, comparison with NSW Department of the Environment and Climate Change (DECC) criteria for stormwater management performance provides guidance to determine the effectiveness of proposed pollution management strategies. To demonstrate adequacy, a comparison with the DECC pollutant retention rates is required and this is achieved by water quality modelling. The post-development model without mitigation is constructed to provide a base-line for comparison against the post-development scenario with mitigation. The average annual load is used as the chosen measure.

Wilsons River catchment

In the Wilsons River catchment a best management practice approach has been adopted for the development of the proposed stormwater treatment measures to mitigate the range of likely chronic impacts.

This would consist of converting the construction phase sediment basins, which have been designed to retain the 80th percentile 5 day rainfall event, to permanent wet basins in accordance with RTA drawing MD.R1.A10.A.

Pollutants

As outlined in Section 4.5 the review of potential effects of road runoff identified that the Event Mean Concentration values for total nitrogen, total phosphorus and total suspended solids proposed by Fletcher *et al* (2004) should be adopted for the water quality modelling work undertaken. The removal of suspended solids will also eliminate bound heavy metals and reduce the potential water quality impacts of road runoff.

Currently there is insufficient scientific data on toxicant specific decay rates with which to use a model such as MUSIC to predict the performance of specific toxicants after treatment. A simplistic approach however, can be adopted which references measured performance of similar treatment devices against those proposed on this project. This is akin to a best management practice approach and has been undertaken.

7.2.2 Acute water quality

The assessment of acute water quality impacts has been undertaken using a risk management framework.

Risk is defined as the chance of something happening that would have an impact on objectives. In the case of drinking water catchments, the primary objective is the protection of human health of water consumers. Related to this is the protection of ecological health which facilitates the operation of the system, and consequently the protection of human health.

Factors that have been considered in the acute risk assessment include:

- Improved road safety.
- Heavy vehicles and the dangerous goods vehicles traffic volumes.
- The probability of a spill occurring if there is an accident.

- An assessment of pollutant fate should a spill occur.

7.3 Treatment options

Three indicative treatment options have been developed for the purposes of modelling the water quality impacts within the Emigrant Creek dam catchment. The treatment measures proposed in the detail design could include a combination of these options or another option however, it would need to be demonstrated in the detail design phase that the proposed treatment measures would meet the design criteria and objectives detailed in this assessment.

Three options that were considered likely to be able to deliver the necessary amount of mitigation were developed so that their water quality performance and life cycle costing could be assessed. While each option and the assessment methods are described in detail in the following sections of this report, the rational for selecting each option for analysis is described briefly below:

- Option 1 – Conversion of construction phase sediment basins into permanent water quality control ponds. This option was chosen because it is a method used by the RTA on other projects and has been considered a best management practice since the 1980s. The wet basins are easy to construct requiring almost no additional resources to build. They typically have a low maintenance regime and it is considered that good water quality outcomes are likely. The wet basin is also able to retain a hydrocarbon spill and this made it attractive given the perceived acute water quality risks.
- Option 2 – Conversion of construction phase sediment basins into a permanent bioretention basin using sand as a filter media. The sand filter option was selected because of the very good measured performance in an environment similar to that of this project (Performance data has been gathered from a sand filter at Kiama on the NSW south coast where there is high rainfall intensity together with very similar traffic loadings). The sand filters would require a gross pollutant trap upstream of each basin. Provision of bioretention (a well grassed surface) would prevent the device from clogging and the need to rake any exposed sand surface. It was also considered that sand which is often used to soak up oil spills would provide a good degree of retention of hydrocarbons if a spill were to occur. The proposed filters are also easy to construct requiring very little specialist knowledge and this ensures that design intent is given the best chance to be carried through to construction. By comparison to traditional constructed wetlands, sand filters are known to be space efficient and to be low maintenance. Unlike constructed wetlands, problems with invasive species do not exist and management of the vegetation can be undertaken without the need of specialists.
- Option 3 – Construction of a linear bioretention trench along the length of the proposed highway together with the conversion of construction phase sediment basins into permanent water quality ponds with a spill retention capability. This option was chosen as an example of a possible best management practice because it could also easily be included within the road corridor and would therefore reduce the need for any larger end of line solutions which would have a greater land take and associated cost.

Other options such as constructed wetlands were not investigated because they were known to be space inefficient (wetlands in this region typically occupy more than 5% to 8% of their catchment whereas a sand filter would occupy only 1% to 2% while delivering equivalent water quality benefits. Wetlands were also considered to be a maintenance intensive requiring regular weeding and control of invasive species often undertaken using pesticides and herbicides that would add unnecessary additional public health risks to both drinking water catchments.

Apart from bioretention and the use of wetlands there are proprietary treatment devices available that could also deliver the high levels of mitigation required. These however rely on filtration much like Option 2 and 3. They require more intensive and regular maintenance and are known to be cost prohibitive by comparison with the options investigated. The proprietary devices are more appropriate where space is a severe limitation such as on an urban freeway development rather than in a rural context such as the proposed upgrade.

7.3.1 Option 1 – wet basins

The standard RTA approach to post-development permanent water quality control is to convert construction phase sediment basins to combined sedimentation and accidental spill basins. The basin conversion is also documented on RTA Model drawing MD.R1.A10.A.

The location and size of construction phase sediment control basins were developed by Arup. Several temporary basins within the proposed highway footprint (necessary due to site constraints and catchment sizes) were not included in the modelling, i.e. only those basins that would be located outside the proposed highway footprint were modelled. Once revegetation of highway batters is completed, it is likely that the proportion of rainfall translating into runoff would be reduced.

For this project Storm_Consulting has recommended that the standard spill control outlet shown on RTA drawing MD.R1.A10.A is modified to provide a greater level of spill containment. The standard single 100mm diameter pipe would be replaced with an alternate system that would allow spill containment up to a 1 in 2 year average recurrence interval (ARI) event. Storm events up to the 1 in 2 year ARI cover a large portion (about 99% of total runoff volume) of all rainfall events thereby significantly increasing the probability that a spill would be contained. An example of an alternate spill containment outlet is shown on drawing 651-D01 in Appendix A. It was assumed that the basins had a permanent pool depth of 1.0 m to limit vegetation growth.

The results of the geotechnical investigation of the preferred route suggest that the in-situ residual soils are silty-clays and clayey-silts with approximate permeabilities of between 10^{-6} and 10^{-8}. These soils may provide adequate lining if prepared correctly. The residual soil profile is variable with thicknesses of between 1 m and 12 m - including the extremely weathered basalt horizon. Detention basins that penetrate this horizon would need to be lined. Borrowed residual soil from other areas of the site may provide an appropriate lining material.

7.3.2 Option 2 – sand filters

Given that the construction phase sediment basins all varied in storage depth between 2 to 3.5 m, an opportunity was identified to convert these basins over to sand filters while still retaining a reasonable storage volume. As per Option 1 only those basins that would be located outside the proposed highway footprint were identified for conversion and modelled.

The conversion consists of placing a drainage manifold and sand filter medium to a depth of 1.3m over some (or all, depending on the basin) of the existing basal area. Internal batter slopes were reduced to 1V:4H from the top of the basin embankment and the basin basal area reduced accordingly. Sand area was adjusted to ensure that the water quality being discharged from each basin would comply with the DECC criteria. A small length of special permeable pipe known as a *HydroCon* pipe would be installed within the sand medium to aid treatment and dispersement of subsurface flows. Inflows to the basin first enter the Hydrocon pipe and water then filtrates through the permeable pipe wall.

Details of the proposed system are included on drawing 651-D01 in Appendix A

The proposed sand filter is made up of many components that all contribute to its operation as a treatment train. Each component within the system contributes to the treatment of flows in a different way. Below is a brief overview of the configuration and operation of the proposed sand filters.

(a) Pre-treatment of flows

Pre-treatment of inflows is required to prevent the sand filter from becoming clogged with debris and coarse sediment. This is to be achieved by placing a gross pollutant trap (e.g. a CDS unit) at the beginning of the system to remove a large portion of suspended solids and litter from the stormwater prior to it entering the sand filter. All flows entering the sand filter should be piped through a gross pollutant trap and not allowed to enter *via* surface runoff to reduce the amount of sediment entering the sandfilter.

(b) *HydroCon* pipes

HydroCon pipes, first manufactured in Germany and now in Australia, are permeable pipes and allow for water to be treated through a number of mechanisms. Essentially by increasing the pH of the water, the pipe leads to changes in the solubility of some ions which in turn leads to settlement and the accumulation of fines in the base and walls of the pipe. As these pipes fill and water flows out through permeable walls, pollutants including metals and phosphorus are chemically precipitated by pipe matrix. ote that soluble nitrogen is not removed within the pipe. The bottom quarter of the pipe is impervious to enable the storage of any settled sediments which can then be removed during periodic maintenance. *HydroCon* pipes are not reinforced with steel or other fibres and therefore cannot be subject to the same traffic loadings as conventional drainage pipe. It is imperative that cars and heavy vehicles are prohibited from driving on the surface of the filter. The pipes can, however, withstand the loads imposed on them by smaller machinery such as ride-on mowers.

(d) Vegetative covering

The sand filter media must have a dense vegetative covering to prevent erosion of the sand and to keep the pores of the sand open. Either a native grass covering or dense covering of tufaceous water tolerant plants such as *Lomandra* spp. and *Dianella* spp. would be suitable. The choice of covering is not critical to performance of the system provided that the cover chosen has a root system capable of minimising erosion potential and keeping infiltration pathways open. Maintenance considerations, water tolerance and also tolerance to the well-drained sandy soil would be a requisite for selection. The vegetative cover is typically established in 100-150mm of quality topsoil. The particle size of the sand media prevents this topsoil from being transported down into the sand.

(e) Surface storage

When the sand matrix is full, water surcharges from pits located on the *HydroCon* pipe system into an above ground, vegetated surcharge area where it is stored temporarily. Over a short period of time the stored surface water infiltrates back down through the sand matrix and in doing so receives treatment.

Note that the surface storages available for the proposed highway construction vary in capacity from about 530m^3 to 3000m^3, and that the time to drain would vary from about 8 to 64 hours when full and inflows cease. The slow release has been optimised to ensure compliance with DECC criteria and is critical to overall treatment efficiency of the proposed system. The release rate would be controlled by a machined orifice on the sub-soil drainage discharge pipe.

(f) Subsoil drainage manifold

A subsoil drainage manifold is constructed at the base of the filter to collect the treated stormwater for disposal back into the watercourse further downstream. The subsoil manifold primarily consists of a proprietary subsoil pipe, such as slotted PVC pipe laid within a blanket of single sized aggregate. A layer of geotextile would be placed between the sand matrix and the aggregate to restrict the movement of fines into the aggregate.

(g) Maintenance access

Access for maintenance vehicles is critical for maintenance of the proposed sand filtration system and in particular the gross pollutant trap. It is recommended that the gross pollutant traps be placed in an accessible location adjacent to the proposed highway in a lay by area or similar so they can be readily maintained.

(h) Spill control

Spill control would be managed in an identical way to Option 1. The gross pollutant trap would also provide partial aid in the capture of accidental spills within the catchment

7.3.3 Option 3 – bio-retention trenches

This proposed treatment measure includes sand filter strips for the entire length of the road (except locations where trench construction is not possible at bridge locations etc). On sections of the alignment with a normal crossfall the trenches are located on the outside edges of the road formation whereas when the road is in superelevation the trench on one side of the road formation is located within the median strip. A physical barrier would need to be installed between the shoulder and the bioretention trench to prevent damage due to vehicles inadvertently driving on the trench. In general vehicle restraint barriers would be required on most sections of fill embankment for safety reasons however additional barriers would be required through cut batters. It is not considered necessary to place barriers adjacent to the trench where the trench is located within the median.

Water filtering through the sand filter strip is collected in a subsoil drain at the bottom of the filter and disposed of at regular intervals into the drainage system.

A shallow swale is located above the filter to convey excess runoff. Excess swale runoff would be captured in a conventional pit and pipe network

The sand filters are assumed to be 1 m wide and 1 m deep. There is assumed to be no storage above the sand filter as the location adjacent to the road restricts any significant depression, though in reality a 100mm depression would allow for surface flows down the swale. The saturated hydraulic conductivity of the filters is assumed at 360 mm/hr (this is considered conservative, as engineered sand is capable of much higher rates).

Emergency spill basins would be required to be retained within each catchment. It is recommended that the construction phase basins be retained in lieu of being rebuilt to a minimum capacity of 60,000 litres to meet the requirements of RTA model Drawing MD.R1.A10.A. Again the spill control outlet would need to be designed to fully contain a 1 in 2 year rainfall event within the basin.

7.4 Water quality modelling

7.4.1 Traffic volumes

The traffic volumes predicted for the highway range from about 16,500 vehicles per day in 2012 growing to about 29,000 in 2042. This volume of traffic would result in the highway falling in the lower of the two distinct groups identified in Section 4.2 and would therefore be associated with lower volumes of pollutant export than very busy highways.

Much of the traffic on the existing Pacific Highway alignment would shift to the upgraded highway however, local traffic would still access and use the existing highway. Therefore, in the future there would be two roads in use with the existing highway experiencing significantly lower volumes of traffic estimated to be of the order of 4,000 vehicles per day.

It would therefore be expected that pollutant loads currently generated on the existing highway would reduce considerably in line with the reductions in traffic volumes.

7.4.2 MUSIC model

The model adopted by Storm_Consulting is MUSIC (the Model for Urban Stormwater Improvement Conceptualisation) which has been developed by the Australian government's Cooperative Research Council for water resource management (eWater CRC).

MUSIC (Version 3) utilises a continuous simulation approach to model water quality and is suitable for simulating catchment areas of up to 100 km^2.

By simulating the performance of stormwater management systems, MUSIC can be used to determine if these proposed systems and changes to land use are appropriate for their catchments and are capable of meeting specified water quality objectives (eWater CRC, 2004). The water quality parameters modelled in MUSIC of relevance to this proposal include total suspended solids, total phosphorous and total nitrogen.

A pre-development model was built to estimate the pollutant loads generated from the site with its current land uses. A model of the proposed upgrade was also built to estimate the pollutant loads generated from the proposed upgrade with treatment options differing depending on the option being assessed.

7.4.3 Model inputs

Model inputs were calculated for the pre-development model and the three treatment option models.

The inputs for the treatment option models identified model parameters in respect of the source nodes such as impervious areas and soil storage capacity in pervious areas together with inputs for the treatment nodes such as basin volumes.

The model inputs are presented in Appendix C.

7.4.3.1 Meteorological data

The MUSIC model enables a continual simulation of actual rainfall. This prevents the need for many of the assumptions associated with using a single design rainfall event.

Moreover as Barry *et al* (2004) found the performance of stormwater treatment measures in small events is critical and their performance in large events is not critical because they happen so rarely. Adopting a continuous simulation approach enables the continual loading, growth and decay of pollutants within stormwater treatment measures to be modelled. This would not be considered if a single design storm event was adopted.

To simulate average export conditions, historical rainfall is used as the best indicator or predictor of future rainfall. Care needs to be exercised to ensure that the rainfall data set contains both dry and wet years and overall simulates average conditions. Experience on a broad range of water quality assessment projects using the MUSIC model has shown that for water quality purposes it is not necessary to model wet and dry years as it would be if one were undertaking a hydrological assessment for say effluent disposal purposes. In accordance with Barry *et al* (2004) one needs to simulate the performance of the proposed treatment measures by using a sufficient number of smaller storm events that would happen regardless in both wet and dry years.

The MUSIC User Manual (CRCCH, 2004) suggests that the model time-step should not be greater than the time of concentration of the smallest sub catchment, and consideration should also be given to the smallest detention time of treatment nodes in the system. To accurately model the performance of the treatment nodes, a 6 minute time step was chosen.

One year of 6 minute rainfall data is normally considered to be sufficient if 6 minute data is to be used. Continuous rainfall (6 minute) data was obtained from the Bureau of Meteorology (BOM) for Alstonville, the closest continuous rainfall station to the site (station number 058131). Meteorological data from 1 January 1981 to 1 January 1986 was used in the model in an attempt to model typical or average climatic conditions of the site. These particular five consecutive years of rainfall data provided a mean annual rainfall of 1940 mm (close to but higher than the annual average for the past 34 years of 1860 mm, obtained from the BOM).

Using 5 years of continuous rainfall will ensure that typical conditions are simulated and this exceeds what is considered to be industry practice.

7.4.3.2 Soil properties

The soil profile of the existing site is expected to be fairly uniform, therefore standard soil storage and infiltration capacity values for the different landuses were used throughout pre-development modelling.

Post-development soil property values were modified to account for the anticipated reduced soil storage and infiltration capacity due to cut and fill activity, i.e. where the proposed road had earthen batters that are in either cut or fill and so the depth of soil (with the possibility of rock close to the surface) was reduced to likely minimum depths. Additionally the steep batters proposed (1 in 2) through the Emigrant Creek catchment are likely to result in reduction in the potential for infiltration and hence soil storage. This would have the effect of generating more runoff and greater loads and is considered to represent a conservative approach to modelling.

Experience with the MUSIC model has shown that performance in a largely impervious catchment is not sensitive to changes in soil properties.

The soil properties of all source nodes are presented in Appendix C.

7.4.3.3 Event mean concentrations

Event mean concentrations (EMCs) describe the average or typical concentration of a pollutant in stormwater runoff. These differ from event sampling which simply measures the concentration of a pollutant in stormwater at one point in time during a storm event. Pollutant concentrations are known to vary with time and so deriving event mean concentrations is one way of more accurately predicting the total pollutant load. EMCs are derived from monitoring (using an autosampler) the stormwater at regular and frequent intervals during the storm event.

