SINCLAIR KNIGHT MERZ

SKM

Warrell Creek to Urunga
Upgrading the Pacific Highway

WATER QUALITY WORKING PAPER

- Final
- January 2010

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Executive Summary

Sinclair Knight Merz (SKM) has been commissioned by the NSW Roads and Traffic Authority (RTA) to prepare an environmental assessment of the Proposal for the Pacific Highway upgrade between Warrell Creek and Urunga, which forms part of the RTA's Pacific Highway Upgrading (PHU) Program. As part of the broader environmental assessment process and to assist with the concept design a water quality assessment is required.

The Proposal corridor is located in the mid-north coast region of NSW and extends for approximately 42 km from the northern end of the existing Allgomera deviation, south of Warrell Creek, to the existing Waterfall Way interchange at Raleigh. This is referred to as 'the Proposal' throughout this document.

The study area has been divided into four separate sections for the purpose of this assessment:

- Section 1 – Warrell Creek at the existing Allgomera Deviation to the Nambucca River (northern bank) at Macksville;
- Section 2 – Nambucca River (northern bank) at Macksville to Nambucca Heads (railway crossing);
- Section 3 – Nambucca Heads (railway crossing) to Ballards Road; and
- Section 4 – Ballards Road to Waterfall Way interchange.

Each of the four sections encompass a number of major and minor watercourses including the Nambucca and Kalang Rivers, Deep and Warrell Creeks and five wetlands protected under *State Environmental Planning Policy No. 14 - Coastal Wetlands* (SEPP14). The majority of the waterways in the study area are estuarine and are therefore dominated by saline conditions with hydraulic and water quality characteristics that are different to freshwater systems.

The purpose of this study is to:

- Provide surface waterway and wetland water quality information for waterways crossed by or in close proximity to the Proposal, including SEPP 14 wetlands;
- Provide groundwater information for the study area, including groundwater quality, groundwater contamination risk, groundwater use and groundwater users;
- Identify risks and potential impacts on surface water and groundwater during pre-construction, construction and post-construction of the Proposal including impacts associated with accidents and runoff with consideration for the criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* 2000; and
- Identify appropriate impact mitigation and management measures for any potential water quality impacts.

The surface water quality of the study area was assessed through sampling to provide background information on the surface water quality to supplement information obtained during the route selection phase and data provided by Nambucca Shire Council. Thirty one sites were identified and sampled on four sampling events, however not all sites were sampled on all occasions. The first two sampling events were undertaken on 24-25 September and 22-24 October 2007 and were classified as ‘dry weather’ events. The third and fourth sampling events were undertaken on the 30 October and 8-9 November 2007 and were classified as ‘wet weather’ events.

Groundwater use, users, quality and risks were assessed through existing information sources such as the Department of Land and Water Conservation (now part of the Department of Environment, Climate Change and Water (DECCW)) risk assessment of groundwater bores in Australia, the Department of Water and Energy Groundwater Database, and results from groundwater and soil analyses undertaken by Golder Associates in 21 bores throughout the study area as part of this Proposal.

The water quality of surface waterways and groundwater resources potentially impacted by the construction and operation for each section of the Proposal are outlined below.

Section 1

The water quality of the freshwater creeks in Section 1 (including Upper Warrell, Butchers, Rosewood, Stony and Williamson Creeks) was generally good for most indicators except dissolved oxygen which was below recommended guidelines at all sites during both dry and wet weather conditions. The estuarine sites of Warrell Creek and Nambucca River in Section 1 generally had high turbidity (10-20NTU in most cases) and low dissolved oxygen concentrations (<80 per cent saturation). Water quality appeared poorer following wet weather due to increased runoff. These sites are all potentially impacted by the Proposal through increased turbidity and subsequent decreases in dissolved oxygen without the implementation of appropriate mitigation and control measures. Wetland No 388 generally had good water quality in dry weather, however dissolved oxygen and pH decreased following a wet weather event and turbidity levels increased. This wetland currently receives runoff from Gumma Road which may have contributed to the poorer water quality following wet weather.

Groundwater use in the area is generally for domestic supply and livestock, with limited use for domestic irrigation and waste disposal. The geotechnical investigations undertaken between March and July 2008 indicate that groundwater lies at 0.7 to 12.78 metres below ground level through this section. The existence of Gumma Gumma wetland is reliant on high groundwater levels through this area.

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Section 2

No major water courses are crossed by the Proposal in Section 2. There are however two SEPP14 wetlands in close proximity. The closest is wetland N^{o}383 present around Newee Creek approximately 20 metres to the west of the Proposal boundary and N^{o} 386 alongside the Nambucca River approximately 800 metres to the east of the Proposal. At the time of sampling there was no water present to determine ambient water quality conditions of these wetlands. Groundwater was measured from three boreholes in the vicinity of the Proposal. The groundwater level within these varied between 12.3 metres and 18.22 metres below ground level between October 2007 and March 2008. Groundwater levels in the vicinity of the wetlands would be higher than this. As with Section 1 the main use for groundwater in the area is for domestic supply and for livestock. Limited use of groundwater also exists for domestic industry, industry and waste disposal.

Section 3

The water quality of waterways crossed by the Proposal in Section 3 varied between sites and between dry and wet weather conditions. There are five waterways in Section 3 (Boggy, Cow, Deep, Oyster and McGraths Creeks). Boggy and Cow Creek are termed 'intermittently closed and open lakes or lagoons' (ICOLLs). Subsequently, guideline values vary depending on whether conductivity levels at the time of sampling were indicative of a freshwater or estuarine system, particularly as estuarine turbidity guidelines are more stringent than those for freshwater. The ICOLL sites were predominantly freshwater during the four sampling events, although one site was always estuarine (Cow Creek downstream of the Proposal crossing). Boggy Creek and Cow Creek upstream of the Proposal crossing were also estuarine during one sample event. The pH on the first (dry) weather sampling event were below recommended limits at four of the six sites sampled on that occasion, but improved on subsequent sampling occasions. On three of the four sampling events turbidity levels were high and exceeded the guidelines at the majority of sites. The high turbidity readings coincided with low dissolved oxygen concentrations. The poor water quality results were most likely due to very low flow conditions and excessive amounts of floating debris. The poorest water quality conditions were at Boggy Creek and a tributary of Oyster Creek. Both Cow Creek and the tributary of Oyster Creek appear quite degraded with shallow banks and minimal riparian vegetation and therefore could be impacted by the construction and operation of the Proposal. The alignment through this section runs alongside the existing Pacific Highway, The groundwater level was measured at one bore in Section 3 in March 2008. There was no groundwater in this bore at this time. Groundwater use in this section includes domestic supply and livestock.