It is possible and in some cases advisable to predict pollutant loads using a stochastic load generator. This effectively takes into account the highly variable distribution of stormwater pollutants. When either modelling a whole catchment i.e. when assessing the impact of a project against specific concentration targets, this method is to be adopted in preference to the use of EMCs. Experience with both methods however, has shown that when assessing average annual loads of pollutants on an isolated part of a catchment the predicted performance would not differ significantly using either method. EMCs have been adopted for use here simply because the results are repeatable whereas stochastic load generation by definition leads to results which are not repeatable and do have differences between each model execution albeit minor ones.

The event mean concentrations adopted reflect more recent data by Fletcher *et al* (2004) for specific land-uses such as roads, rural and agricultural lands. The recommended value for total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) include lower quartile, typical and upper quartile values. The adopted value of EMC's for different land-use for both pre- and post-development are highlighted in **Table 8** over.

Table 8 EMC adopted for land use for pre- and post-development

Pre-development		Post-development	
Node	**EMC**	**Node**	**EMC**
Existing Highway - pavement	Typical	Existing Highway –pavement	Lower
Existing Highway - batters	Lower	Existing Highway - batters	Lower
Rural (crops)	Typical	Future Highway – pavement Future Highway – batters	Typical Lower
Agricultural (grazing)	Typical	Future Access Roads	Lower

Research cited in Kumar *et al* (2002) noted that exhaust deposition accounted for only 7.5% of the pollutant loading on a road surface. The drainage system proposed for the upgrade would capture all pavement runoff at the road surface. Given that runoff would not overtop the batter and vehicles would not drive directly on the batters it is considered that the batters therefore would only generate pollutant loads equivalent to the lower quartile road pavement pollutant loads.

The actual concentrations adopted for each land-use are presented in Appendix C.

The values adopted were compared with values derived Barry *et al* (2004), the UK Highways Agency, Drapper *et al* (2000) and Driscol *et al* (1990) and while there were minor differences in general the values were found to be consistent. The values derived by Fletcher *et al* (2004) were adopted because they have been provided by the Department of Environment and Climate Change (DECC) specifically for use on projects in NSW. They are therefore likely to be the values that formed the basis of the proposed new DECC stormwater criteria against.

7.4.4 Model configuration

7.4.4.1 Pre-development model

There are two components to the pre-development model:

1. The existing highway (including pavement and batters).
2. The existing rural and agricultural areas that cover the footprint of the proposed highway and access roads.

The existing highway pavement is represented by an urban node with associated pollutant generation loads typical for roads. The total length of the existing highway through the Emigrant Creek dam catchment is 5.2 km, with a measured area of 6.212 Ha. The roadside batters (measured at 4.759 Ha) have been modelled separately in another node which was considered to be 100% pervious but with shallow soil stores as defined in Section 9.4.2.2.

The land that falls within the area designated for the proposed highway alignment is currently used for a variety of uses as defined in Section 5.1.1. These land uses are represented in the pre-development model by agriculture and rural nodes. Rural encompasses all crops, house blocks and farming, agriculture includes grazing / pastures and cleared waterways (assuming grazing could be the only use on waterways and also considering the limited riparian buffers available). The rural and agricultural nodes are assumed to be 100% pervious.

7.4.4.2 Post-development models

The post-development models comprise the existing highway with reduced vehicle use and subsequent reduction in EMC values. The existing highway area (road and batters) was reduced to take into account the construction of the proposed flyover and associated highway deviation at Ch 141100.

The proposed highway pavement was modelled as an urban node with typical EMC values consistent with a road of this nature. A road pavement width of 14.5m in either direction (3 x 3.5 m traffic lanes, 2.5 m and 0.5 m shoulders and 1.0 m dish drain) was modelled to account for future additional lanes. Impervious areas were calculated separately for each catchment.

The surrounding batters are also represented as urban nodes and have lower quartile EMC values to ensure they are consistent with the pre-development state. They are assumed to be 100% pervious but have reduced soil storage and infiltration capacity.

Typically only runoff from cut batters and the road surface is assumed to be conveyed to the treatment nodes. Fill batters were assumed to discharge untreated to the catchment although this approach is somewhat conservative as in reality discharge will be *via* vegetation buffers in most circumstances. In Option 3, cut batters were further divided into two categories: cut batters and cut batters in superelevation. When the road is in superelevation and a bioretention trench is located within the median, the cut batter would not drain to the median. Rather, it would be collected in a concrete dish drain or similar adjacent to the road shoulder and disposed of without being routed through the bioretention trench in the median.

The proposed road design has changed slightly from the assumptions made above. The fill batters would in fact be directed toward the treatment devices and therefore additional catchment area would drain to the treatment measures. This is a positive change because it would further reduce the risk of a spill reaching a receptor outside of the road corridor. Furthermore the design was also enhanced such that all but the last 5 to 7 meters of all cuttings would no longer be directed toward the treatment devices. This relatively clean runoff would be directed away from the highway. The bottom 5 to 7 metres of the cut batters would still however be directed toward the spill basins.

This is considered to provide a substantially enhanced outcome however, it does not automatically mean there would be an improvement in water quality leaving the road and the effect of this minor change needs to be taken into account when the detailed design is undertaken.

The actual effect of this change is considered to be minor in terms of future water quality with any decline in quality able to be compensated for through enlargement of the treatment measures. The impact of this change is considered to be minor and therefore this assessment remains valid.

The proposed access roads have lower EMC’s commensurate with their expected traffic use and are also shown as urban nodes. Both road and batter catchment areas were accurately measured from design alignment strings produced by Arup.

Treatment nodes reflecting the treatment options identified in Section 7.2 have been placed according to their physical location within each catchment. Typical treatment efficiencies and treatable flow rates for CDS units and HydroCon pipes were adopted from manufacturers’ recommendations.

7.5 Chronic water quality impacts for the Emigrant Creek dam catchment

7.5.1 Model results

Water quality of only the Emigrant Creek dam catchment was undertaken in accordance with the methods described in Section 7.3. The results are tabulated below together with the relevant performance criteria.

Note that the results presented have changed from those results reported previously because the EMC value adopted for the modelling of the highway batters has been reduced to a lower quartile EMCs value to remove an element of conservatism in the previous models. The reduction rate is expressed as a percentage and compares the post-development with the pre-development pollutant loads. When a positive reduction percentage is achieved, there is a net decrease in pollutant loads as a result of development.

Table 9 Comparison of pre-development and post-development annual pollutant loads for Emigrant Creek dam catchment

Analyte	Pre-development	Option 1		Option 2		Option 3	
		Post-development	% change	Post-development	% change	Post-development	% change
Total Suspended Solids (tonnes/yr)	51.6	35.5	31% reduction	24.9	52% reduction	39.9	23% reduction
Total Phosphorus (kg/yr)	121	96	21% reduction	61	50% reduction	97	20% reduction
Total Nitrogen (kg/yr)	685	816	19% increase	590	14% reduction	643	6% reduction

Table 9 demonstrates that each option would mitigate the impact of total suspended solids (TSS) and total phosphorus (TP) to levels less than the pre-development condition. Option 1 would result in additional contributions of total nitrogen (TN) to the catchment while Options 2 and 3 would result in a reduction in the export of TN into the catchment.

Table 10 Comparison of predicted annual pollutant retention of the proposed upgrade with DECC criteria for Emigrant Creek dam catchment

Analyte	Sources	Option 1		Option 2		Option 3		Current criteria	Draft criteria
		Residual	Retained	Residual	Retained	Residual	Retained		
Total Suspended Solids (tonnes/yr)	99	24.5	75%	13.9	[86%]	28.9	71%	80	85
Total Phosphorus (kg/yr)	180.6	78	(57%)	42	[77%]	79	(56%)	45	65
Total Nitrogen (kg/yr)	846	693	18%	467	[45%]	520	39%	45	45

Notes:

- Source column represents the modelled pollutant load entering the treatment option.
- Residual column represents the modelled pollutant load following treatment of the water in the treatment option.
- Retained column indicates percentage of pollutant load removed by treatment option.
- Values in [parentheses] demonstrate compliance with current and proposed DECC criteria.
- Values in (parentheses) demonstrate compliance with current DECC criteria only.

Table 10 shows that Option 2 only complies with the current and predicted DECC criteria. Option 1 and Option 3 comply with current DECC criteria for TP and perform well in respect of TSS.

7.5.2 First flush retention capacity

The literature review documented in Section 4 noted that design measures need to focus on the first flush of pollutants predicted to leave a catchment. Specifically the capture and treatment of the first flush (including TPH, BTEX and metals such as zinc and copper) will have significant impacts on reducing the toxicity of road runoff.

The first flush capability of the proposed treatment options was investigated to establish if adequate retention can be achieved. The first flush is normally considered to be equivalent to the first 10mm of rainfall.

The depth of rainfall runoff capable of being stored in each of the treatment options was investigated. The volume of storage available for each option was measured, i.e. the air space between the surface of the water or filter and the spillway for option 1 and 2 and the volume of storage available in the sand filter media in option 3. The volume of storage was then divided by the catchment area draining to the device. A runoff coefficient of 0.4 was adopted to include the possibility of runoff from fill batters.

The results for option 1 and 2 are tabulated in **Table 11** below.

The method described above is considered to be a conservative way of estimating the depth of rainfall that can be captured in the treatment device before any overflow occurs. This is because while the calculations above assumed no water would be flowing out of the treatment device the whole time it rained. In reality treated flow does leave the device and a greater depth of rainfall would be treated than those stated above. For long duration low intensity storm events this depth would be significantly higher. For short duration high intensity events this depth would not be significantly higher.

Table 11 Depth of rainfall first flush that can be captured by each treatment device for options 1 and 2

Basin Reference	Option 1 rainfall depth (mm)	Option 2 rainfall depth (mm)
12	108	57
13	191	117
14	87	54
15	90	56
16	63	39
17	61	38
20	16	10
22	45	27
24	283	174
25	61	39
27	65	41
28	34	24

The depth of rainfall available for capture of option 3 only considered the 14.5m wide road pavement draining directly to it. It was found that 23mm depth of rainfall can be treated in the bioretention trench before it overflows.

Option 1 provides the greatest average first flush capture depths while Option 3 provides 23mm uniformly across the proposed highway. Option 2 would still provide a minimum of 10mm depth of capture at Basin 20 while at least 10mm of first flush capture is provided.

As a minimum, all options can be said to provide at least 10mm of first flush capture at every treatment device. This is considered to be appropriate and in line with best practice. It is also considered to ensure that the first flush of most contaminated runoff would be treated and would therefore reduce any present toxicity.

Note that each treatment device allows for the storage of the first flush. Because there is surface storage in Options 1 and 2, the first flush is likely to be well mixed. This would result in some dilution of the first flush though this is not quantified here.

7.5.3 Performance for road pollutants

7.5.3.1 Performance for copper and zinc

Kumar *et al* (2002), which accords with current UK highway design guidelines, found that copper and zinc form the most toxic components of the first flush of stormwater and these are discussed in detail and considered here to be indicators of all heavy metals.

The removal processes and estimated performance for copper and zinc for each option are noted below.

Option 1

Option 1 is likely to achieve settlement of fine sediment particles and therefore to be able to settle a fraction of the metals which are known to bind to sediment. Other removal processes may involve removal of dissolved metals through biofilm sequestration that occurs in the vegetated fringe of the wet basins. It is thought, however, that this would be minimal due to the limited surface area available for biofilms to grow and develop.

Bruckner *et al* (2006) with a data set of only 3 storm events tested the performance of two densely vegetated sediment basins on the Pacific Motorway near Coomera in southeast Queensland. While they found retention rates for suspended solids and nutrients that are within the right order of magnitude with those estimated by modelling in this working paper, they were able to form some conclusions with regard to the removal of heavy metals.

Bruckner *et al* (2006) found that the sediment basins removed copper to levels below the ANZECC guidelines however, they found little benefit gained in the reduction of Total Zinc. They noted that on one occasion zinc in the outlet was measured at levels higher than the inlet. This can occur for a few reasons including the possibility of sampling outflow from a previous storm event. The work indicates that total zinc has the potential to be scoured from within a sediment basin (even more so one which is not densely vegetated). This is likely to happen because unlike other heavy metals which are known to have a strong correlation with suspended solids, total zinc does not. This implies that zinc does not effectively bind to sediment particles and therefore its removal process is not principally through sedimentation.

Caution must be exercised in the reliance on the work of Bruckner *et al* (2006) as it is based on sampling from only three storm events.

In conclusion, based on the limited data available, Option 1 is likely to retain Copper (50% retention reported by Bruckner *et al,* 2006) and other heavy metals however, zinc may be considered to readily scour from sediment basins without any effective retention. Sediment basins would, however, capture the whole of the first flush and allow some dilution. Whether the concentrations are diluted to the point where they cease to cause toxicity is not easily quantified here because zinc pollutographs are not known to have been derived.

Option 2

Options 2 involves the incorporation of HydroCon filtration pipes together with sand filtration/bio-retention. The HydroCon pipes were developed in Germany specifically to retain heavy metals such as zinc and copper that were being exported in significant quantities into groundwater where many German towns source their drinking water. This product has therefore had its origins in protecting drinking water catchments and groundwater from being polluted by heavy metals.

The removal process in the pipes occurs *via* chemical precipitation as water flows through the pipe wall. The pipes have a finite life and will need replacement after about 20 years. A second removal process takes place inside the pipe. The pH of water is increased inside the pipe due to the construction of the pipe with concrete which is known to be basic. As a result some metals will precipitate out of solution due to the rise in pH.

The principal form of heavy metal removal would occur through sand filtration. Dunphy *et al* (2005) reported retention rates of over 90% for total zinc and retention rates of about 60% for iron from a sand filter constructed at Kiama in NSW.

Sand filters are thought to be so effective because they provide an extensive surface area on which biofilms can attach and grow in perpetuity. Biofilms are comprised of bacteria and other microorganisms that can feed on stormwater pollutants.

Sand filters are known for their ability remove heavy metals with the metals trapped within the upper 10 cm of the sand profile (pers com, Dr Simon Beecham, Associate Professor of Water Engineering, University of South Australia). To some extent it is thought that the vegetation present in the filters would remove the metals through uptake as sources of trace elements needed for their survival. The rooting depth of grass within the Kiama sand filter referred to in Section 7.3 extended to about 1m below the grass surface when last investigated. It is hypothesized that this would ensure a ready supply of oxygen deep into the filter media which is required to nourish aerobic bacteria some of which would degrade heavy metals and while other microflora, such as Nitrobactor and Nitrosomonas bacteria are required for nitrification and deninitrification, respectively.

Bound or attached heavy metals, such as copper would be removed through enhanced sedimentation and filtration. The sand filter at Kiama was able to retain 80% of suspended solids. This would indicate that a significant quantity of other bound heavy metals would also be removed.

Referring to the predicted EMC values for zinc in stormwater published by Barry *et al* (2004) which are similar to the value published by Driscoll *et al* (1990), an EMC value of 0.32 mg/l could be expected. Retention of 90% of this concentration would result in a discharge concentration of about 0.032 mg/l. This is comparable to the LC80 value (0.031 mg/l) for zinc in the ANZECC guidelines.

The maximum recorded level of influent zinc measured at Kiama was found to be a little over 1.1 mg/l. Retention of 90% of this would result in a discharge concentration of 0.150 mg/l of zinc. The LC50 value developed by Kumar *et al* (2002) for rainbow fish was 0.255 mg/l.

From this simplistic comparison it is possible to conclude that the sand filters (if designed and built correctly) would mitigate the impacts of zinc and most other heavy metals to levels close to the LC80 value documented in ANZECC and that LC50 values are unlikely to be exceeded.

Copper is known to be strongly correlated with suspended solids (Bruckner 2006 and Austroads 2003) and so it may be possible that 80% removal of suspended solids would equate with 80% removal of copper. If this were true then copper loads of 31 µg/l derived by Barry *et al* (2004) would be reduced to about 6.2 µg/l of copper which falls somewhere between the LC50 (18.7 µg/l) and the LC80 (2.5 µg/l

Option 3

Option 3 incorporates a linear bioretention trench using sand as a filter media. Its performance with respect to heavy metal retention is expected to be very similar to Option 2 due to the removal of suspended solids. The benefits in respect of the HydroCon pipes however would not occur for Option 3.

7.5.3.2 Hydrocarbons and BTEX

Option 1

Noting that Kumar *et al* (2002) found that hydrocarbons were present in the first flush but that they were not present thereafter treatment of the first flush is essential for the retention of hydrocarbons. They found that the composite (post first-flush) samples of stormwater did not contain detectable levels of TPH or BTEX. This strongly suggests that these compounds either volatilised from the flow or simply were not present.

Option 1 provides significant retention of the first flush volume. The water quality ponds would also be fitted with a baffled outlet to ensure that all floatable, i.e. visible oil and grease is retained within the pond.

Based on first principles, Option 1 is likely to retain all TPH present in the first flush, however, the fate and decay of the TPH between storm events is not known. Two things are possible. Either the TPH decays through a combination of volatilisation and biodegradation or it is simply washed out of the water quality pond the next time the water quality pond overflows. Given that the ponds are not maintained between storm events there is little opportunity to limit the discharge of TPH or BTEX if it is present.

It is therefore not possible to form a conclusion without better data.

Option 2

Sand is commonly used to spread on road surfaces to soak up accidental spillages of hydrocarbons. Therefore the sand filter media in the bioretention basins is capable of absorbing a significant quantity of TPH or BTEX from chronic loading. Degradation may occur through UV degradation, volatilisation or biodegradation within the sand filter media.

Once again there is an absence of performance data with which to assess the predicted performance of Option 2 with respect to retention of TPH or BTEX.