Section 4

The Kalang River, which would be crossed by the Proposal upstream of the existing highway crossing, has moderate water quality. The pH was generally good, although turbidity and dissolved oxygen are indicative of poorer water quality conditions. Turbidity was slightly elevated and dissolved oxygen was below guidelines during one dry weather sampling event, however both worsened slightly following wet weather. Two SEPP14 wetlands N^{o}'s351 and 353 are present within Section 4, however only N^{o} 351 was sampled during investigations as wetland N^{o}353had no water present on any of the sampling occasions. When sampled, wetland N° 351, which lies approximately 80 metres to the east of the Proposal, was found to have poor water quality with high turbidity and low dissolved oxygen concentrations.

Groundwater levels were taken from three boreholes installed along Section 4. The levels, taken between September 2007 and July 2008, were between 15.75 metres and 21.40 metres. Groundwater use in the area includes domestic supply, livestock and limited use for recreation.

Overall the water quality of waterways in the Warrell Creek to Urunga study area was slightly better under dry weather conditions than following wet weather, although the smaller tributaries (predominately those classified as lowland rivers) had poor water quality during dry weather due to very low flow and/or stagnant water conditions at the time of sampling.

Poor water quality during dry weather was generally due to high turbidity and low dissolved oxygen and pH concentrations which failed to meet the ANZECC/ARMCANZ (2000) trigger values for slightly disturbed estuarine and lowland river ecosystems. Following wet weather, the water quality at all sites deteriorated due to increased turbidity and lower dissolved oxygen levels. The extent to which the waterways were affected by wet weather appears dependent on the surrounding catchment and the amount of riparian vegetation. Sites with well vegetated banks and permeable catchment surfaces are less affected by rainfall and runoff as the sediment can become trapped by the vegetation thereby reducing the amount of runoff entering the waterways. The groundwater levels are variable through the study area, and based on the land use. Whilst being the main groundwater user, agricultural practices also represent the greatest risk in terms of groundwater contamination where fertilisers or pesticides are or have historically been applied to the land.

Providing adequate sedimentation, erosion and environmental management measures are implemented the risks of construction and operation on the quality of both surface and groundwater are considered to be minimal. The high water table in many locations indicated by the presence of SEPP 14 and other wetland ecosystems highlights the potential for acid sulphate soils to be present. The route has been aligned to avoid direct impact to SEPP 14 wetlands, and providing excavations within low lying areas are managed appropriately the potential for impact from acid sulphate soil run off is considered to be minimal.

1. Introduction

1.1. Background

Sinclair Knight Merz (SKM) has been commissioned by the NSW Roads and Traffic Authority (RTA) to conduct an environmental assessment of the Proposal for the Pacific Highway upgrade between Warrell Creek and Urunga, which forms part of the RTA's Pacific Highway Upgrading (PHU) Program. The Proposal corridor is located in the Mid-North Coast region of NSW and extends for approximately 42 km from the northern end of the existing Allgomera deviation, south of Warrell Creek, to the existing Waterfall Way interchange at Raleigh.

The study area encompasses a number of major and minor water courses, including wetlands protected under *State Environmental Planning Policy No. 14 - Coastal Wetlands* (SEPP 14), and has been split into four sections as shown in **Figure 1-1**. These include:

- Section 1 – Allgomera Deviation to Nambucca River
- Section 2 – Nambucca River to Nambucca Heads
- Section 3 - Nambucca Heads to Ballards Road
- Section 4 - Ballards Road to Raleigh Deviation

Water, including water way, wetland and groundwater quality, is identified as a key issue in the Department of Planning (DoP) (now part of the Department of Planning & Local Government) Director-General's Requirements (DGRs). A detailed assessment of the Proposal was undertaken as part of the broader environmental assessment process and to assist with the concept design and is presented in this Working paper.

1.2. Objectives

The objectives of this study are to:

- Provide surface waterway and wetland water quality information for waterways crossed by or in close proximity to the Proposal, including SEPP 14 wetlands;
- Provide groundwater information for the study area, including groundwater quality, groundwater contamination risk, groundwater use and groundwater users;
- Identify risks and potential impacts on surface water and groundwater during pre-construction, construction and post-construction of the Proposal including impacts associated with accidents and runoff with consideration for the criteria specified in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* 2000 (ANZECC/ARMCANZ (2000)); and
- Assess the potential impacts of the Proposal on surface and groundwater quality.

FIGURE 1-1 | THE PROPOSAL

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- Identify a comprehensive suite of measures to mitigate any potential impacts on water quality during construction and operation of the Proposal.
- To satisfy the relevant Director General's Requirements (DGRs) relating to waterway and wetland water quality, groundwater contamination risk, groundwater use and groundwater users.

Hydrology and flooding impacts are addressed separately to this Working paper.

2. Description of the study area

2.1. Investigation area

The area of investigation encompasses portions of the following catchments:

- The Bellinger River Catchment (Kalang River is part of the Bellinger River Catchment). The confluence of these rivers occurs about 750 m before discharge to the ocean;
- Deep Creek; and
- The Nambucca River Catchment (this includes Warrell Creek which combines with the Nambucca River approximately 900 metres before discharging into the ocean).

The Bellinger and Kalang Rivers flow within the same river basin and have a common ocean entrance at Urunga. They comprise a total catchment area of approximately 1,110km^2, (770km^2 for the Bellinger and 340km^2 for the Kalang).

The catchment area of Deep Creek is 93km^2.

The Nambucca River catchment has a total area of approximately 1,310km^2. (1020 km^2 for the Nambucca and 290 km^2 for Warrell Creek). The major towns of Nambucca Heads and Macksville are located at the entrance and 13km upstream of the entrance, respectively. There are a number of significant estuarine tributaries, although not all of these fall within the study area or are impacted by the Proposal. Estuarine tributaries within the study area include:

- Taylors Creek;
- Watt Creek;
- Taylors Arm;
- Warrell Creek; and
- Swampy Creek.

Thirty one monitoring sites were identified in the study area, however not all were sampled at all times due to lack of water and access difficulties. The location of monitoring sites on left and right banks are referred to as if heading downstream and site names ending with an ‘a’ or ‘b’ refer to upstream and downstream of the Proposal respectively.

2.1.1. Section 1 – Allgomera deviation to Nambucca River

Section 1 encompasses the southern portion of the study area, commencing 100m south of Browns Crossing Road at the northern end of the existing Allgomera deviation south of Warrell Creek village. This Section of the study area encompasses the catchments of Warrell Creek and the

Nambucca River, as well as the smaller tributaries of Butchers, Stony, Rosewood and Williamson Creeks. A portion of SEPP 14 Wetland N^{o} 388 is also present at the eastern edge of the study area.