Option 3

Expected performance would be improved from Option 2 due to the end of line spill basins which would permit additional inter storm decay to occur.

7.5.3.3 Pathogens

Option 1

None of the studies reviewed for this project, apart from Dunphy *et al* (2005) analysed for coliforms in the stormwater flow. Dunphy *et al* (2005) used data collected from Kiama CBD which showed unusually elevated levels of coliforms in the influent that were thought to be the result of a sewage leak within the catchment. This data is therefore to be used with caution.

The proposed highway upgrade is not likely to contribute significant loads of pathogens simply because the proposal does not involve the management of human or animal waste products. Some pathogens may be discharged from the highway through accidental minor spills of animals or waste products during transport along the highway corridor however these minor or chronic spills of waste are not considered to be a significant source of pathogens.

As was noted in Section 4.2.3, stormwater typically carries about 4,000 cfu/100 ml. SKM (2005) found that wet weather concentrations of *E. coli* varied in Emigrant Creek Dam between 3,000 and 5,000. The pathogens to be expected from the highway would include coliforms but it is not likely that one would find any significant levels of *E. coli* which is usually associated with human or animal faecal matter.

Ultraviolet (UV) degradation would occur within the open water section of the pond. UV is a known disinfectant. No additional data on the performance of the converted sediment basins with respect to the retention of pathogens is available with which to form a conclusion on the actual amount of pathogens that may be discharged from the converted sediment basins.

Option 2 and Option 3

Option 2 and 3 can to be assessed in a similar manner due to similar treatment and pollutant removal processes.

Dunphy *et al* (2005) reported that the Kiama sand filter achieved 95% reduction of pathogens. Sand filtration is widely used by the waste water industry as a secondary treatment system to assist with the removal of pathogens amongst other things. It is considered to be a necessary treatment to reduce turbidity levels in the water column to such an extent that UV degradation can occur naturally in-stream thereafter.

It is considered that the sand filter (Option 2 and Option 3) would provide the best levels of protection and are considered practically capable of reducing pathogens by two orders of magnitude.

7.5.4 Conclusions

Water quality modelling is a developing science and at present there is sufficient data to model key pollutants of concern such as TN, TP and TSS.

Water quality modelling of these three key parameters for this project has shown that Option 1 would result in a minor decline in water quality in terms of TN while TSS and TP would be improved. Option 2 and 3 would improve all 3 measures.

Only Option 2 would meet the DECC guideline criteria that is used to assess any new development within the State of NSW.

Bruckner *et al* (2006) found that sediment basins constructed to treat runoff on the Pacific Motorway failed to effectively retain zinc while they did retain 50% of copper.

By reference to the performance of the Kiama sand filter 90% of zinc can be expected to be retained by using either Option 2 or 3 which have similar pollutant removal processes.

BTEX and TPH are likely to be present in the first flush of stormwater but not in the flow that occurs following the first flush. It is important to capture and treat at least the first 10mm of rainfall. Each option would be able to capture and treat at least the first 10mm of rainfall runoff.

It is not possible to quantify TPH or BTEX pollutant retention rates for any of the proposed options.

Typically stormwater contains about 4,000 fcu/100ml. No human or animal waste management activities will take place within the road corridor in either the Emigrant Creek Dam or Wilsons River catchments. It is not possible to estimate the ability of converted sediment basins (Option 1) to retain pathogens while sand filters (Option 2 and 3) may reduce pathogens by two orders of magnitude achieving 95% retention. Adoption of Option 2 and 3 is likely to result in a level of pathogenic export significantly lower than the other rural land uses within these catchments.

7.6 Chronic water quality impacts for the Wilsons River catchment

As stated in Section 7.2.1 in the Wilsons River catchment a best management practice approach has been adopted for the development of the proposed stormwater treatment measures to mitigate the range of likely chronic impacts.

This would consist of converting the construction phase sediment basins, which have been designed to retain the 80th percentile 5 day rainfall event, to permanent wet basins in accordance with RTA drawing MD.R1.A10.A.

The proposed measures would target the following prime pollutants:

- Coarse sediment.
- Litter, debris and organics.
- Total suspended solids.

- Heavy metals.
- Free oil and grease.
- Nutrients.

The removal efficiency for the various pollutants would not be as high as those anticipated for the sand filter (Option 2) proposed in the Emigrant Creek catchment however it is expected that removal of both coarse sediment and total suspended solids would be ~ 75% based on previous experience.

In considering the surrounding land use characteristics, the area of the proposed upgrade as a proportion of the catchment area, the distance of the proposed upgrade from the Lismore Source water extraction point the proposed approach is considered an acceptable as a stormwater treatment measure.

7.7 Acute water quality impacts to the Emigrant Creek dam catchment

The assessment of acute water quality impacts has been undertaken using a risk management framework. An acute water quality risk assessment was undertaken for Emigrant Creek dam catchment only. The principles and findings however, can be extrapolated to the Wilsons River catchment.

7.7.1 Risk assessment framework

Risk is defined as the chance of something happening that would have an impact on objectives. In the case of drinking water catchments, the primary objective is the protection of human health of water consumers. Related to this is the protection of ecological health which facilitates the operation of the system, and consequently the protection of human health.

Risk assessment and management is about reducing the risk associated with a hazard to an acceptable level. Because of the uncertainty associated with both the assessment of risks associated with specific hazards and the effectiveness of risk reduction actions, a ‘multiple barrier’ approach is adopted in drinking water quality management (NHMRC 2004) involving the following activities:

- Control hazards.
- Provide for process reliability.
- Incorporate redundancy.
- Enhance overall performance.

In relation to the proposed upgrade of the Pacific highway, the RTA can through its design, construction and operational phases attempt to control hazards. Rous Water has responsibility for all the water supply activities in consultation with stakeholders such as the RTA and Emergency Services, etc. This multiple barrier approach is particularly pertinent in describing the management of runoff risks. It is also akin to the notion of a “treatment train” in the language of modern stormwater management where each component of a treatment system provides incremental treatment or containment of runoff containing pollutants.

Complementing the multiple barrier approach and applying to high risk hazards are critical control points. A critical control point confers system operators the following advantages:

- Substantially reduces or eliminates a hazard.
- Can be monitored and corrective action can be applied.
- If the measure fails, would lead to immediate notification of key stakeholders.

In *Drinking Water Quality Risk Management Review for Rous Water* Egis Consulting (2001) state the following in relation to risk, which is applicable to the proposed highway upgrade.

- Realistic expectations for hazard identification and risk assessment are important. Hazard identification and risk assessment are predictive activities that will inevitably be based on less evidence than is desirable for definitive calculation. It is also common that histories of failure (which highlight the relevant risks) are rare. These inherent limitations must be recognised by viewing the predictions as no more than reasonable and practical judgements and not as scientifically derived determinations of the “real” risk.

Priorities for risk management and application of preventive strategies must be established and documented. Generally risk assessment will be at best semi-quantitative and will often include subjective judgements. The aim should be at least to distinguish between very high risks and low risk. Very high risks require implementation of preventive strategies whereas low risks might be tolerated

The Cooperative Research Centre for Water Quality and Treatment undertook a risk assessment for drinking water supplies. The results in relation to the risks pertaining to highways are summarised in **Table 12** over.

This information is provided for comparative purposes. Note that the risk of a traffic accident leading to an oil/fuel leakage is categorised as Possible (likelihood) x Minor (consequence) = **Moderate level of risk**. With road reserve barriers as the only mitigation measure, the level of risk is reduced to **Minor**.

Table 12 Drinking water quality risk management: Highway and Road Projects (from A Guide to Hazard Identification & Risk Assessment for Drinking Water Supplies CRC for Water Quality and Treatment Research Report No. 11)

Source / Hazardous Event	Hazards (Of most concern)	Maximum Risk			Existing Preventive Measures	Residual Risk			Further Comments, Considerations & Improvements
		Likelihood	Severity	Level of Risk		Likelihood	Severity	Level of Risk	
Pre - Construction	Site disturbance through site investigation (e.g. soil strata bore testing)	A	1	Moderate	Silt fencing, check dams & silt traps	D	1	Low	
Construction	Vegetation removal – loss of riparian zone around storage leading to higher nutrient load	A	4	Very High	Replanting of construction zone after completion of works	C	2	Moderate	Vegetation survey to be undertaken before any site disturbance, with restoration to use endemic riparian species
	Major earth moving – increased sediment load entering water supply	A	4	Very High	Silt fencing, check dams & silt traps	C	2	Moderate	Construction environmental management plan to be followed
Traffic Accident	Oil / Fuel leakage	C	2	Moderate	Road reserve barriers	D	2	Low	Emergency services or catchment management authority to employ suitable confinement control
Motorist associated pollutants	Non - Biodegradable garbage	A	1	Moderate	Road reserve barriers and rest zone amenities	C	1	Low	Appropriate waste disposal facilities recommended
Erosion of roadway or road shoulder	Rock, rubber shards and other similar contaminants entering waterway	A	2	High	Litter collection & road maintenance procedures	C	2	Moderate	Road management authority to undertake

(A=Almost Certain, B=Likely, C=Possible, D= Unlikely, E=Rare) (1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic)

7.7.2 Project specific risk

The RTA in association with Rous Water conducted a risk assessment pertaining to Pre-construction (planning and design), construction and operational stages of the Pacific Highway upgrade in the Emigrant Creek dam catchment.

A workshop was conducted between the RTA and Rous Water to jointly develop a risk matrix in which risk categories were identified in each stage, and then likelihood and consequence of each risk category was scored leading to an overall risk rating. Standard RTA management measures were applied to each risk, and the residual risk rating was then also determined.

The risk matrix that was developed jointly by Rous Water and the RTA, was then refined and forwarded to Rous Water for comment.

7.7.3 Risk in a catchment and water supply context

This assessment is undertaken given the following understanding of existing Emigrant Creek dam catchment conditions:

- The existing Pacific Highway has no formal pollution control measures.
- No other roads within the Emigrant Creek dam catchment are known to have any formal pollution control measures.
- The catchment contains a range of other diffuse and point pollution sources including:
    - Agricultural chemicals and their application (e.g. 80 tonnes of Phosphorus, 130 tonnes of Nitrogen and 4,000 L of herbicide/pesticide are delivered to the catchment per annum).
    - Former (unremediated) dip sites.
    - An operational dairy.
    - Large areas of cultivated bare ground on steep slopes associated with macadamia nut farming.
    - Diesel pumps operating on streams.
    - Widespread use of septic tanks.
    - Diesel and other fuel storages on farms.

The catchment is 1,900 Ha. The annual average catchment yield is 2,600 ML. The volume of the dam is 829 ML over 31 Ha. The depth of the dam at the off take is 9 m (average depth of whole dam 2.7 m). The spillway is 37m long and the dam is usually full and overflowing over the spillway. Total yield from the catchment is expected to be 1600 ML/a when environmental flows are considered. The flow patterns within the dam are such that dilution of contaminant loads can not be predicted.

Pollutants that enter the proposed upgrade's drainage system also have potential to enter local watercourses. There are approximately ten tributaries that these pollutants could enter with the following characteristics:

- Three tributaries exist with very short (1-2km) flow paths to the main body of Emigrant Creek Dam. These are all intermittently flowing streams at their closest point to the proposed Highway.
- Seven tributaries of Emigrant Creek exist with longer flow paths (3-7km) along Emigrant Creek to the main body of Emigrant Creek Dam, and these are a mix of perennial and intermittently flowing streams. Emigrant Creek is a perennial stream.

The tributaries vary in catchment area and slope and this also contributes to their flow status. A spill entering a dry watercourse has more potential for attenuation in the stream compared to one that is flowing.

In summary, any potential pollutant incident resulting from a spill occurs against a background of other water quality risks throughout the catchment that are largely unmitigated, and flow paths from the point of a pollution spill to the water treatment plant off take are in some instances quite short meaning short response times.

For any spilt product that reaches the Emigrant Creek water treatment plant, the plant has key critical control points and multiple barriers (alarms, various treatment processes, shut-down capability, etc) which are integral to the protection of human health of Rous Water's consumers.

7.7.4 Road safety

The proposed upgrade would result in a significant reduction in the risk of an accident and associated spill through improved safety of the proposed highway. This is one of the primary objectives for the Pacific Highway Upgrade Program.

It is expected that the existing accident rate within the Emigrant Creek dam catchment of 23 accidents per 100 million vehicle kilometres travelled (MKV) would be reduced to the target rate of 15 accidents per 100 MKV.

7.7.5 Dangerous goods assessment

Dangerous Goods (DG) are divided into nine classes depending on the risk associated with the substance transported. Dangerous goods are classified as follows:

Class 1 - explosives

Class 2 - gases, which are subdivided into:

Class 2.1 - flammable gases
Class 2.2 - non-flammable, non-toxic gases
Class 2.3 - toxic gases

Class 3 - flammable liquids

Class 4 - solids with a flammability hazard, which are subdivided into:

Class 4.1 - flammable solids
Class 4.2 - spontaneously combustible materials
Class 4.3 - dangerous when wet substances

Class 5 - oxidising substances, which are subdivided into

Class 5.1 - oxidising agents
Class 5.2 - organic peroxides

Class 6 - toxics, which are subdivided into

Class 6.1 - toxic substances
Class 6.2 - infectious substances

Class 7 - radioactive substances

Class 8 - corrosives

Class 9 - miscellaneous dangerous goods

These dangerous goods can be further divided into solids and liquids, soluble and insoluble, buoyant and non-buoyant substances.

7.7.5.1 Proportion of dangerous goods vehicles

This report focuses on acute pollution incidents along the highway including spills. In order to ascertain the likelihood of a spill occurrence, it is important to assess the number of vehicles travelling along the highway and the proportion of dangerous goods vehicles. Here the risk of a spill from a car is considered to be minor as the quantity of spilt material would be small. Heavy vehicles conversely transport large quantities of dangerous goods.

Traffic classification surveys were conducted by Arup in December 2006 to determine the types of dangerous goods vehicles as a proportion of the total number of heavy vehicles. Earlier work had already determined the expected proportion of heavy vehicles (18% of all vehicles) and the annual average daily volume (AADV) of through traffic of 10,326 vehicles per day in 2006).

Dangerous goods vehicles make up on average about 4.27% of all heavy vehicles and although this percentage was based on a 3 day count (December 2006) in daylight hours only, it has been assumed that this percentage would be relatively constant and has been applied to the 18% heavy vehicles to estimate the number of dangerous goods vehicles in each case. Multiplying the 4.27% by 18% means dangerous goods vehicles represent about 0.8% of all vehicles. Without information regarding the safety record of dangerous goods vehicles compared to heavy vehicles, it has been assumed that the involvement of dangerous goods vehicles in accidents would be proportional to the percentage of dangerous goods vehicles making up the heavy vehicles volume.

Similarly the make up of the dangerous goods vehicles volume into the 9 dangerous goods classes defined by the Australian Standard has been based on the 3 day counts in daylight hours only. It has been assumed that theses percentages would be relatively constant and can be applied to the 24 hour AADV. Although there were only 110 dangerous goods vehicles counted in the daylight hours over the three days, there was a reasonable correlation with the dangerous goods vehicles percentages arising from counts undertaken on the Pacific Highway at Coffs Harbour from 2003.

Table 13 provides an estimated forecast of dangerous goods vehicles based on the above analysis for the section of the proposed upgrade. No vehicles were recorded as Class 1 (Explosives), Class 6 (Toxic and Infections Substances) or Class 7 (Radioactive Substances) however it is still possible that vehicles belonging to the last two classes may use the highway. Transport of Class 1 goods (Explosives) are currently prohibited on the Pacific Highway.

Table 13 Vehicle classifications as adopted for accident forecasts

Vehicle Type			Existing Highway north of Bangalow				
			%	% Of Total Veh	2006 veh	2012 forecast	2032 forecast
All Vehicles (AADT)							
	Light Vehicles			82%	8,467	10,744	15,942
	Heavy Vehicles			18%	1,859	2,358	3,500
	Total Vehicles (AADT)			**100%**	**10,326**	**13,102**	**19,442**
HV's							
	Non DG's		95.7%	17.2%	1,779	2,257	3,351
	DG's		4.3%	0.8%	79	101	149
	Total HV's		**100.0%**	**18.0%**	**1,859**	**2,358**	**3,500**
DG's							
	Class 1	Explosives	0.0%	0.00%	0	0	0
	Class 2	Flammable Gases	10.0%	0.08%	8	10	15
	Class 3	Flammable Liquid	49.7%	0.38%	39	50	74
	Class 4	Flammable Solids	5.8%	0.04%	5	6	9
	Class 5	Oxidising Agents, Organic Peroxides	0.9%	0.01%	1	1	1
	Class 6	Toxic and Infectious Substances	0.0%	0.00%	0	0	0
	Class 7	Radioactive Substances	0.0%	0.00%	0	0	0
	Class 8	Corrosives	4.5%	0.03%	4	5	7
	Class 9	Miscellanous DG	29.1%	0.22%	23	29	43
	na	Mixed load of DG's					
	Total DG's		**100.0%**	**0.8%**	**79**	**101**	**149**

7.7.5.2 Forecast number of accidents

Arup undertook accident modelling and forecasting to determine the likelihood of a dangerous goods vehicle accident occurrence for a range of different operational scenarios. The scenarios investigated can be described as follows:

- Scenario 1 – All vehicles on existing highway – (i.e. new highway not constructed)
- Scenario 2 – All vehicles on new highway with no dangerous goods vehicle restrictions on tunnel
- Scenario 3 – All vehicles on new highway with full dangerous goods vehicle restrictions on tunnel (i.e all DGV use existing highway)
- Scenario 4 – All vehicles on new highway with limited dangerous goods vehicle restrictions on tunnel (i.e. All Class 1 and 2 DGV use existing highway)

It has been assumed that for Scenarios 3 and 4 that any dangerous goods vehicle restriction on the tunnel would not result in dangerous goods vehicle traffic flows on the existing highway through the Rous Water catchment due to the presence of a proposed interchange between the tunnel and the catchment boundary. Therefore only scenarios 1 and 2 are relevant to this assessment.