Of the 31 monitoring sites in the study area, 17 were selected in Section 1 to ascertain current surface water quality conditions of the creeks, and to aid in the identification of any potential impacts that the Proposal may have on water quality. Sites were located on Warrell Creek, Butchers Creek, Stony Creek, Rosewood Creek, Williamson Creek and the Nambucca River. SEPP14 Wetland N^{o} 388 was also sampled to determine existing conditions. Site details include (refer to **Figure 2–1**):

- Site 1: Upper Warrell Creek at Browns Crossing (start of Proposal);
- Site 2: Upper Warrell Creek and Butchers Creek confluence at the Pacific Highway crossing;
- Site 3a: Butchers Creek upstream of the Proposal;
- Site 3b: Butchers Creek downstream of the Proposal;
- Site 4a: Rosewood Creek upstream of the Proposal;
- Site 4b: Rosewood Creek downstream of the Proposal;
- Site 5a: Stony Creek upstream of the Proposal;
- Site 5b: Stony Creek downstream of the Proposal;
- Site 6: Stony Creek downstream of the Proposal crossing at Albert Drive;
- Site 7: Rosewood Creek downstream of Proposal crossing at Albert Drive;
- Site 8a: Williamson Creek upstream of existing highway crossing at Donnellyville;
- Site 8b: Wiilliamson Creek downstream of existing highway crossing at Donnellyville;
- Site 9a: Warrell Creek upstream of existing highway crossing at Donnellyville;
- Site 9b: Warrell Creek downstream of existing highway crossing at Donnellyville;
- Site 10a: Nambucca River, southern bank upstream of Proposal;
- Site 10b: Nambucca River, southern bank downstream of Proposal; and
- SEPP 388: immediately downstream of SEPP 14 Wetland N^{o} 388, Gumma Creek.

2.1.2. Section 2 – Nambucca River to Nambucca Heads

Section 2 commences on the northern bank of the Nambucca River at Macksville and follows the ridgeline in the vicinity of Old Coast Road before crossing the North Coast Railway Line to rejoin the existing highway west of Nambucca Heads. The Proposal avoids direct impact on the Newee Creek wetland (SEPP 14 wetland N^{o} 383). SEPP14 Wetland N^{o} 386 is also in the vicinity of Section 2.

Although the DGRs do not specifically require water quality assessment of SEPP 14 Wetland N^{o} 383 and 386, sites were selected in these wetlands to provide important information about ambient water quality and the impact of the Proposal on these ecosystems. Hence, the following two sampling sites were selected for surface water quality monitoring (refer to **Figure 2–2**):

- SEPP 383: SEPP 14 Wetland N^{o} 383, Newee Creek Wetland; and
- SEPP 386: SEPP 14 Wetland N^{o} 386, Champions Lane.

2.1.3. Section 3 – Nambucca Heads to Ballards Road

Section 3 originates north of the North Coast Railway Line at Nambucca Heads, and follows the length of the existing highway up to Ballards Road. This Section of the study area is relatively long and narrow, and contains sections of Boggy, Cow, Deep, Oyster and McGraths Creeks.

Seven sites were monitored for surface water quality as follows (refer to **Figure 2–3**):

- Site 11: Boggy Creek downstream of Proposal crossing (upstream access was hindered by very dense vegetation);
- Site 12a: Cow Creek upstream of Proposal crossing;
- Site 12b: Cow Creek downstream of Proposal crossing;
- Site 13a: Deep Creek upstream of Proposal crossing;
- Site 13b: Deep Creek downstream of Proposal crossing;
- Site 14a: Unnamed tributary of Oyster Creek, upstream of Proposal crossing; and
- Site 14b: Unnamed tributary of Oyster Creek, downstream, of Proposal crossing.

2.1.4. Section 4 – Mines Road, South Urunga to Waterfall Way interchange

Section 4 commences north of Ballards Road and diverts to the west of the existing highway to traverse through Newry State Forest and cross the Kalang River in the vicinity of South Arm Road. The proposal then passes to the west of SEPP 14 wetland No. 351 before passing to the east of Ridgewood Drive and the Raleigh Industrial area to rejoin the existing highway at Raleigh. SEPP 14 wetland No. 353 also falls within Section 4.

Five sites were monitored for surface water quality in this Section (refer to **Figure 2–4**):

- Site 15a: Kalang River upstream of the Proposal crossing;
- Site 15b: Kalang River downstream of the Proposal crossing;
- Site 16 Bellinger River (left bank) 800m north or Proposal ;
- SEPP 351: SEPP 14 Wetland N^{o} 351, Shortcut and South Arm Road; and
- SEPP 353: SEPP 14 Wetland No 353, South Arm Road Bellingen.

FIGURE 2-1 | WATER QUALITY MONITORING LOCATIONS SECTION 1 OF 4

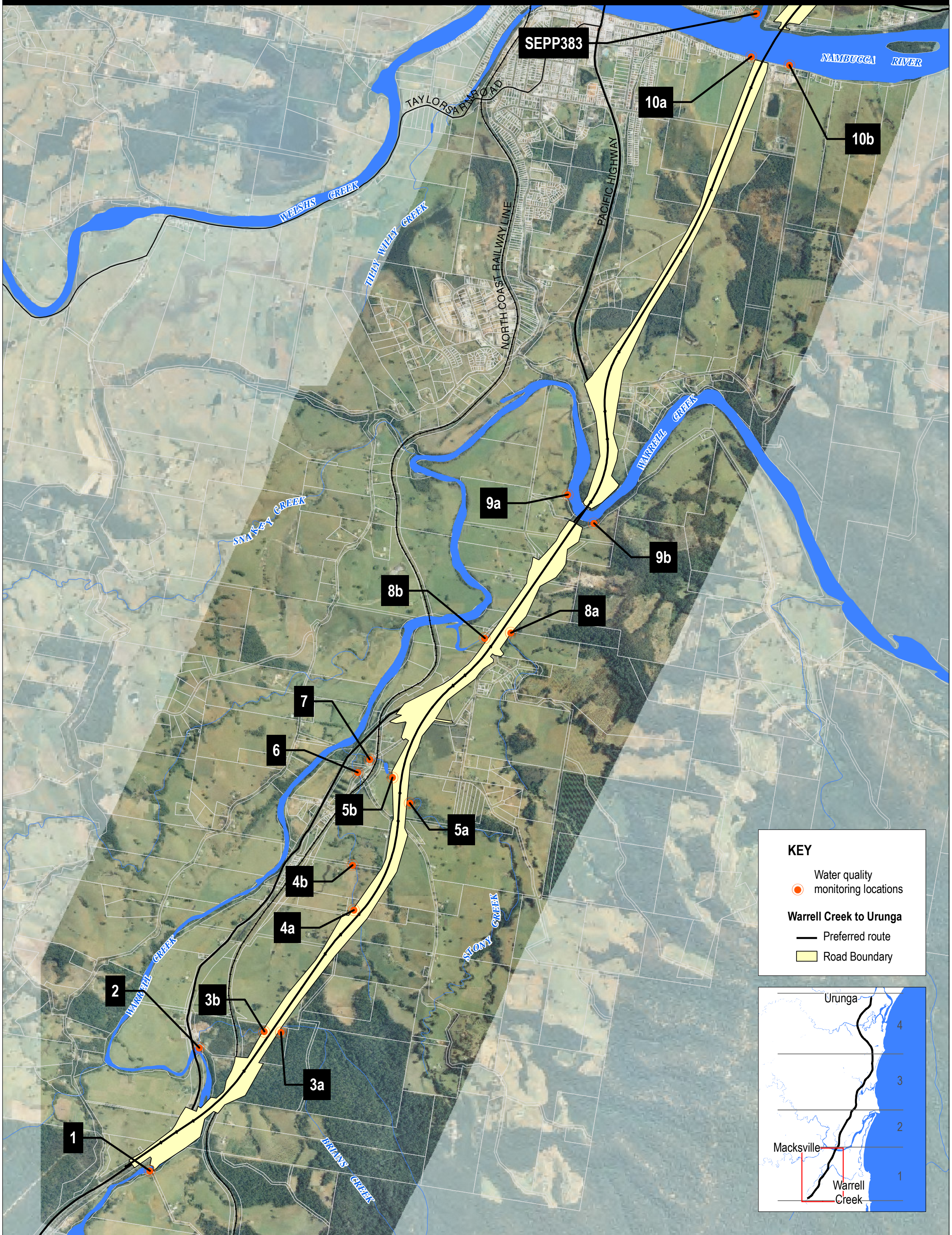

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FIGURE 2-2 | WATER QUALITY MONITORING LOCATIONS SECTION 2 OF 4

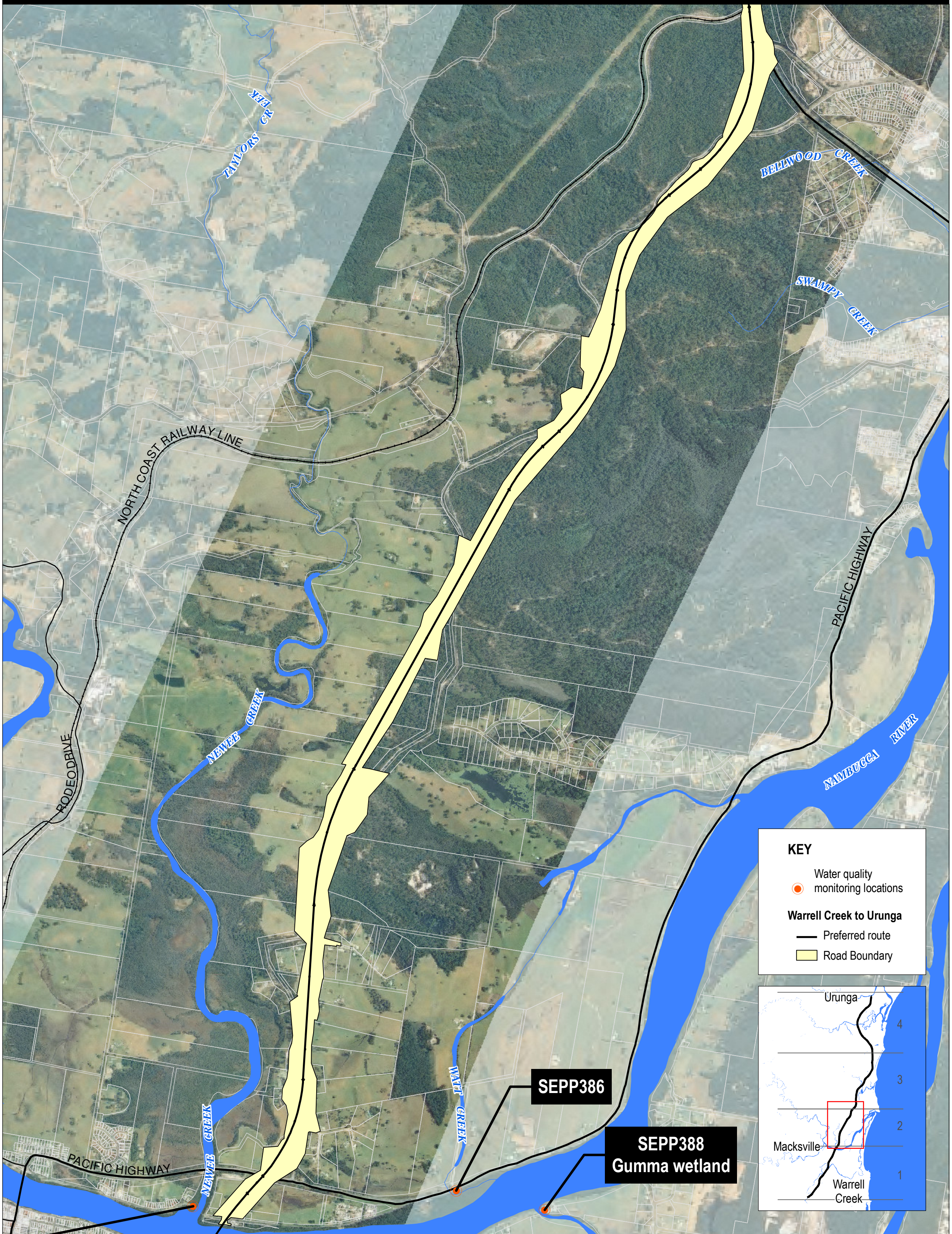

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FIGURE 2-3 | WATER QUALITY MONITORING LOCATIONS — **SECTION 3 OF 4**