The results of the accident forecasting are summarised below.

- The total number of all vehicle accidents is likely to decrease from 466 to 97 accidents over a 20 year period as a result of the highway upgrade.
- The total number of all heavy vehicle accidents is likely to decrease from 147 to 31 accidents over a 20 year period as a result of the highway upgrade.

The total number of all dangerous goods vehicle accidents is likely to decrease from 6 to 1 accident over a 20 year period as a result of the highway upgrade (or once every 3.33 years to once every 20 years)

- Class 1 and 2 dangerous goods vehicle accidents are likely to reduce from once every 27 years to once every 128 years, whilst Class 3 to 9 dangerous goods vehicle accidents are likely to reduce from once every 3 years to once every 14 years as a result of the highway upgrade.

7.7.5.3 Probability of spills

A literature review was undertaken that focused on researching acute risks associated with road operations. Data sources relating to acute or spill risk were limited despite requests made to the RTA, NSW Fire Brigades, DECC and Federal Government. Furthermore it should be noted that the risk of spills are not widely researched. The best source of data came from the Department of Transport's *Dangerous Goods Code*. The Code is adopted by each state and territory (as law) and requires compliance with regard to the transport of dangerous goods. Since implementation of the Code a significant reduction in the number of spills has been observed. This is due to better driver training and awareness, better loading and containment of goods. Trucks, in particular bulk liquid storage trucks, have more stringent requirements and many in built safety measures such as multiple skins, separated compartments, pressure relief valves, automatic stopping valves, spill containment equipment, driver incident training, etc. are now mandatory.

Lacey and Cole (2003) reported that the probability of an accident involving a spill of more than 150kg is 0.043 or about 1 in 23. We note that this report does not distinguish between wet and dry probabilities; rather it simply shows the risk of a spill associated with an accident. Applying this probability to the forecast number of accidents from Section 7.7.5.2 provides us with estimated occurrence of accidental spills shown in **Table 14**.

Table 14 DGV Accident and Spill Probabilities

Scenario	Probability of DGV Accident	Probability of DGV Accident involving spill > 150kg
Scenario 1 – Highway Not upgraded	1 in 2.7 years	1 in 63 years
Scenario 2 – Highway Upgraded	1 in 12.8 years	1 in 298 years

It is evident that the proposed upgrade would result in a significant reduction in the potential for an accident involving all forms of vehicles including dangerous goods.

The probability of a dangerous goods vehicle accident involving a pollutant spill for the upgraded highway is 1 in 298 years (down from 1 in 63 years for the existing highway). This reduction is as a result of improvement in design standards applied to the new highway (improved horizontal and vertical geometry, improved sight distances, better pavement drainage, etc).

The improvement in design standards is likely to be the greatest factor in reducing the risk of accidental spills.

7.7.6 Pollutant fate

7.7.6.1 Assessment of pollutant fate up to the Emigrant Creek water treatment plant

Figure 6 over the page provides a qualitative indication of the fate of pollutants that are liberated onto the upgraded Pacific Highway. The graphs relate to a spill of pollutant product from a serious dangerous goods vehivcle rollover where up to 20,000 L or 20 tonnes of product ends up on the road carriageway or adjacent road shoulders or medians. They do not take into account spills of multiple pollutant products from the one incident. While it is acknowledged that larger loads may be carried by DGVs, it is very rare that an entire payload will be liberated. This is especially true for liquid-carrying DGVs which are compartmentalised, and which have double 'skins'.

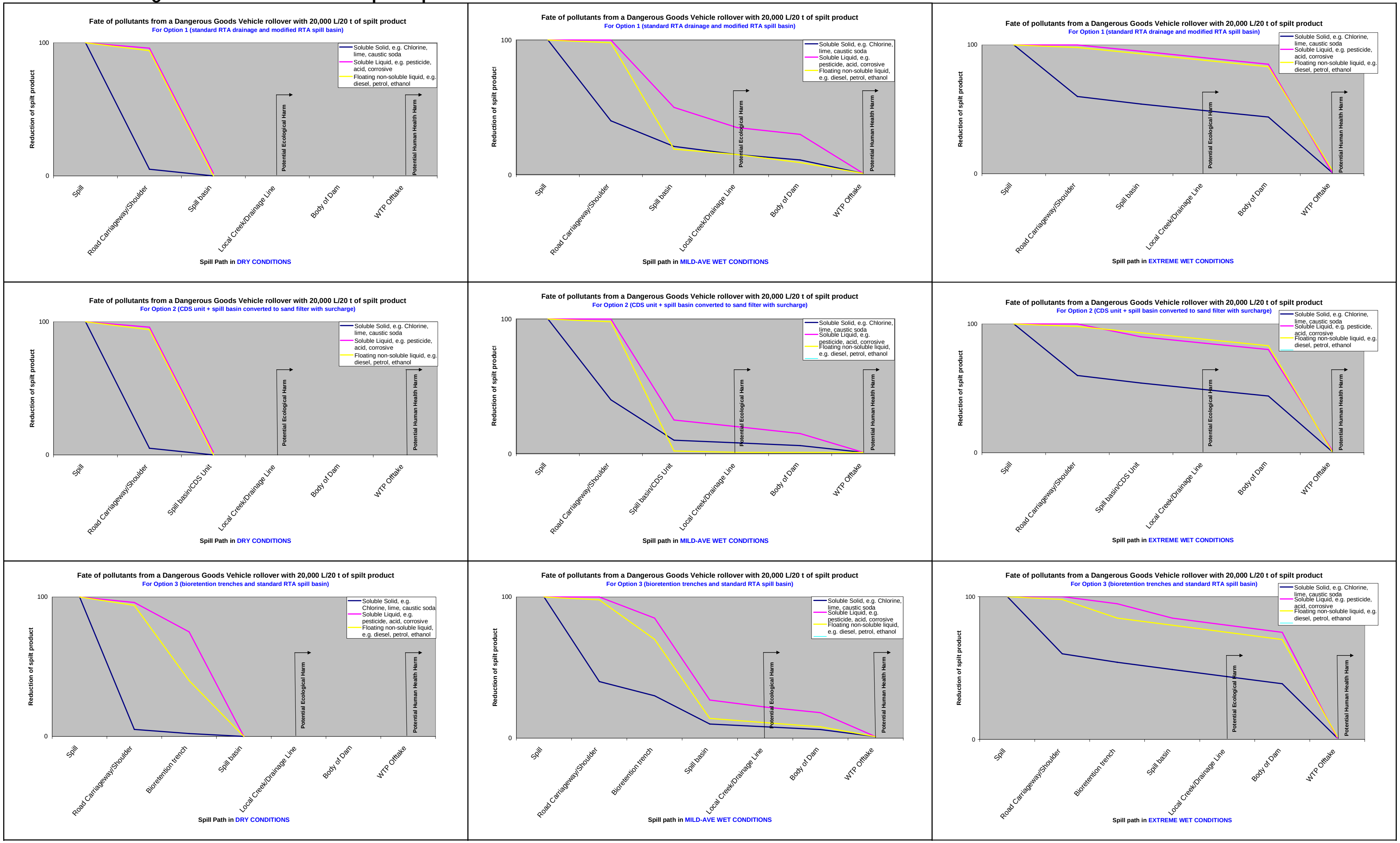
The graphs track the reduction of pollutants for the three mitigation measure options modelled in the chronic impact assessment i.e.

- Option 1: RTA Spill Basins with a modified outlet (i.e. a wet basin)
- Option 2: Gross pollutant trap prior to RTA spill basins converted into sand filters
- Option 3: Bioretention trenches along the carriageway prior to standard RTA spill basins

The graphs also show the pollution reductions for each option relative to the climatic conditions prevailing at the time of the incident, i.e.:

- Dry conditions
- Mild-average wet conditions - representing all rain events up to the 1 in 2 year ARI
- Extreme wet conditions - representing events greater than the 1 in 2 year ARI

Figure 6 Pollutant fate for spilled products



The probability of occurrence of each prevailing climatic condition has been estimated based on the probabilities associated with each rainfall condition.

The Bureau of Meteorology reports an average 120 rainfall days a year at the closest weather station (Alstonville). By subtraction, the average number of dry days is therefore 245 and therefore the probability of a dry condition is 245/365 or 0.67.

It has already been established that the mild-average wet condition represents a 1 in 2 year rainfall event, the probability of such an event is 1/2 or 0.5. Similarly an extreme wet condition represents a condition greater than a 1 in 2 year condition up to a practical limit of say a 1 in 100 year event. The occurrence of a 1 in 100 year event has a probability of 1/100 or 0.01.

The joint probabilities of a dangerous goods vehicle accident involving a spill greater than 150kg (0.0034 or once in 298 years) and the prevailing climatic condition used to indicate the qualitative fate of pollutants are as shown in **Table 15**.

Table 15 Joint probability of a DGV pollution incident and a specific climatic condition

Climatic Condition	Probability of a DGV accident involving a spill >150kg	Probability of Climatic Condition	Joint Probability
Dry	0.0034	0.67	$2.3x10^{-3}$ (1 in 440yrs)
Mild–Average Wet	0.0034	0.67-0.5	$2.3x10^{-3}$ - $1.7x10^{-3}$ (1 in 440 – 1 in 590 yrs)
Extreme Wet	0.0034	0.5-0.01	$1.7x10^{-3}$ - $3.4x10^{-5}$ (1 in 590 – 1 in 30,000+ yrs)
		Total	$3.3x 10^{-3}$ 1 in 298

It should be noted that no evidence from the literature review was found to suggest that the probability of an accident involving HV's or DGV's increased as a result of rainfall and as such the above joint probabilities have been developed on that basis.

An assessment of the average number of outflows from the Option 2 basins was undertaken using MUSIC and adopting 1985 historical rainfall data from the Alstonville rainfall station. Outflows were assessed on a 12 minute time step. 1985 was chosen as it represented a reasonably average rainfall year with close to average rainfall.

The modelling found that in general basin outflows occurred for between 0 and 48 hours for the modelled year, with average outflow duration of approximately 12 hours. The modelled year had 927 hours of rainfall throughout the year therefore basin outflows would only occur between 0 – 5% (average just over 1%) of the time during which it is raining. Outflow volumes ranged between 0 and 23 ML for the modelled year with an average of 5.2 ML.

It should be stressed that these outflows include both outflows through the spill control structure and any spills that may occur over the spillway. It is not known whether the 1985 data contained a rainfall event in excess of a 1 in 2 year ARI event and therefore there has been no differentiation between the flows. In all reality the majority of outflows would have occurred through the spill control structure.

In relation to **Figure 6**, it should be stated that the assigning of pollutant reduction for each component of each option is subjective, and another author may derive different relative reductions. It is not the intent of this assessment to assign absolute numbers, nor to argue each reduction on a case by case basis. The intent is, however, to enable a comparative assessment of the performance of each of the options, and to comment on them in the context of the likely comparative ecological and human health risks that might ensue from dangerous goods vehicle incidents.

Having stated this, there are some key assumptions that led to the derivation of pollutant reductions, and these are as follows:

- Bioretention trenches and sand filters (Options 3 and 2 respectively) which both comprise a sand matrix would retain more pollutants than a wet basin, especially hydrocarbons
- Assuming emergency service authorities do not use water hoses, no soluble solid would be dissolved and transported beyond the incident scene as a result of a spill in dry conditions. This spilt product would be retrieved from the carriageway.
- For any spill of soluble solids, only a proportion of the spilt product would dissolve in mild-average wet conditions and more would dissolve in extreme wet conditions.
- Soluble pollutants would be more readily washed out of spill basins compared to floating pollutants (the latter would be partially retained by the spill control outlet structure (baffle), moreso in mild-average wet conditions).
- In mild-average wet conditions, a proportion of floating pollutants would be washed out of a spill basin due to the effect of mixing in water column caused by turbulence, moreso for Option 2 than Option 1 due to smaller retention volumes afforded by Option 2.
- In extreme wet conditions, despite the effect of baffles, overtopping of the spillway would occur and a larger portion of floating pollutants would be washed out of spill basins.
- Limited entrainment or retention of pollutants would occur within the sand media present within the treatment train of Options 2 and 3, moreso for floating non-soluble pollutants.
- Limited entrainment or retention of pollutants would occur in local streams, e.g. capture in vegetation, moreso for floating non-soluble pollutants.
- Losses of pollutants would occur in the main body of the dam, e.g. volatilisation, evaporation, foreshore entrainment.
- The effects of dilution in the local streams and main body of the dam are ignored (but expected to result in a significant pollutant concentration reduction in the case of dissolved or suspended pollutants).
- The water supply off take is a submerged dual level one. Floatable pollutants (e.g. hydrocarbons) would only be able to enter the off take if there is significant turbulence (e.g. rain drops, wave action) in the main body of the dam that causes entrainment of the floating pollutant to the depth of the off take. Therefore, only a small proportion of any floating pollutant would be able to enter the off take.
- The water treatment plant can extract 7.5ML/d from one side of the dam only. Pollutants in the main body of the dam would be expected to pass the water treatment plant off take across the whole width of the dam meaning that only a very small proportion of pollutants passing the off take can enter it. The exception would be floating pollutants that may be rafted by wind toward the off take, but as stated above, only a small proportion of these pollutants could enter the off take due to the fact that the off take is submerged.

If these broad assumptions are accepted, and if the comparative pollutant retentions shown in Figure 6 are broadly agreed, the following conclusions can be drawn about the fate of pollutants:

- Dry conditions pose the least risk in the result of a spill. For any conceivable pollutant type, no spilt product would travel beyond a spill basin in any of the three options. Increasingly wet weather increases the chances of pollutants being washed out of spill basins and into local creeks and the main body of the dam where ecological harm would occur, and where they may enter the water treatment plant off take.

- Increasing the proportion of pollutant retained within the highway corridor through a treatment train approach, ultimately reduces the volume of pollutant reaching the main body of the dam, resulting in reduced potential for entry to the water treatment plant off take.
- Each of the three mitigation options substantially reduces the amount of ecological and human health risk compared to a situation where no mitigation measures are in place. Spill basins perform a critical function in retaining significant amounts of pollutants in 99% of rain events.
- Due to the presence of sand filter matrix material, the best performing mitigation options are Options 2 and 3, though each option performs similarly and relatively poorly in extreme wet conditions.
- For any given spill on the upgraded highway, only a fraction of the pollutant would be able to enter the water treatment plant off take. When the effects of both dilution in local streams and the main body of the dam and the limited ability of floating pollutants to enter the WTP off take are taken into account, we predict that <1% of any spill would enter the WTP off take.

Pollutants from dangerous goods vehicle spills that enter local streams and the main body of the dam would kill organisms with the recovery time of ecosystems dependent on the type of pollutant, the level of exposure (amount and concentration of pollutant) and the effectiveness of clean-up and remediation actions.

Rous Water has a spill notification procedure which involves notification from emergency services in the event of spills from in the catchment.

7.7.6.2 Fate of pollutants that enter the Emigrant Creek water treatment plant

While section 7.7.6.1 focused on the reductions of pollutants up to the water treatment plant, the plant itself has various critical control points and multiple barriers to prevent water consumers from harm to their health, listed and described as follows:

- Potassium permanganate is dosed to the water treatment plant feed water to oxidise manganese and iron for removal in filtration processes.
- The dam is aerated for up to 15 hours/day to minimise manganese (Mn) and iron (Fe) levels (anoxic bottom sediments). The lab conducts daily tests for Mn and Fe which facilitate manual adjustment of the potassium permanganate dose rate on a daily basis.
- Alchlor, a coagulant, is dosed prior to ultrafiltration (UF). The coagulant aids removal of turbidity, suspended solids and dissolved organics from the raw water. Coagulation of hydrocarbons should be possible to a limited extent. Emigrant Creek water treatment plant uses Norit membranes.
- Filtered water from the UF (membrane) plant is ozonated and fed through a biologically activated carbon (BAC) column to remove organic contaminants such as algal taste and odour compounds, pesticides and herbicides. Ozone/BAC was specifically selected by Rous Water for its ability to manage organic contaminant risks. These risks include road run-off containing hydrocarbons.
- Water from Nightcap (70 ML/d) and Emigrant Creek (7.5 ML/d) mix at Knockrow providing significant dilution of any potential pollutants. It is understood that no customers receive only Emigrant Creek water (i.e. no off takes from the system without treatment and consumers received blended Nightcap and Emigrant Creek water).
- The treatment process has the following contaminant removal capabilities:
  - UF can remove dissolved organics above a certain molecular weight which is related to the UF pore size.

  - Only precipitated metals would be removed by UF. Chemicals above a certain molecular weight related to the UF pore size would be removed (UF pore size ranges between 0.1 and 0.01 micron)
  - Ozone/BAC would remove a range of organics to differing degrees including pesticides, herbicides and hydrocarbons.
  - It appears that the Emigrant Creek water treatment plant is equipped to deal with particular metals that are associated with road run-off including:
    - Cromium (VI), which may be removed by coagulation/filtration.
    - Copper, which may be removed by coagulation/filtration at an elevated pH.
    - Nickel, which may be co-precipitated with Fe/Mn oxides.
    - Zn, which may be removed by coagulation/filtration or more efficiently by lime softening.
- UF is particularly sensitive to contact with hydrocarbons, grease and foulants. The location of the intake pumps below the surface water level will help to mitigate problems associated with hydrocarbon spills in the main body of Emigrant Creek dam. Heavier fractions of hydrocarbons will foul the membranes quicker, but are also less likely to pass through. Lighter fractions of hydrocarbons are more likely to pass through membranes. Membrane flux will quickly reduce if there are significant concentrations of hydrocarbons in the feed water to the membranes. Some hydrocarbons associated with petroleum and diesel are solvents to Norit membranes. Examples include benzene, naphthalene and toluene. Contact of these hydrocarbons with the membranes should be avoided.
- Ozone/BAC will remove a proportion of hydrocarbons present.
- Chloramination is used to disinfect the treated water prior to distribution.

7.7.7 Residual operational risk and its abatement

This risk assessment demonstrates that the multiple barrier treatment train approach devised is appropriate in mitigating the identified ecological and human health risks arising from acute pollution incidents on the proposed Pacific Highway upgrade.

Where the consequences of pollutants harming ecosystems or ecological health are high (e.g. in extreme wet conditions), the corresponding likelihood of this occurring is very low, equating to a low overall risk.

Measures that would confer Rous Water with more control of risks arising from acute pollution incidents include:

- Preparation of an emergency response plan for the catchment in consultation with all stakeholders, including the RTA. This should include incident reporting protocols agreed with emergency services.
- Preparation of an emergency response plan for the water treatment plant operations. This could include installation of (additional) alarms and shut-down protocols based on the detection of high risk pollutants in the water treatment plant.
- Placement of floating booms at suitable locations at watercourse inflows to Emigrant Creek dam.
- Signage within the catchment related to reporting of pollution incidents

7.8 Acute water quality impacts to the Wilsons River catchment

The acute risk to the Wilsons River catchment and the Lismore Source is expected to be substantially lower than the risk to Emigrant Creek dam due to the large distance between the proposed upgrade and the water extraction point.

Operational measures, as detailed in Section 7.7.7 would be applied to the proposed upgrade as it passes through the catchment area which would allow of any residual risks arising from acute pollution incidents.

8 Mitigation proposals

8.1 Construction phase

During construction a number of mitigation measures would be put in place. These are:

- Top soil will be stockpiled and reused during vegetation. Stockpile heights would be minimised to limit wind erosion.
- Disturbed areas would be limited to only those areas which need to be worked on at that point in time and areas will be rehabilitated and sealed as soon as possible following construction.
- Batters slopes would be minimised to ensure that minimum possible area is disturbed.
- Clean run on water would be diverted around all works using diversion drains.
- Sediment basins to retain the 85th percentile 5 day rainfall event for the Emigrant Creek dam catchment. These basins would include the ability to retain an accidental spill that occurs during construction. The basins would meet the requirements of *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction*, i.e. provide a sediment storage and settling zone and have a suitable spillway.
- Sediment basins to retain the 80th percentile 5 day rainfall event for the Wilsons River catchment. These basins would include the ability to retain an accidental spill that occurs during construction. The basins would meet the requirements of *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction*, i.e. provide a sediment storage and settling zone and have a suitable spillway
- The sediment basins would be operated to ensure that sediment is removed when the sediment storage zone has reached 80% of capacity.
- Sediment basins would be flocculated with appropriate, approved flocculants to enhance the settling of dispersible and small sediment particles.
- Best practice soil and water management would also be put in place. This would include the use of sediment fences, check dams, level spreaders and other devices to mitigate the export of soil from the site.
- Trees would be mulched on site and the mulch used in the revegetation and stabilisation of the site.
- Top soil dressing and revegetation will take place as soon as possible.
- Revegetation would only use native endemic species.
- Temporary sterile grass covers will be used to seal areas whenever practical.
- The use of floating booms shall be made where major crossings and permanent pools are put at risk from construction activities.
- All storages of fuel and chemicals would be bunded and stored in approved storage containers.
- Where possible steep batter slopes would be sealed using jute matt or mesh as appropriate or equivalent erosion control blankets would be employed. These shall be biodegradable.
- The preparation and implementation of an audited environmental management aystem and plan.
- The preparation of a construction phase best practice waste management plan.

8.2 Operation phase

8.2.1 Chronic pollution mitigation measures for Emigrant Creek dam catchment

A life cycle costing analysis has been undertaken to assess the relative costs of each of the three options investigated in this working paper.

The results of the life cycle costing analysis are reported below in **Table 16**.

Table 16 Life cycle cost estimates (40 years)

Component	Option 1	Option 2	Option 3
Total Capital Cost	$60,000	$1,660,000	$2,410,000
Total Annual Maintenance Cost	$285,000	$1,230,000	$0
Total Renewal/Adaptation Cost	$1,200,000	$1,300,000	$5,270,000
Total Decommissioning Cost	$5,000	$80,000	$120,000
Total Life cycle cost ($2007)	**$1,550,000**	**$4,270,000**	**$7,800,000**

Based on the life cycle costing it was found Option 3 has a significantly higher cost than either Option 1 or 2 without affording any greater level of protection. On this basis, Option 3 is excluded from further consideration.

Options 1 and 2 would mitigate the impacts of the proposal to differing extents but their performance in terms of their ability to mitigate acute risks is considered to be similar.

It is difficult to predict the ability for Option 1 to retain pollutants other than nutrients and suspended solids without further information. Option 2 however is considered likely to be able to provide retention of heavy metals and pathogens while retention of TPH is not able to be predicted with any great degree of certainty.

With respect to suspended solids and nutrient retention and based on the water quality modelling and references to other similar devices that have been constructed and monitored it is likely that Option 1 would achieve a high level of sediment and nutrient retention but this may not be sufficient to reduce total nitrogen exports to levels below the current state. Option 2 is likely to be able to reduce nutrients and suspended solids to levels below the current state as well as comply with the NSW DECC criteria. There is however, some degree of uncertainty associated with water quality modelling as it is a relatively new technology with limited science available to support its confident application.

With the modelling undertaken to date, it is clear that only Option 2 would meet the proposed water quality criteria for the Emigrant Creek dam catchment (i.e. overall load reductions and compliance with DECC guidelines for pollution retention). Therefore, Option 2 – spill basins converted to sand filters and preceded with a gross pollutant trap - is proposed as one water quality impact mitigation measure in the Emigrant Creek dam catchment.

In developing detailed design responses, further modelling and design refinement can occur to optimise performance and function. Through this process, other design solutions that also provide compliance with the load reduction and pollution criteria may be considered. If it can be demonstrated that alternative solutions can be developed which satisfy these criteria that can provide better value for money and/or are easier to maintain, then it would considered responsible to install these alternatives. Any process to identify and propose alternative measures should be undertaken in consultation with Rous Water.

The conversion of construction phase sediment basins to sand filters shall be undertaken not less than 6 months after the highway becomes operational. This is to allow the highway construction to seal appropriately and limit the potential for the sand filter to become clogged with sediment early in its life. In the intermittent period the sediment basin shall be operated as a permanent feature with a permanent pool of water.

It should be noted that:

- All proposed sand filters would capture 100% of the road pavement surface and medians and effectively 100% of the fill batters.
- Runoff from cuttings would be directed away from the road through the use of benches.
- Only the bottom few metres of a cutting which cannot be drained to a bench would be directed toward the treatment devices for treatment.

In general, pavement and fill batter runoff would be directed toward the basins *via* a grassed lined swale placed at the toe of the fill batters. This grassed lined swale would also afford a measure of treatment of the runoff that has not been taken into account and monitoring shall do so.

8.2.2 Chronic pollution mitigation measures for Wilsons River catchment

For varying reasons based on model inputs and design criteria, the water quality modelling undertaken in Emigrant Creek Dam catchment is not able to be extrapolated to the Wilsons River catchment.

Where for reasons of reduced public health risk, water quality modelling is not undertaken in a catchment to prove performance, the adoption of Best Practice chronic pollution management strategies for any new development is considered appropriate.

For reasons of reduced risk to public health related to the size of the catchment and distance of the water supply offtake from the proposed highway upgrade, it is proposed to install Option 1 spill basins at each discharge point as the best management practice control measures

Note that the basins for Wilsons River would capture 100% of the pavement surface and medians and most of the fill batters resulting in about 93% of the road corridor being directed toward the sediment basins for treatment. This excludes all but the last few metres of a cutting where benches in the cutting can be used to direct clean water away from the road without the need for further treatment. Once again all pavement runoff and runoff from fill batters would be collected in a grass lined swale located at the base of the fill batter. The swales then discharge directly into the sediment basins.

8.2.3 Acute mitigation measures

Option 2 sand filters and Option 1 sediment basins will be provided for all highway discharges points. Both options will provide a significant ability to retain an accidental spill.

In addition to these measures, the following measures are also recommended:

- Signage within the road corridor related to reporting of pollution incidents
- Active participation by the RTA in the preparation of an emergency response plan
- Placement of emergency telephones to maximise response times.

9 Conclusion

The scope of this working paper includes the water quality impact assessment of the proposed upgrading of the Pacific Highway from Tintenbar to Ewingsdale.

The Director General's requirements for the assessment of this project included the need to consider ANZECC guidelines, chronic and acute water quality impacts and to also assess the risk to public health.

The Director General's requirements were assessed and a wide range of water quality impact assessment criteria, including ANZECC were examined. It was found that:

- The Pacific Highway upgrade needs to be assessed in isolation of the rest of the catchment or there is a risk that the impact would be imperceptible.
- Application of default ANZECC guideline trigger values is not appropriate to assess the impact of one isolated act of development within a broader catchment.
- The most appropriate performance criteria were deemed to be load based criteria including a test for an improvement of the pollutant loadings and the criteria used by the NSW DECC which apply to all new developments in NSW.

This working paper defines the existing environment by reference to existing water quality data that showed that Emigrant Creek and the Wilsons River catchments are "highly modified". The impact of the existing highway was found to be imperceptible. The aquatic ecology working paper prepared by Ecology Lab was reviewed and showed that no protected species were present in the catchment, however, there are numerous species of fish, crustaceans, macro-invertebrates and other aquatic fauna found with the tributaries of Emigrant Creek, in the dam and in the tributaries of the Wilson river affected by this project. It was also found that the existing highway impacts on fish passage.

In respect of the potential impact of the proposed upgrade on the two drinking water catchments it was concluded that:

- The proximity of the proposed upgrade to the Emigrant Creek dam and the dam off take means that the potential impact of the highway on the water quality in the Emigrant Creek catchment area is of higher consequence than in the Wilsons River catchment.
- Mitigation measures proposed for the section of the proposed upgrade within the Emigrant Creek catchment should reflect the greater potential impacts.
- The proposed upgrade should include facilities to capture accidental spills during both construction and operation.

A literature review identified that stormwater first flushes can be toxic to macro-invertebrates and the toxic components are likely to be Zinc and Copper. Other pollutants of concern include nutrients, suspended solids, TPH and BTEX and pathogens.

Construction sediment basins, along with other sediment and erosion control devices, designed in accordance with the guidelines in *Managing Urban Stormwater – Soils and Construction Volume 2D – Main Road Construction* is deemed to be appropriate for the management of construction water quality treatment measures.

- For Emigrant Creek dam catchment the basins are to be sized to contain all runoff expected from the 85^{th} percentile, 5 day rainfall event.
- For the Wilsons River catchment and other areas outside of the Emigrant Creek dam catchment the basins are to be designed to capture and treat the 80^{th} percentile, 5 day rainfall event.

Three options for the mitigation of stormwater were assessed using MUSIC to establish how well the proposed options would be able to retain pollutants. Other pollutants were also assessed. Of the options examined only Option 2 was considered to fully conform with the DECC criteria and simultaneously provide a reduction in the export of pollutants when compared with the pre-development state.

It was also concluded, however, that water quality modelling is a developing science and its application is limited in part by a lack of scientific data. Apart from MUSIC which assessed only TSS, TP and TN, impacts of heavy metals, hydrocarbons and pathogens were also assessed. It was found that there is limited data with which to be able to model the performance of the proposed mitigation measures with confidence.

A life cycle cost analysis was undertaken which on the basis of limited performance in relation to cost excluded Option 3 bioretention trenches from further consideration.

A strategy has been proposed which is to construct Option 2 sand filters in Emigrant Creek dam catchment and to construct Option 1 spill basins in Wilsons River catchment. Both devices will be constructed by conversion of construction phase sediment basins.

Further refinement of design may consider alternatives to Option 2 sand filters in the Emigrant Creek catchment, however, any alternative proposal must meet compliance with overall pollutant load reductions and the DECC criteria for pollutant retention.

Acute impacts associated with the risk and probability of an accidental spill leaving the highway has been undertaken. This found that the probability of a spill will be significantly reduced by the construction of the proposed highway. It also assessed the acceptability of the risk of a spill to both the environment and the drinking water catchments (and therefore to public health). It found that the probability of a spill after mitigation was about 1 in 600 years. This is benchmarked against an acceptable probability of a spill into the environment of 1 in 100 years. The acceptable probability of a spill into the drinking water catchment, however, was assessed to be much higher at 1 in 500 years which takes into account the treatment plant and public health. In conclusion there is an acceptable level of risk of a spill associated with this proposal provided that mitigation measures are put in place. Either option 1 or options 2 are deemed to be acceptable to mitigate the risks of a spill.

In conclusion, chronic, acute and public health risks have been considered in detail. Acute and chronic risks and impacts are able to be mitigated to levels that fall within acceptable limits.

10 References

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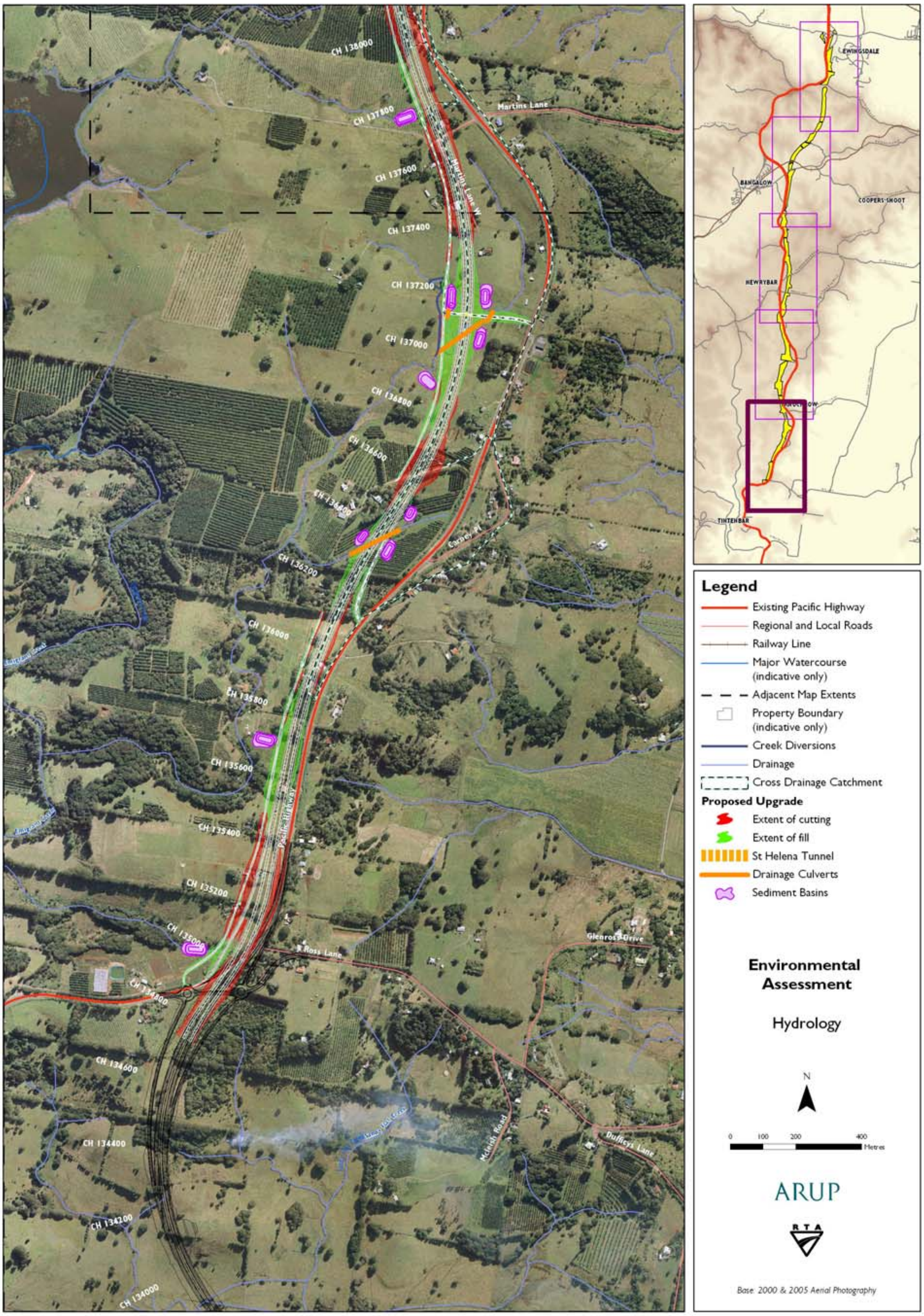
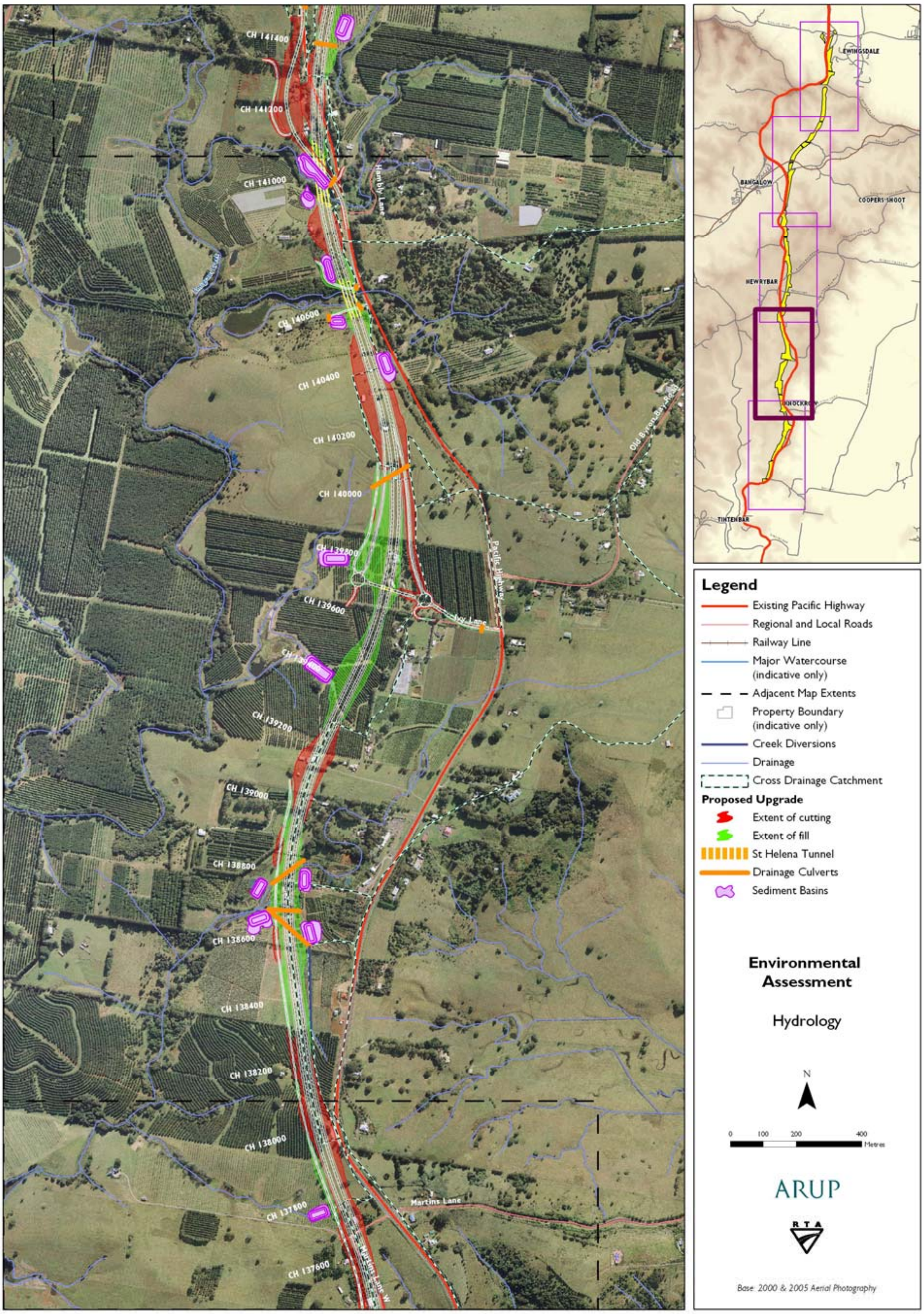
Appendix A