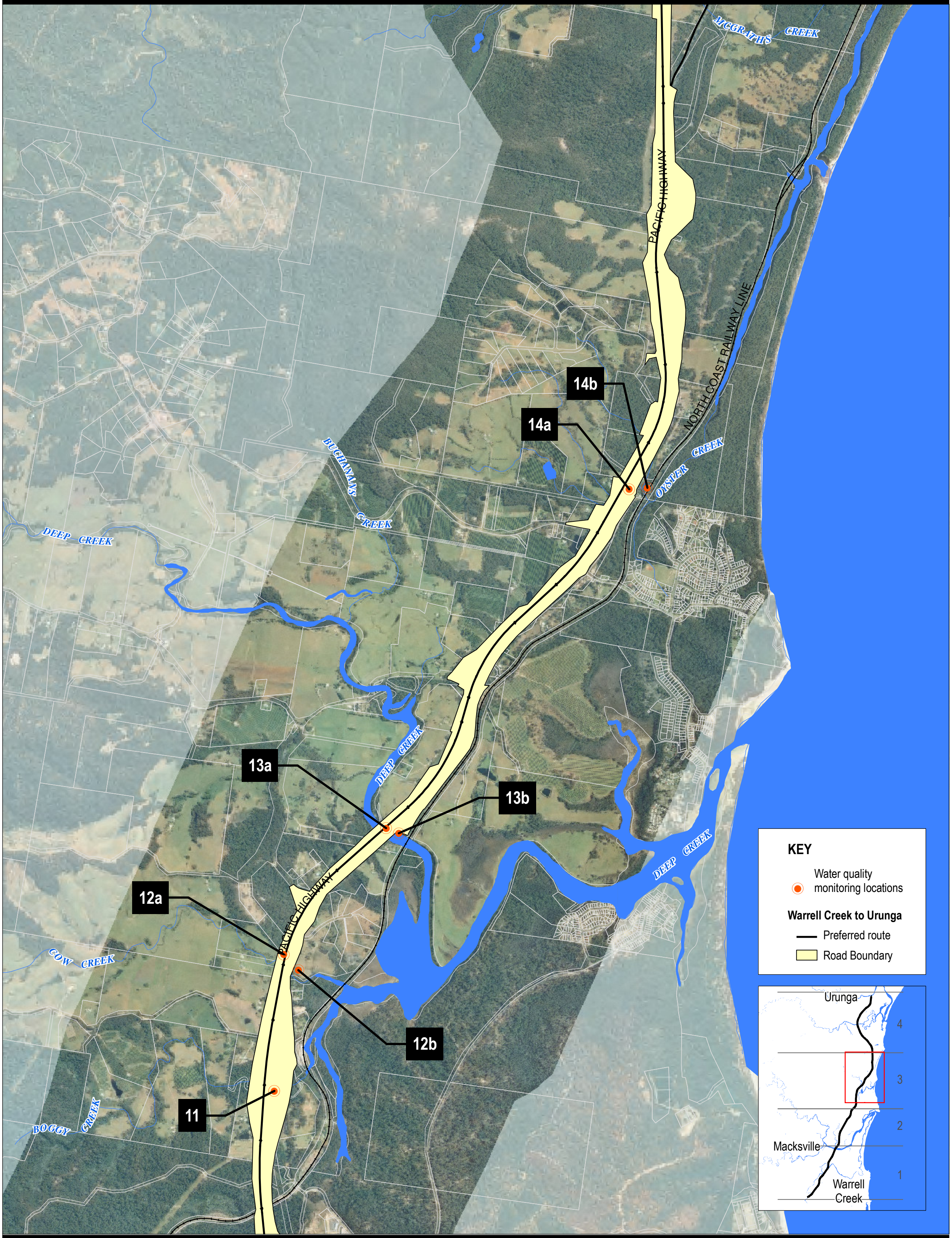

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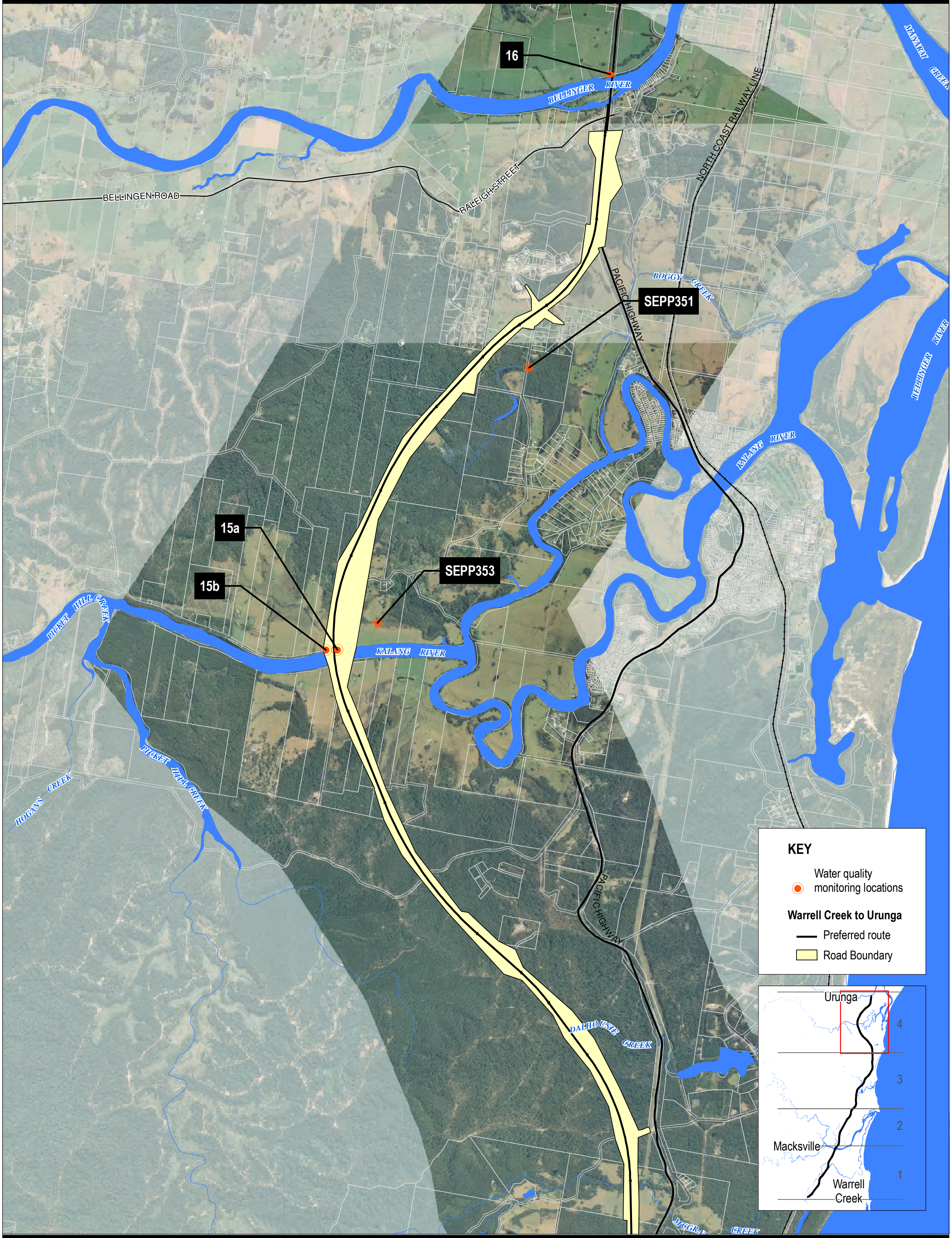
FIGURE 2-4 | WATER QUALITY MONITORING LOCATIONS SECTION 4 OF 4



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3. Surface water

3.1. Assessment of water quality

In order to assess existing water quality in a waterway it is necessary to compare water quality data for the relevant indicators against appropriate criteria. The assessment of water quality in this report is made in accordance with default trigger values for chemical and physical stressors for the protection of aquatic ecosystems for south-east Australia for slightly disturbed estuarine and lowland river ecosystems as outlined in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000).

3.2. Nambucca and Bellinger River catchments

The DECCW classified streams within both the Nambucca and Bellinger River Catchments as either estuarine, mainly forested, affected by urban development or uncontrolled (freshwater) streams (EPA 1999a,b). The Proposal does not traverse forested streams, however the remaining three stream classifications are relevant. The Kalang and Nambucca rivers, and Deep and Warrell Creeks are classified as estuarine, due to the dominance of saline conditions (EPA, 1999a and b). A small proportion of the Nambucca River around Macksville and the Kalang River at Urunga is classified as being affected by urban development (EPA, 1999b). These streams are typically significantly modified and heavily impacted by stormwater. The remaining streams were classified as uncontrolled. These are typically fresh water and include Upper Warrell, Butchers, Stony, Rosewood and Williamson creeks.

The former NSW Department of Land and Water Conservation (now part of DECCW) published a Stressed Rivers Assessment Report summary for NSW (DLWC, 1998). The stressed rivers assessment was based on an index of hydrological stress (proportion of water extraction to streamflow estimate) and environmental stress (stream health, conservation value and future risk). The Bellinger catchment (both Coastal Bellinger and Coastal Kalang subcatchments) were classified as medium priority subcatchments, with a low hydrological stress but high environmental stress. Within the Nambucca catchment, the Lower Deep Creek subcatchment was classified as high priority due to high hydrological stress and medium environmental stress, and the Coastal Nambucca subcatchment was classified as low priority, with low hydrological and medium environmental stress.

3.2.1. Waterway classifications

Waterways identified along the length of Proposal have been classified in accordance with the *Policy and Guidelines for Bridges, Roads, Causeways and Similar Structures* (NSW Fisheries 1999) are shown on **Figures 3-1** to **3-4**.

FIGURE 3-1 WATERWAY CROSSING CLASSIFICATIONS

SECTION 1 OF 4

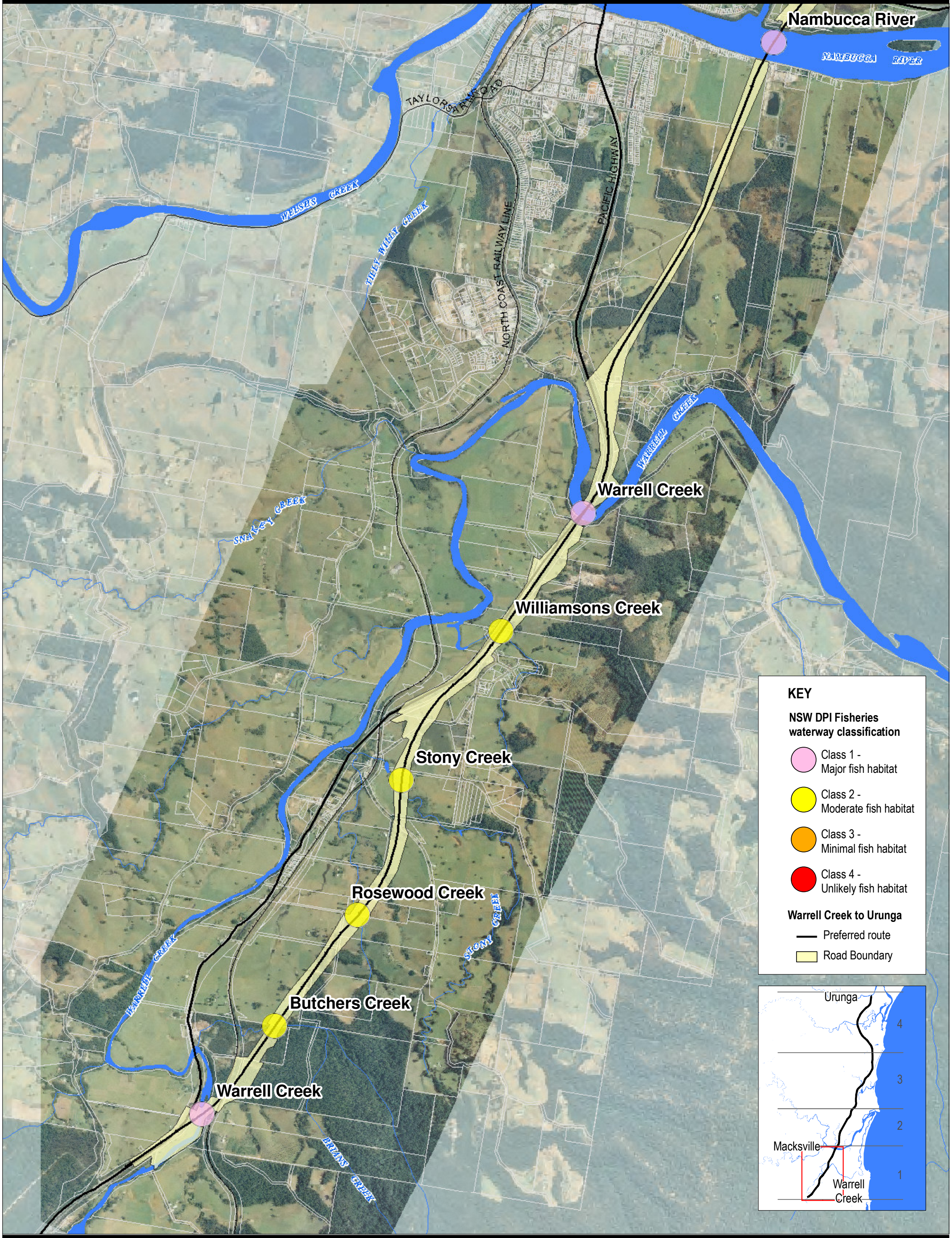

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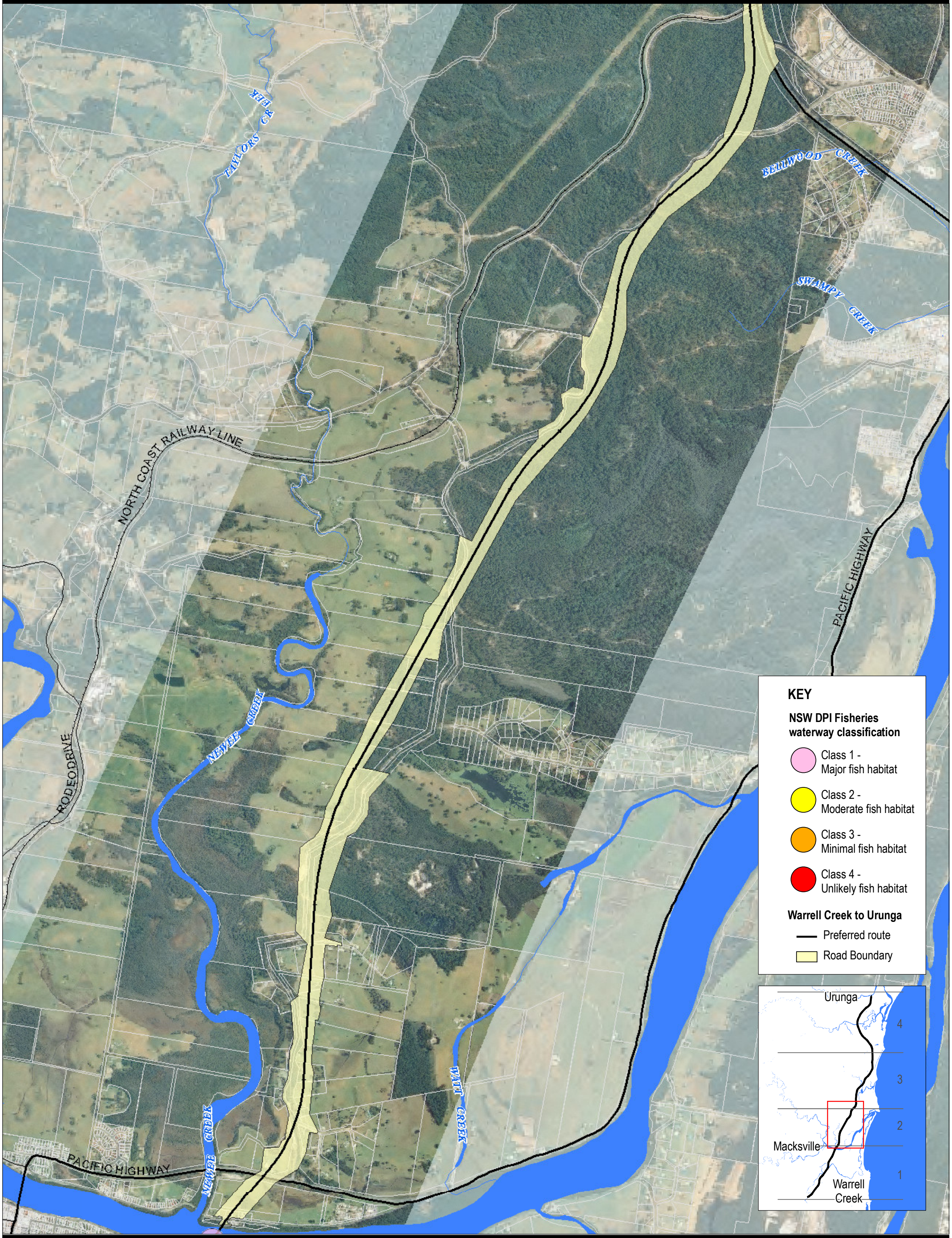
FIGURE 3-2 WATERWAY CROSSING CLASSIFICATIONS