Layout Plans

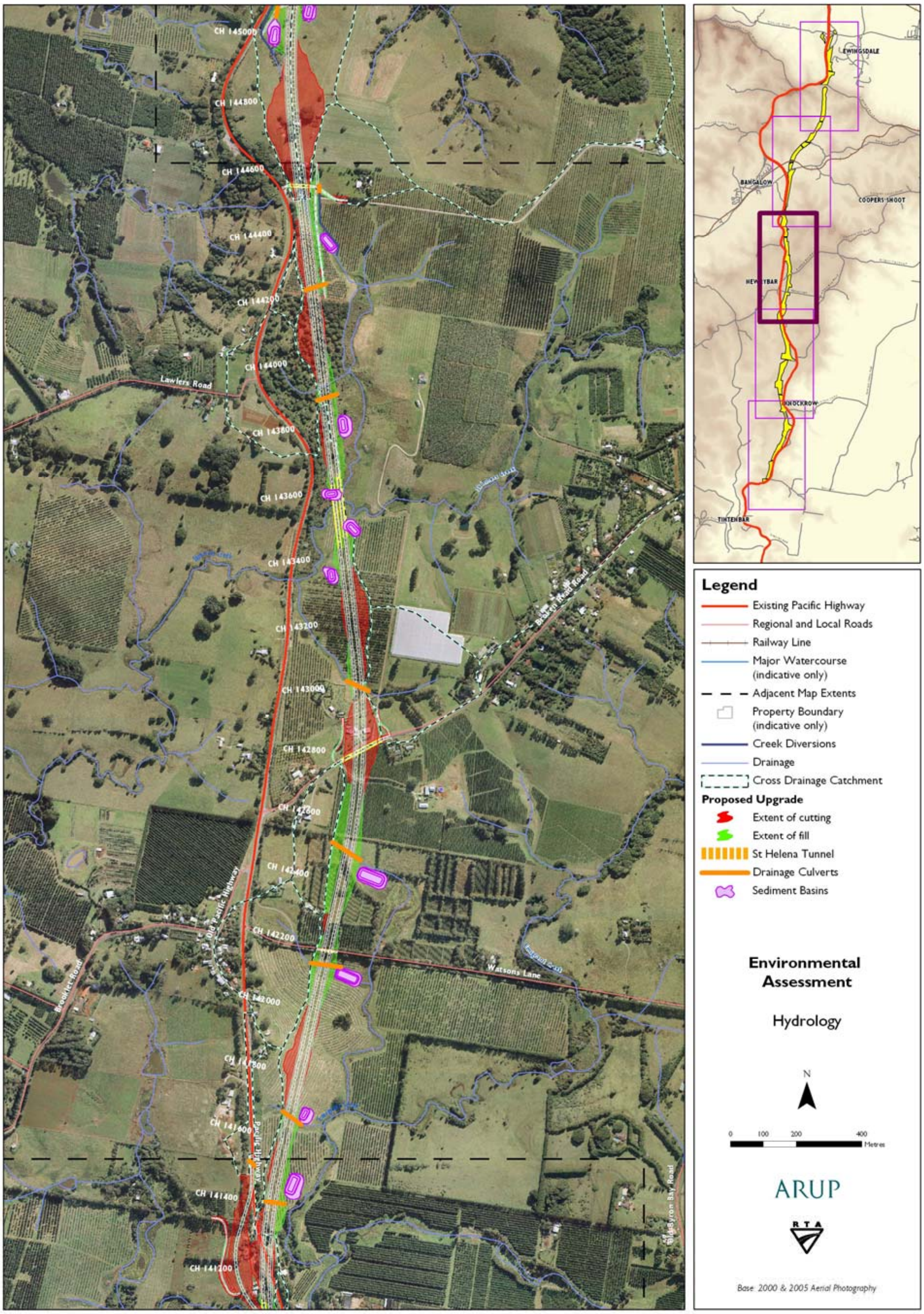
Layout Plan 1 – Hydrology Proposals



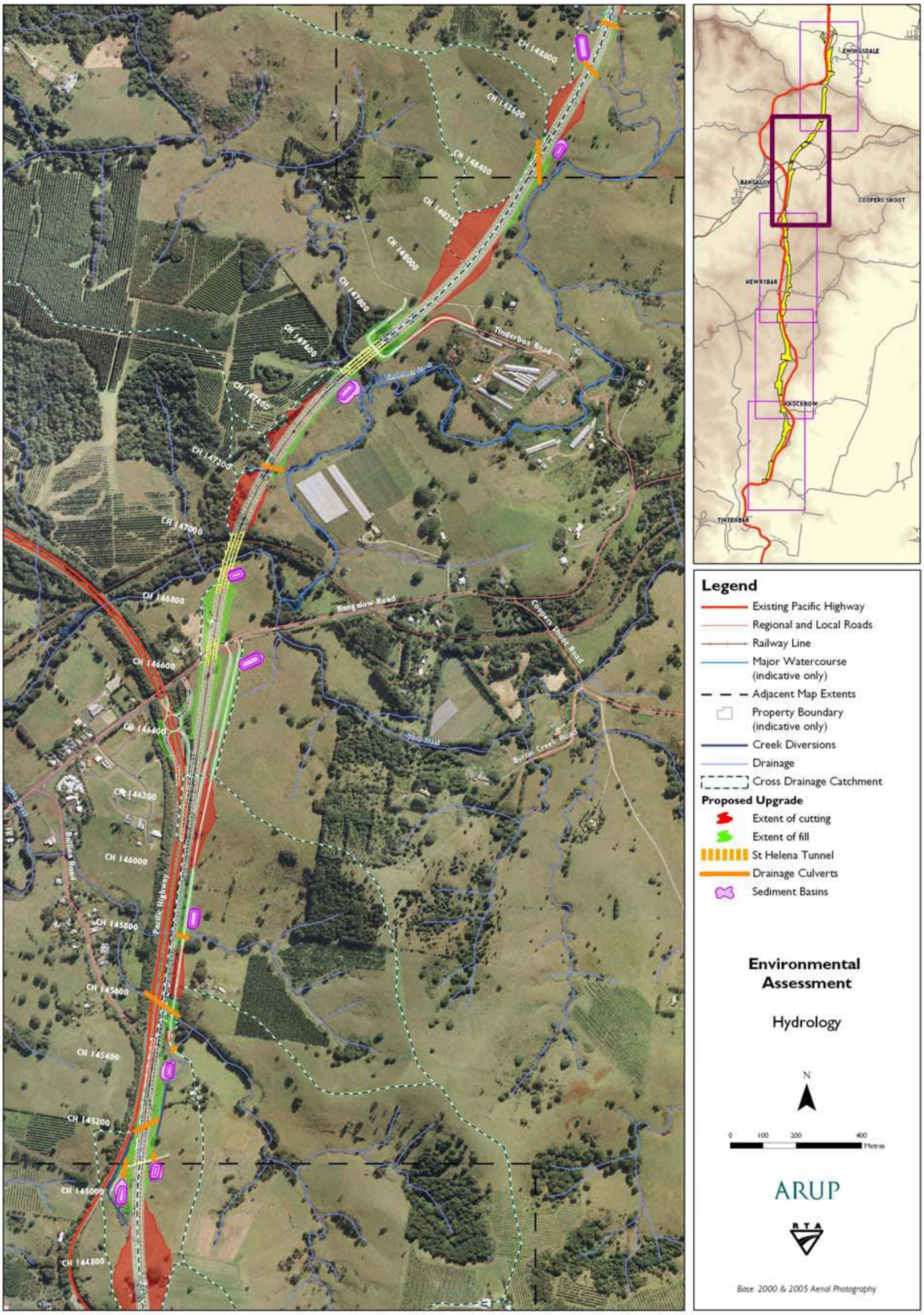
Layout Plan 2 – Hydrology Proposals



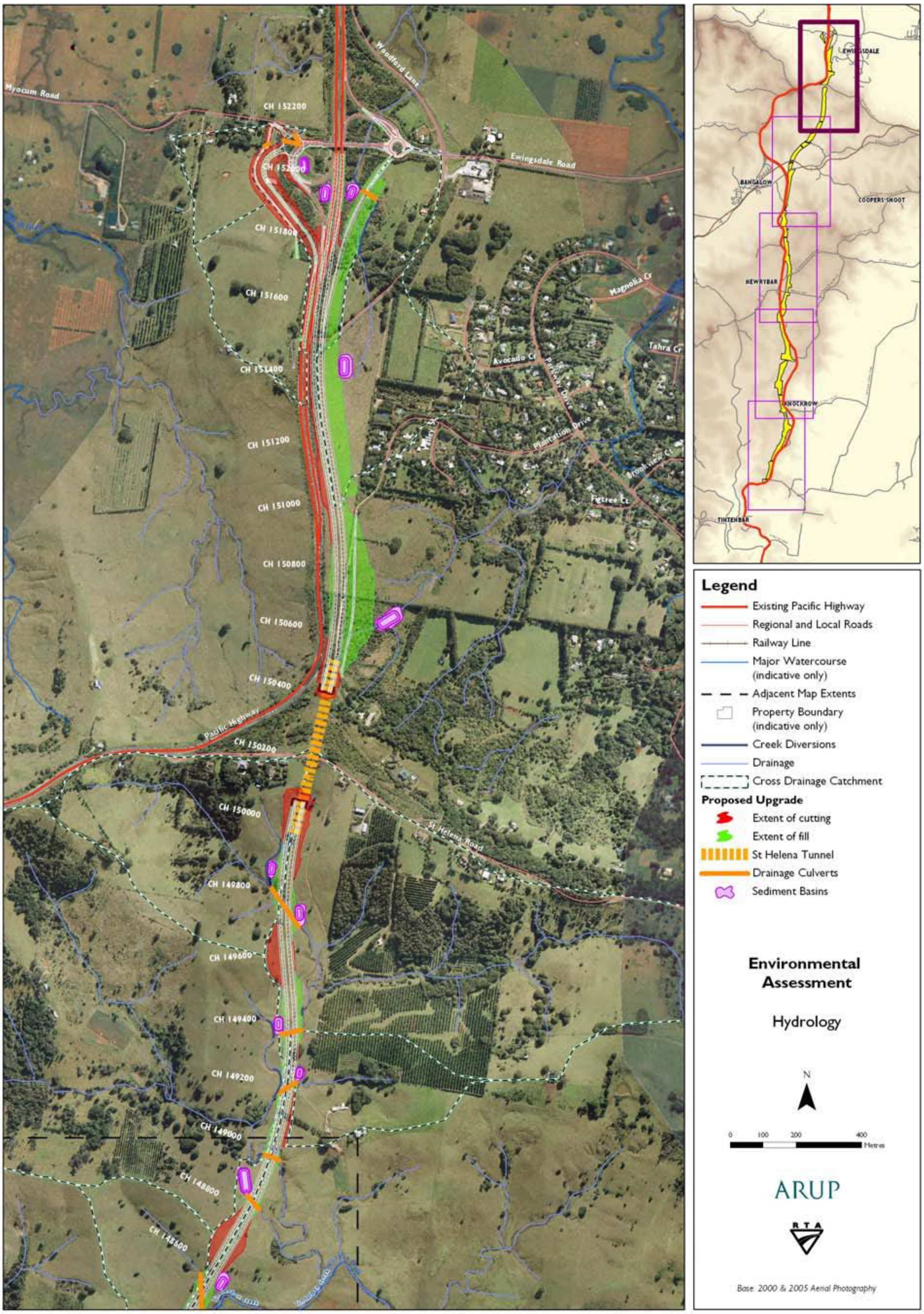
Layout Plan 3 – Hydrology Proposals



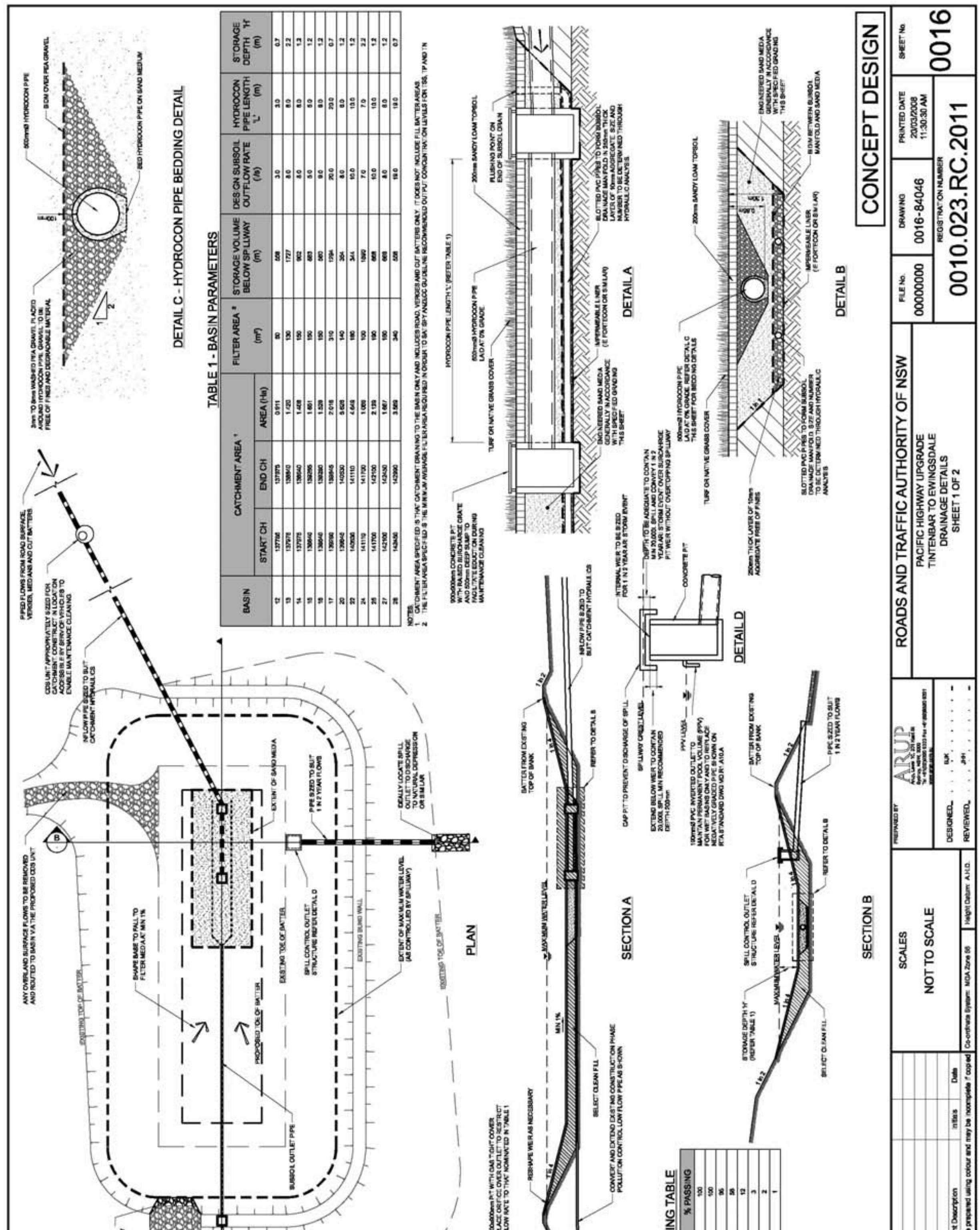
Layout Plan 4 – Hydrology Proposals



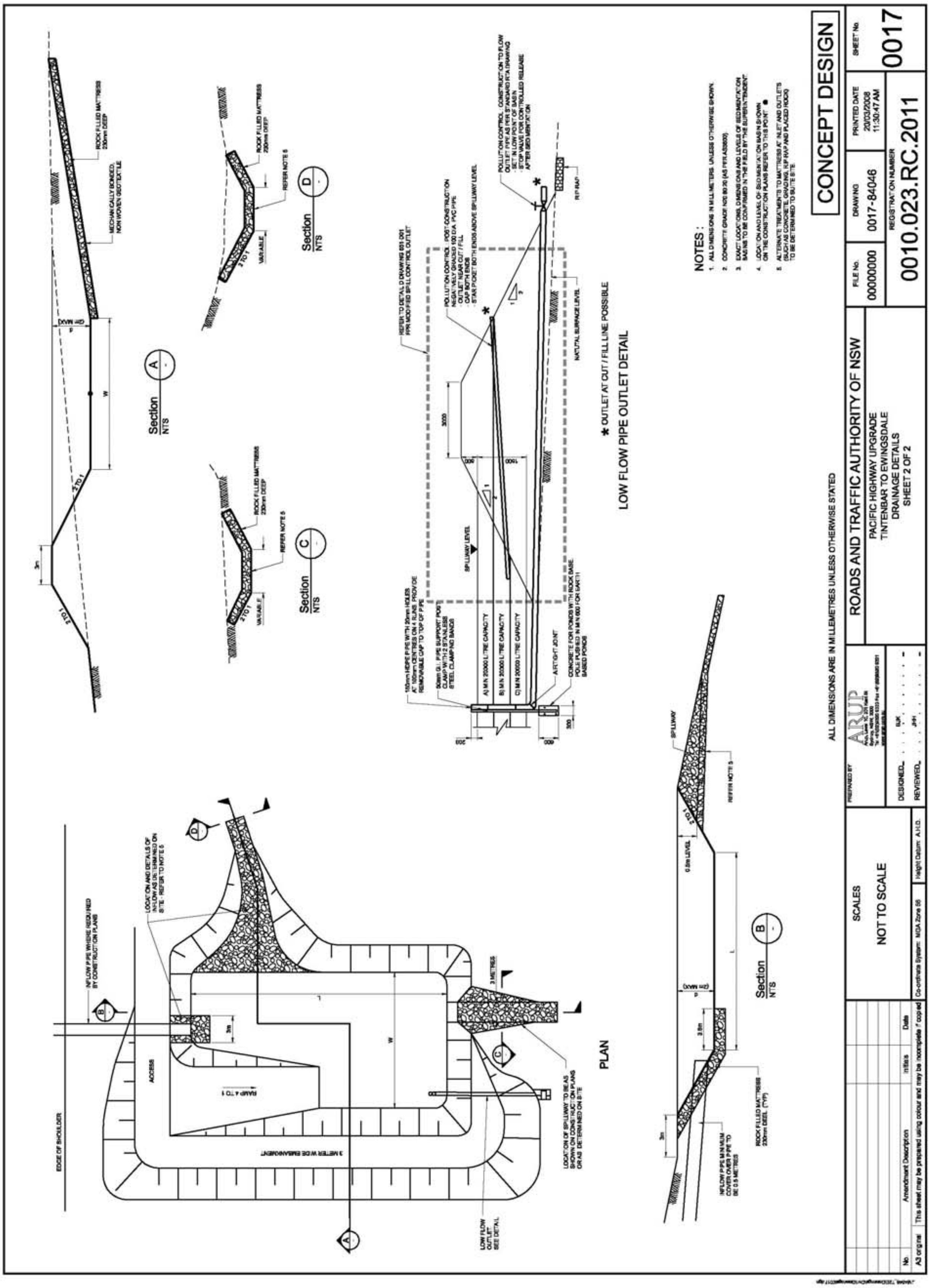
Layout Plan 5 – Hydrology Proposals



Concept Design Drawing 0016 – Sand Filter Details



Concept Design Drawing 0017 – Construction Sediment Basin Details



Appendix B

Runoff Pollutants

Extract from DMRB Volume 11, Section 3, Part 10 – HA216/06

Determinand	**% Events Detected**	**Runoff Concentration**				**Runoff Load**	
		LOD	**Units**	**Mean**	**Max. Observed**	**Units**	**Mean/ 1000m²**
Copper	100	0.3	μg/l	41.00	242.00	mg	60.59
Copper (Dissolved)	100	0.3	μg/	20.58	90.00	mg	29.04
Zinc	100	0.6	μg/l	140.30	688.00	mg	205.30
Zinc (Dissolved)	100	0.6	μg/l	57.49	536.00	mg	74.09
Cadmium	100	0.001	μg/l	0.49	5.40	mg	0.61
Lead	88	0.1	μg/l	23.05	178.00	mg	26.54
Platinum	3	0.15	μg/l	4.00	120.00	mg	0.86
Palladium	30	0.5	μg/l	0.38	7.00	mg	0.37
Nickel	92	0.01	μg/l	5.31	40.00	mg	9.36
Chromium	90	0.3	μg/l	5.98	49.90	mg	8.48
Simazine	28	0.1	μg/l	0.06	0.90	μg	199.31
Amitrole	0	0.01	μg/l	ND	ND	μg	ND
Glyphosate	28	0.02	μg/l	0.72	17.50	μg	1142.52
Diuron	3	0.02	μg/l	0.05	2.02	μg	139.09
Bromacil	7	0.1	μg/l	0.02	0.20	μg	18.39
Atrazine	16	0.1	μg/l	0.02	0.20	μg	14.37
Naphthalene	55	0.01-0.05	μg/l	0.11	4.75	μg	32.26
Acenaphthylene	32	0.01-0.05	μg/l	0.02	0.22	μg	15.18
Acenaphthene	28	0.01-0.05	μg/l	0.02	0.31	μg	30.54
Fluorene	38	0.01-0.05	μg/l	0.03	0.26	μg	24.95
Phenanthrene	63	0.01-0.05	μg/l	0.08	0.80	μg	74.74
Anthracene	55	0.01-0.05	μg/l	0.05	0.39	μg	61.95
Fluoranthene	73	0.01-0.05	μg/l	0.16	1.40	μg	275.92
Pyrene	75	0.01-0.05	μg/l	0.16	1.30	μg	307.56
Benzo(a)anthracene	67	0.01-0.05	μg/l	0.11	1.30	μg	160.59
Chrysene	70	0.01-0.05	μg/l	0.12	1.00	μg	200.34
Benzo(b)fluoranthene	70	0.01-0.05	μg/l	0.14	1.10	μg	217.00
Benzo(k)fluoranthene	67	0.01-0.05	μg/l	0.09	0.70	μg	93.66
Benzo(a)pyrene	75	0.01-0.05	μg/l	0.15	0.70	μg	232.27
Indeno(123)cdpyrene	63	0.01-0.05	μg/l	0.11	0.90	μg	171.84
Dibenzo(ah)anthracene	43	0.01-0.05	μg/l	0.07	0.58	μg	77.32
Benzo(ghi)perylene	50	0.01-0.05	μg/l	0.08	0.90	μg	51.4
Na	100	0.5 mg/l	mg/l	171.51	2100.00	g	323.24
Hardness	100	0.5 mg/l	mg/l	148.80	619.00	g	360.43
Chloride (De-Icing Salts)	15	0.2 mg/l	mg/l	258.43	3120.00	g	525.73
BOD	100	1.0 mg/l	mg/l	6.59	31.27	g	14.17
COD	100	20.0 mg/l	mg/l	88.62	458.00	g	218.09
TSS	100	1.0 mg/l	mg/l	114.58	1350.00	g	275.92
NH4-N	100	0.05 mg/l	mg/l	0.25	0.73	g	0.55

ND = not detected

Table 3.2 – Summary of Event Mean Concentrations (EMCs) and Loads Found in Road Runoff (WRc, 2002)

ANZECC LC85% to LC99%

Guideline trigger values for toxicants are also included in the ANZECC (2000) guideline and repeated below. These provide concentrations of various toxicants for which a given organism survival rate will occur. For example 99% of organisms will survive if exposed to Aluminium concentrations of not more than 27 micrograms/litre while only 80% of organisms will survive if exposed to 150 micrograms/litre of Aluminium. Note that exposure is measured as the median toxicant level and is to reflect chronic rather than acute exposure.

Chemical		Trigger values for freshwater (μgL^{-1})			
		Level of protection (% species)			
		99%	95%	90%	80%
METALS & METALLOIDS					
Aluminium	pH >6.5	27	55	80	150
Aluminium	pH <6.5	ID	ID	ID	ID
Antimony		ID	ID	ID	ID
Arsenic (As III)		1	24	94 [C]	360 [C]
Arsenic (AsV)		0.8	13	42	140 [C]
Beryllium		ID	ID	ID	ID
Bismuth		ID	ID	ID	ID
Boron		90	370 [C]	680 [C]	1300 [C]
Cadmium	H	0.06	0.2	0.4	0.8 [C]
Chromium (CrIII)	H	ID	ID	ID	ID
Chromium (CrVI)		0.01	1.0 [C]	6 [A]	40 [A]
Cobalt		ID	ID	ID	ID
Copper	H	1.0	1.4	1.8 [C]	2.5 [C]
Gallium		ID	ID	ID	ID
Iron		ID	ID	ID	ID
Lanthanum		ID	ID	ID	ID
Lead	H	1.0	3.4	5.6	9.4 [C]
Manganese		1200	1900 [C]	2500 [C]	3600 [C]