SECTION 2 OF 4



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0 400 800 Metres

FIGURE 3-3 WATERWAY CROSSING CLASSIFICATIONS

SECTION 3 OF 4

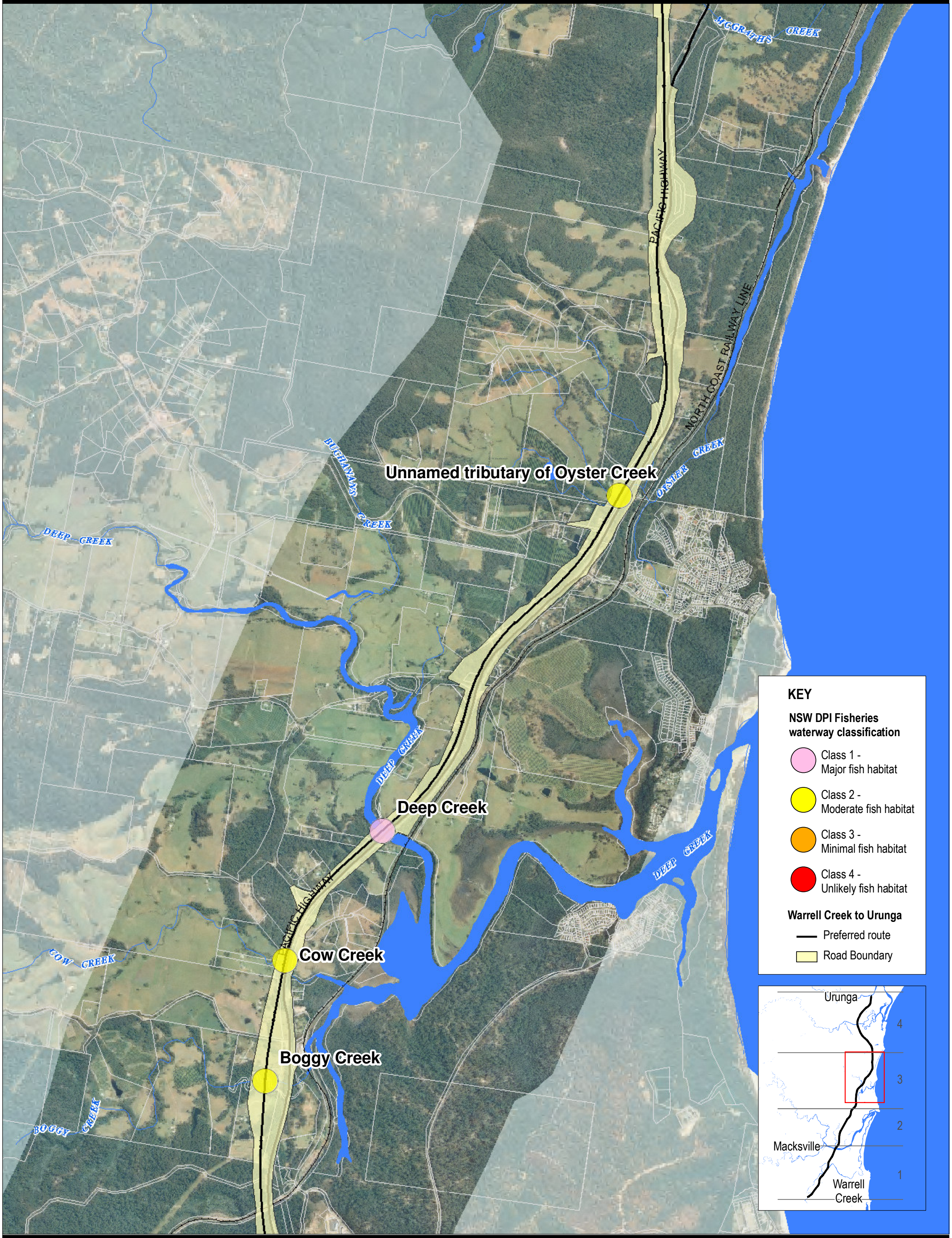

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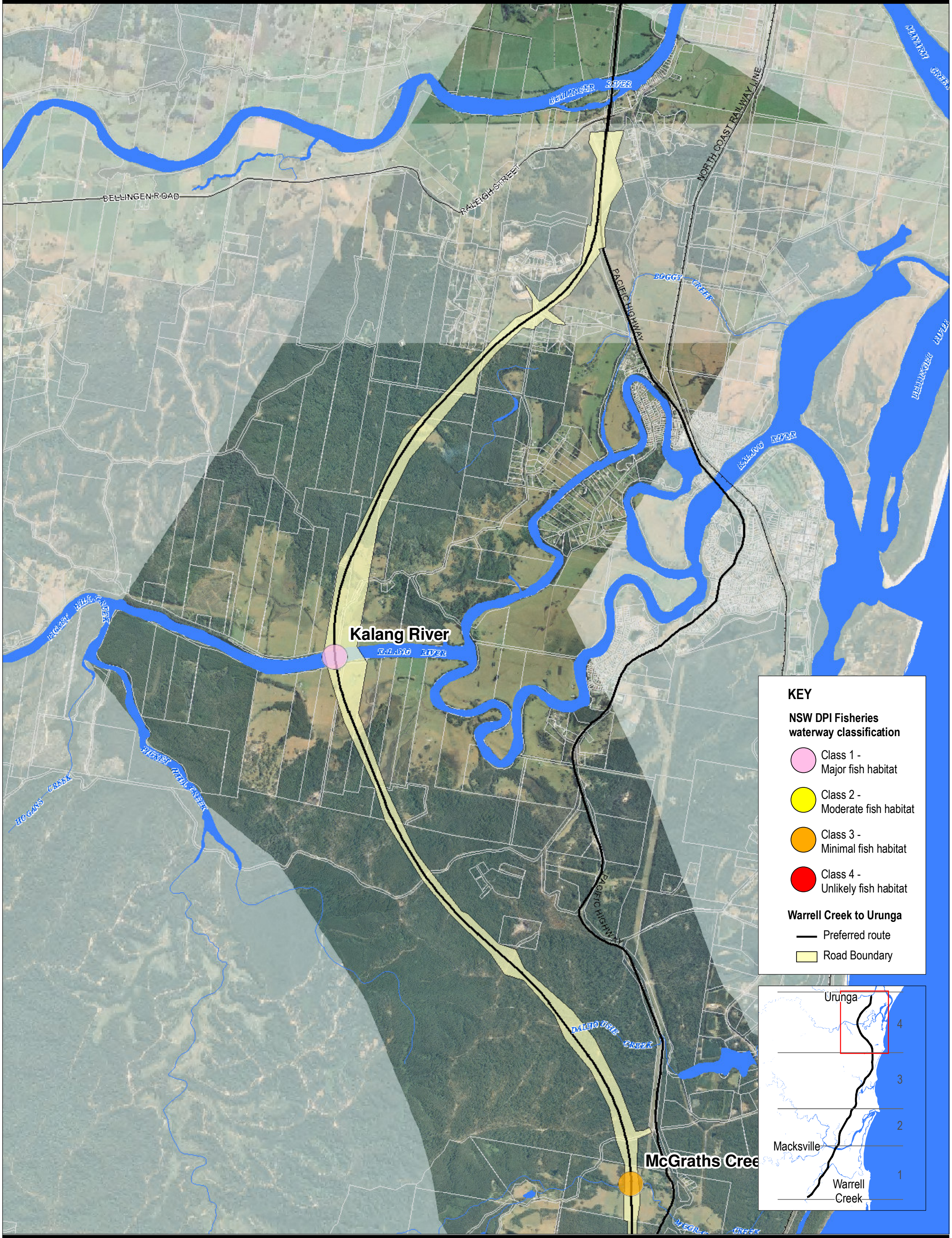
FIGURE 3-4 WATERWAY CROSSING CLASSIFICATIONS **SECTION 4 OF 4**



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3.3. Surface water quality monitoring

Thirty-one monitoring locations were selected for ascertaining existing surface water quality of rivers and creeks intersected by the Proposal. For most waterways, monitoring was generally undertaken immediately upstream or downstream of the proposed crossing, unless site access was prevented. Sites labelled ‘a’ were located upstream of the proposed crossing, whereas sites labelled ‘b’ were located downstream of the proposed crossing. In accordance with specific requirements from the Department of Environment, Climate Change and Water (DECCW), SEPP14 wetland water quality was monitored. Five SEPP14 wetlands were monitored: N^{o}s 351, 353, 383, 386 and 388, however results are available for only two of the five wetlands (N^{o}s 351 and 388) as the other wetlands were dry on each sampling occasion. The Gumma wetland (SEPP N^{o} 388) was also dry, but surface water was sampled from immediately downstream in Gumma Creek (**Figure 2–1** and **Figure 2–2**).

The monitoring dates for each site are shown in **Table 3-1**. Three dry weather sampling events were conducted between 24 and 25 September 2007, 22 and 24 October 2007 and 14-16 July 2008. Dry weather is classified as less than 20mm of rainfall in the study area 48hours prior to sampling. Wet weather sampling was undertaken on 30 October and 8-9 November 2007. Wet weather is classified as >20mm of rainfall recorded at Bureau of Meteorology rainfall gauges