Mercury (inorganic)	B	0.06	0.6	1.9 [C]	5.4 [A]
Mercury (methyl)		ID	ID	ID	ID
Molybdenum		ID	ID	ID	ID
Nickel	H	8	11	13	17 [C]
Selenium (Total)	B	5	11	18	34
Selenium (SeIV)	B	ID	ID	ID	ID
Silver		0.02	0.05	0.1	0.2 [C]
Thallium		ID	ID	ID	ID
Tin (inorganic, SnIV)		ID	ID	ID	ID
Tributyltin (as µg/L Sn)		ID	ID	ID	ID
Uranium		ID	ID	ID	ID
Vanadium		ID	ID	ID	ID
Zinc	H	2.4	8.0 [C]	15 [C]	31 [C]
NON-METALLIC INORGANICS					
Ammonia	D	320	900 [C]	1430 [C]	2300 [A]
Chlorine	E	0.4	3	6 [A]	13 [A]
Cyanide	F	4	7	11	18
Nitrate	J	17	700	3400 [C]	17000 [A]
Hydrogen sulfide	G	0.5	1.0	1.5	2.6
ORGANIC ALCOHOLS					
Ethanol		400	1400	2400 [C]	4000 [C]
Ethylene glycol		ID	ID	ID	ID
Isopropyl alcohol		ID	ID	ID	ID

Chemical		Trigger values for freshwater (μgL^{-1})			
		Level of protection (% species)			
		99%	95%	90%	80%
1,2,4,5-tetrachloro-3-nitrobenzene		ID	ID	ID	ID
1,5-dichloro-2,4-dinitrobenzene		ID	ID	ID	ID
1,3,5-trichloro-2,4-dinitrobenzene		ID	ID	ID	ID
1-fluoro-4-nitrobenzene		ID	ID	ID	ID
Nitrotoluenes					
2-nitrotoluene		ID	ID	ID	ID
3-nitrotoluene		ID	ID	ID	ID
4-nitrotoluene		ID	ID	ID	ID
2,3-dinitrotoluene		ID	ID	ID	ID
2,4-dinitrotoluene		16	65 [C]	130 [C]	250 [C]
2,4,6-trinitrotoluene		100	140	160	210
1,2-dimethyl-3-nitrobenzene		ID	ID	ID	ID
1,2-dimethyl-4-nitrobenzene		ID	ID	ID	ID
4-chloro-3-nitrotoluene		ID	ID	ID	ID
Polycyclic Aromatic Hydrocarbons					
Naphthalene		2.5	16	37	85
Anthracene	B	ID	ID	ID	ID
Phenanthrene	B	ID	ID	ID	ID
Fluoranthene	B	ID	ID	ID	ID
Benzo(a)pyrene	B	ID	ID	ID	ID
Nitrobenzenes					
Nitrobenzene		230	550	820	1300
1,2-dinitrobenzene		ID	ID	ID	ID
1,3-dinitrobenzene		ID	ID	ID	ID
1,4-dinitrobenzene		ID	ID	ID	ID
1,3,5-trinitrobenzene		ID	ID	ID	ID
1-methoxy-2-nitrobenzene		ID	ID	ID	ID
1-methoxy-4-nitrobenzene		ID	ID	ID	ID
1-chloro-2-nitrobenzene		ID	ID	ID	ID
1-chloro-3-nitrobenzene		ID	ID	ID	ID
1-chloro-4-nitrobenzene		ID	ID	ID	ID
1-chloro-2,4-dinitrobenzene		ID	ID	ID	ID
1,2-dichloro-3-nitrobenzene		ID	ID	ID	ID
1,3-dichloro-5-nitrobenzene		ID	ID	ID	ID
1,4-dichloro-2-nitrobenzene		ID	ID	ID	ID
2,4-dichloro-2-nitrobenzene		ID	ID	ID	ID

Appendix C

MUSIC Model Inputs

PRE DEVELOPMENT MUSIC MODELLING INPUTS

Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
Rural - crops	25.784	0	25.784	80	200	1	1	120	30	10	25	0	0
existing highway (main road)	6.212	6.212	0	80	50	0.5	1	100	30	10	25	0	0
existing highway (batters)	4.759	0	4.759	80	50	0.5	1	100	30	10	25	0	0
Agricultural - grazing	12.133	0	12.133	80	200	1	1	120	30	10	25	0	0

OPTION 1 MUSIC MODELLING INPUTS - SOURCE NODES

Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
12 Road	0.690	0.559	0.131	80	50	0.5	1	100	30	10	25	0	0
13 Road	1.195	0.967	0.228	80	50	0.5	1	100	30	10	25	0	0
14 Road	1.191	0.969	0.222	80	50	0.5	1	100	30	10	25	0	0
15 Road	1.126	0.912	0.214	80	50	0.5	1	100	30	10	25	0	0
16 Road	1.140	0.923	0.217	80	50	0.5	1	100	30	10	25	0	0
17 Road	2.016	1.632	0.384	80	50	0.5	1	100	30	10	25	0	0
20 Road	3.315	2.669	0.646	80	50	0.5	1	100	30	10	25	0	0
21 Road	2.016	1.641	0.375	80	50	0.5	1	100	30	10	25	0	0
22 Road	1.267	1.026	0.241	80	50	0.5	1	100	30	10	25	0	0
24 Road	0.877	0.710	0.167	80	50	0.5	1	100	30	10	25	0	0
25 Road	1.435	1.155	0.280	80	50	0.5	1	100	30	10	25	0	0
27 Road	1.275	1.038	0.237	80	50	0.5	1	100	30	10	25	0	0
Road 28	1.963	1.598	0.365	80	50	0.5	1	100	30	10	25	0	0
12 Fill	0.010	0.000	0.010	80	50	0.5	1	100	30	10	25	0	0
13 Fill	0.237	0.000	0.237	80	50	0.5	1	100	30	10	25	0	0
14 Fill	0.558	0.000	0.558	80	50	0.5	1	100	30	10	25	0	0
15 Fill	0.518	0.000	0.518	80	50	0.5	1	100	30	10	25	0	0
16 Fill	0.440	0.000	0.440	80	50	0.5	1	100	30	10	25	0	0
17 Fill	1.731	0.000	1.731	80	50	0.5	1	100	30	10	25	0	0
20 Fill	0.021	0.000	0.021	80	50	0.5	1	100	30	10	25	0	0
21 Fill	0.211	0.000	0.211	80	50	0.5	1	100	30	10	25	0	0
22 Fill	0.190	0.000	0.190	80	50	0.5	1	100	30	10	25	0	0
24 Fill	0.163	0.000	0.163	80	50	0.5	1	100	30	10	25	0	0
25 Fill	0.265	0.000	0.265	80	50	0.5	1	100	30	10	25	0	0
27 Fill	0.381	0.000	0.381	80	50	0.5	1	100	30	10	25	0	0
28 Fill	0.561	0.000	0.561	80	50	0.5	1	100	30	10	25	0	0

Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
existing highway (batters)	4.125	0.000	4.125	80	50	0.5	1	100	30	10	25	0	0
existing highway (main road)	5.285	5.285	0.000	80	50	0.5	1	100	30	10	25	0	0
12 Cut	0.221	0.000	0.221	80	50	0.5	1	100	30	10	25	0	0
13 Cut	0.225	0.000	0.225	80	50	0.5	1	100	30	10	25	0	0
14 Cut	0.278	0.000	0.278	80	50	0.5	1	100	30	10	25	0	0
15 Cut	0.525	0.000	0.525	80	50	0.5	1	100	30	10	25	0	0
16 Cut	0.389	0.000	0.389	80	50	0.5	1	100	30	10	25	0	0
20 Road Untreatable	0.372	0.303	0.069	80	50	0.5	1	100	30	10	25	0	0
20 Cut	2.314	0.000	2.314	80	50	0.5	1	100	30	10	25	0	0
20 Fill Untreatable	0.313	0.000	0.313	80	50	0.5	1	100	30	10	25	0	0
21 Cut	0.484	0.000	0.484	80	50	0.5	1	100	30	10	25	0	0
22 Cut	0.882	0.000	0.882	80	50	0.5	1	100	30	10	25	0	0
24 Cut	0.209	0.000	0.209	80	50	0.5	1	100	30	10	25	0	0
25 Cut	0.694	0.000	0.694	80	50	0.5	1	100	30	10	25	0	0
27 Cut	0.392	0.000	0.392	80	50	0.5	1	100	30	10	25	0	0
28 Cut	1.626	0.000	1.626	80	50	0.5	1	100	30	10	25	0	0
Access Roads	0.905	0.905	0.000	80	50	0.5	1	100	30	10	25	0	0
Access Road Cut Batters	0.529	0.000	0.529	80	50	0.5	1	100	30	10	25	0	0
Access Road Fill Batters	1.080	0.000	1.080	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramps	0.466	0.466	0.000	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramp Fill Batters	0.045	0.000	0.045	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramp Cut Batters	0.197	0.000	0.197	80	50	0.5	1	100	30	10	25	0	0
Highway Dev	0.580	0.580	0.000	80	50	0.5	1	100	30	10	25	0	0
Highway Dev Cut Batters	1.680	0.000	1.680	80	50	0.5	1	100	30	10	25	0	0
Highway Dev Cut Batters	0.070	0.000	0.070	80	50	0.5	1	100	30	10	25	0	0
Highway Dev	0.210	0.210	0.000	80	50	0.5	1	100	30	10	25	0	0

OPTION 1 MUSIC MODELLING INPUTS - TREATMENT NODES

Treatment Node	Lo-flow bypass rate (cum/sec)	Hi-flow bypass rate (cum/sec)	Inlet pond volume	Area (sqm)	Extended detention depth (m)	Permanent pool volume (cum)	Equivalent pipe diameter (mm)	Overflow weir width (m)	Notional Detention Time (hrs)	Evap Loss as proportion of PET	Length (m)	Bed slope	Base Width (m)	Top width (m)	Vegetation height (m)	Seepage Rate (mm/hr)
Basin 12	0	100	0	940.4	0.8	722.7	100	5	10	0.7						
Basin 13	0	100	0	1068.6	2.3	651.6	100	5	19.3	0.7						
Basin 14	0	100	0	944.2	1.3	666	100	5	12.8	0.7						
Basin 15	0	100	0	925.7	1.3	656.1	100	5	12.6	0.7						
Basin 16	0	100	0	633.3	1.3	413.1	100	5	8.61	0.7						
Basin 17	0	100	0	2069.6	0.8	1735.2	100	5	22.1	0.7						
Basin 20	0	100	0	408.2	1.3	237.6	100	5	5.55	0.7						
Basin 25	0	100	0	719.2	1.3	482.4	100	5	9.78	0.7						
Basin 27	0	100	0	719.2	1.3	482.4	100	5	9.78	0.7						
Basin 28	0	100	0	940.4	0.8	722.7	100	5	10	0.7						
Basin 22	0	100	0	1199	1.3	834.3	100	5	16.3	0.7						
Basin 24	0	100	0	1157.5	2.3	722.7	100	5	20.9	0.7						
Swale	0				0.38						2680	0.01	0.5	3.5	0.15	1

OPTION 2 MUSIC MODELLING INPUTS - SOURCE NODES

Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
existing highway (batters)	4.125	0.000	4.125	80	50	0.5	1	100	30	10	25	0	0
existing highway (main road)	5.285	5.285	0.000	80	50	0.5	1	100	30	10	25	0	0
12 Cut	0.221	0.000	0.221	80	50	0.5	1	100	30	10	25	0	0
12 Road	0.690	0.559	0.131	80	50	0.5	1	100	30	10	25	0	0
13 Cut	0.225	0.000	0.225	80	50	0.5	1	100	30	10	25	0	0
13 Road	1.195	0.967	0.228	80	50	0.5	1	100	30	10	25	0	0
12 Fill	0.010	0.000	0.010	80	50	0.5	1	100	30	10	25	0	0
13 Fill	0.237	0.000	0.237	80	50	0.5	1	100	30	10	25	0	0
14 Cut	0.278	0.000	0.278	80	50	0.5	1	100	30	10	25	0	0
14 Road	1.191	0.969	0.222	80	50	0.5	1	100	30	10	25	0	0
14 Fill	0.558	0.000	0.558	80	50	0.5	1	100	30	10	25	0	0
15 Cut	0.525	0.000	0.525	80	50	0.5	1	100	30	10	25	0	0
15 Road	1.126	0.912	0.214	80	50	0.5	1	100	30	10	25	0	0
15 Fill	0.518	0.000	0.518	80	50	0.5	1	100	30	10	25	0	0
16 Cut	0.389	0.000	0.389	80	50	0.5	1	100	30	10	25	0	0
16 Road	1.140	0.923	0.217	80	50	0.5	1	100	30	10	25	0	0
16 Fill	0.440	0.000	0.440	80	50	0.5	1	100	30	10	25	0	0
17 Road	2.016	1.632	0.384	80	50	0.5	1	100	30	10	25	0	0
17 Fill	1.731	0.000	1.731	80	50	0.5	1	100	30	10	25	0	0
20 Road	3.315	2.669	0.646	80	50	0.5	1	100	30	10	25	0	0
20 Cut	2.314	0.000	2.314	80	50	0.5	1	100	30	10	25	0	0
20 Fill	0.021	0.000	0.021	80	50	0.5	1	100	30	10	25	0	0
20 Road Untreatable	0.372	0.303	0.069	80	50	0.5	1	100	30	10	25	0	0
21 Fill	0.211	0.000	0.211	80	50	0.5	1	100	30	10	25	0	0
20 Fill Untreatable	0.313	0.000	0.313	80	50	0.5	1	100	30	10	25	0	0
21 Cut	0.484	0.000	0.484	80	50	0.5	1	100	30	10	25	0	0

Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
21 Road	2.016	1.641	0.375	80	50	0.5	1	100	30	10	25	0	0
22 Road	1.267	1.026	0.241	80	50	0.5	1	100	30	10	25	0	0
22 Cut	0.882	0.000	0.882	80	50	0.5	1	100	30	10	25	0	0
22 Fill	0.190	0.000	0.190	80	50	0.5	1	100	30	10	25	0	0
24 Road	0.877	0.710	0.167	80	50	0.5	1	100	30	10	25	0	0
24 Cut	0.209	0.000	0.209	80	50	0.5	1	100	30	10	25	0	0
25 Cut	0.694	0.000	0.694	80	50	0.5	1	100	30	10	25	0	0
25 Road	1.435	1.155	0.280	80	50	0.5	1	100	30	10	25	0	0
25 Fill	0.265	0.000	0.265	80	50	0.5	1	100	30	10	25	0	0
27 Cut	0.392	0.000	0.392	80	50	0.5	1	100	30	10	25	0	0
27 Road	1.275	1.038	0.237	80	50	0.5	1	100	30	10	25	0	0
28 Cut	1.626	0.000	1.626	80	50	0.5	1	100	30	10	25	0	0
Road 28	1.963	1.598	0.365	80	50	0.5	1	100	30	10	25	0	0
28 Fill	0.561	0.000	0.561	80	50	0.5	1	100	30	10	25	0	0
27 Fill	0.381	0.000	0.381	80	50	0.5	1	100	30	10	25	0	0
24 Fill	0.163	0.000	0.163	80	50	0.5	1	100	30	10	25	0	0
Access Road Cut Batters	0.529	0.000	0.529	80	50	0.5	1	100	30	10	25	0	0
Access Roads	0.905	0.905	0.000	80	50	0.5	1	100	30	10	25	0	0
Access Road Fill Batters	1.080	0.000	1.080	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramp Fill Batters	0.045	0.000	0.045	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramp Cut Batters	0.197	0.000	0.197	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramps	0.466	0.466	0.000	80	50	0.5	1	100	30	10	25	0	0
Highway Dev	0.580	0.580	0.000	80	50	0.5	1	100	30	10	25	0	0
Highway Dev Cut Batters	1.680	0.000	1.680	80	50	0.5	1	100	30	10	25	0	0
Highway Dev	0.210	0.210	0.000	80	50	0.5	1	100	30	10	25	0	0
Highway Dev Cut Batters	0.070	0.000	0.070	80	50	0.5	1	100	30	10	25	0	0

OPTION 2 MUSIC MODELLING INPUTS - TREATMENT NODES

Treatment Node	Lo-flow bypass rate (cum/sec)	Hi-flow bypass rate (cum/sec)	Area (sqm)	Extended detention depth (m)	Overflow weir width (m)	Filter area (sqm)	Filter depth (m)	Filter median particle diameter (mm)	Saturated hydraulic conductivity (mm/hr)	Voids ratio	Length (m)	Bed slope	Base Width (m)	Top width (m)	Vegetation height (m)	Seepage Rate (mm/hr)	Depth in metres below the drain pipe
Bio-Ret 13	0	100	728	2	5	133	1.3	0.5	217	0.3						0	0
Bio-Ret 12	0	100	746	0.5	5	50	1.3	0.5	216	0.3						0	0
Bio-Ret 14	0	100	699	1	5	154	1.3	0.5	187	0.3						0	0
Bio-Ret 15	0	100	685	1	5	156	1.3	0.5	115	0.3						0	0
Bio-Ret 16	0	100	441	1	5	151	1.3	0.5	214	0.3						0	0
Bio-Ret 17	0	100	1771	0.5	5	308	1.3	0.5	234	0.3						0	0
Bio-Ret 20	0	100	262	1	5	143	1.3	0.5	188	0.3						0	0
Bio-Ret 22	0	100	868	1	5	182	1.3	0.5	198	0.3						0	0
Bio-Ret 24	0	100	800	2	5	98	1.3	0.5	220	0.3						0	0
Bio-Ret 25	0	100	512	1	5	191	1.3	0.5	189	0.3						0	0
Bio-Ret 27	0	100	512	1	5	158	1.3	0.5	183	0.3						0	0
Bio-Ret 28	0	100	746	0.5	5	335	1.3	0.5	204	0.3						0	0
Swale	0			0.38							2680	0.01	0.5	3.5	0.15	1	

OPTION 3 MUSIC MODELLING INPUTS - SOURCE NODES

Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
existing highway (batters)	4.125	0.000	4.125	80	50	0.5	1	100	30	10	25	0	0
existing highway (main road)	5.285	5.285	0.000	80	50	0.5	1	100	30	10	25	0	0
12 Cut	0.221	0.000	0.221	80	50	0.5	1	100	30	10	25	0	0
12 Road	0.690	0.559	0.131	80	50	0.5	1	100	30	10	25	0	0
13 Cut/s	0.225	0.000	0.225	80	50	0.5	1	100	30	10	25	0	0
13 Road	1.195	0.967	0.228	80	50	0.5	1	100	30	10	25	0	0
12 Fill	0.010	0.000	0.010	80	50	0.5	1	100	30	10	25	0	0
13 Fill	0.237	0.000	0.237	80	50	0.5	1	100	30	10	25	0	0
14 Cut	0.278	0.000	0.278	80	50	0.5	1	100	30	10	25	0	0
14 Road	1.191	0.969	0.222	80	50	0.5	1	100	30	10	25	0	0
14 Fill	0.558	0.000	0.558	80	50	0.5	1	100	30	10	25	0	0
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20 Road	3.315	2.698	0.617	80	50	0.5	1	100	30	10	25	0	0
20 Cut	1.000	0.000	1.000	80	50	0.5	1	100	30	10	25	0	0
20 Fill	0.021	0.000	0.021	80	50	0.5	1	100	30	10	25	0	0
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Source Node	Total Area (ha)	Area Impervious (ha)	Area Pervious (ha)	Field Capacity (mm)	Pervious Area Infiltration Capacity coefficient - a	Pervious Area Infiltration Capacity exponent - b	Impervious Area Rainfall Threshold (mm/day)	Pervious Area Soil Storage Capacity (mm)	Pervious Area Soil Initial Storage (% of Capacity)	Groundwater Initial Depth (mm)	Groundwater Daily Recharge Rate (%)	Groundwater Daily Baseflow Rate (%)	Groundwater Daily Deep Seepage Rate (%)
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25 Fill	0.265	0.000	0.265	80	50	0.5	1	100	30	10	25	0	0
27 Cut	0.392	0.000	0.392	80	50	0.5	1	100	30	10	25	0	0
27 Road	1.275	1.038	0.237	80	50	0.5	1	100	30	10	25	0	0
27 Fill	0.381	0.000	0.381	80	50	0.5	1	100	30	10	25	0	0
28 Cut	0.863	0.000	0.863	80	50	0.5	1	100	30	10	25	0	0
Road 28	1.963	1.598	0.365	80	50	0.5	1	100	30	10	25	0	0
28 Fill	0.561	0.000	0.561	80	50	0.5	1	100	30	10	25	0	0
20 Cut/s	1.314	0.000	1.314	80	50	0.5	1	100	30	10	25	0	0
22 Cut	0.103	0.000	0.103	80	50	0.5	1	100	30	10	25	0	0
24 Cut/s	0.083	0.000	0.083	80	50	0.5	1	100	30	10	25	0	0
28 Cut/s	0.763	0.000	0.763	80	50	0.5	1	100	30	10	25	0	0
Access Road Fill Batters	1.080	0.000	1.080	80	50	0.5	1	100	30	10	25	0	0
Access Roads	0.905	0.905	0.000	80	50	0.5	1	100	30	10	25	0	0
Access Road Cut Batters	0.529	0.000	0.529	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramp Fill Batters	0.045	0.000	0.045	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramp Cut Batters	0.197	0.000	0.197	80	50	0.5	1	100	30	10	25	0	0
Fly Over Ramps	0.466	0.466	0.000	80	50	0.5	1	100	30	10	25	0	0
Highway Dev Cut Batters	1.750	0.000	1.750	80	50	0.5	1	100	30	10	25	0	0
Highway Dev	0.790	0.790	0.000	80	50	0.5	1	100	30	10	25	0	0

OPTION 3 MUSIC MODELLING INPUTS - TREATMENT NODES

Treatment Node	Lo-flow bypass rate (cum/sec)	Hi-flow bypass rate (cum/sec)	Area (sqm)	Extended detention depth (m)	Overflow weir width (m)	Filter area (sqm)	Filter depth (m)	Filter median particle diameter (mm)	Saturated hydraulic conductivity (mm/hr)	Length (m)	Bed slope (%)	Base Width (m)	Top width (m)	Vegetation height (m)	Seepage Rate (mm/hr)	Depth in metres below the drain pipe
Linear Filter 12	0	0.035	0.1	0.01	2	351	1	0.5	360						0	0
Swale 12	0.035			0.1						175	0.6%	0.5	1.4	0.25	0	
Linear Filter 13	0	0.066	0.1	0.01	2	665	1	0.5	360						0	0
Swale 13	0.066			0.1						332	2.6%	0.5	1.4	0.25	0	
Linear Filter 15	0	0.063	0.1	0.01	2	630	1	0.5	360						0	0
Swale 15	0.063			0.1						315	3.0%	0.5	1.4	0.25	0	
Linear Filter 17	0	0.114	0.1	0.01	2	1144	1	0.5	360						0	0
Swale 17	0.114			0.1						572	2.3%	0.5	1.4	0.25	0	
Linear Filter 20	0	0.136	0.1	0.01	2	1360	1	0.5	360						0	0
Swale 20	0.136			0.1						680	1.8%	0.5	1.4	0.25	0	
Linear Filter 21/22	0	0.138	0.1	0.01	2	1381	1	0.5	360						0	0
Swale 21/22	0.138			0.1						690	0.7%	0.5	1.4	0.25	0	
Linear Filter 24	0	0.049	0.1	0.01	2	486	1	0.5	360						0	0
Swale 24	0.049			0.1						243	1.2%	0.5	1.4	0.25	0	
Linear Filter 25	0	0.079	0.1	0.01	2	790	1	0.5	360						0	0
Swale 25	0.079			0.1						395	1.2%	0.5	1.4	0.25	0	
Linear Filter 27	0	0.069	0.1	0.01	2	690	1	0.5	360						0	0
Swale 27	0.069			0.1						345	1.2%	0.5	1.4	0.25	0	
Linear Filter 28	0	0.108	0.1	0.01	2	1080	1	0.5	360						0	0
Swale 28	0.108			0.1						540	1.2%	0.5	1.4	0.25	0	
Linear Filter 16	0	0.063	0.1	0.01	2	630	1	0.5	360						0	0
Swale 16	0.063			0.1						315	3.0%	0.5	1.4	0.25	0	
Linear Filter 14	0	0.066	0.1	0.01	2	665	1	0.5	360						0	0
Swale 14	0.066			0.1						332	2.6%	0.5	1.4	0.25	0	
Swale Access road	0			0.38						2680	1.0%	0.5	3.5	0.15	1	