located within the study area 48 hours prior to sampling. An average of approximately 26.6mm, 23.3mm and 12.7mm of rain fell in the Bellinger, Kalang and Nambucca River catchments respectively in the 48hrs prior to 30 October 2007. Most of the rain fell on 29 October 2007 at all three river catchments. An average of approximately 38.9mm, 29.9mm and 50.3mm of rain fell in the Bellinger, Kalang and Nambucca River catchments respectively in the 48hrs prior to 9 November 2007. Most of the rain fell on 8 November 2007 at all three river catchments.

- **Table 3-1 Sampling dates for each water quality monitoring site**

Site	24-25 Sep 2007 (Dry)	22-24 Oct 2007 (Dry)	30 Oct 2007 (Wet)	8-9 Nov 2007 (Wet)	14-16 July 2008 (Dry)
1	√	√	√	√	
2	√	√	√	√	
3a					√
3b					√
4a					√
4b					√
5a					√
5b					√
6	√	√	√	√	
7	√	√	√	√	
8a	√	√		√	
8b	√	√		√	

Site	24-25 Sep 2007 (Dry)	22-24 Oct 2007 (Dry)	30 Oct 2007 (Wet)	8-9 Nov 2007 (Wet)	14-16 July 2008 (Dry)
9a	√	√	√	√	
9b	√	√	√	√	
10a	√	√	√	√	
10b	√	√	√	√	
11	√	√	√	√	
12a	√	√	√	√	
12b		√	√	√	
13a	√	√	√	√	
13b	√	√	√	√	
14a	√	√	√	√	
14b	√	√	√	√	
15a	√	√	√	√	
15b	√	√	√	√	
16	√	√	√	√	
SEPP 388		√	√	√	
SEPP 383					
SEPP 386					
SEPP 351		√	√	√	
SEPP 353					

Water quality parameters were measured using a Yeo-Kal 611 intelligent water quality analyser. Parameters measured included:

- Turbidity (NTU) – is a measure of the 'muddiness' of the water. It is important as an indication of the amount of suspended colloidal and particulate matter in the water and how much light can penetrate for important biochemical processes such as photosynthesis. Elevated levels of particulate matter can also impact on dissolved oxygen concentrations and pH;
- Conductivity ($mS.cm^{-1}$) – is a measure of the amount of dissolved salts in the water and its ability to conduct an electrical current. It is important as some plant and animal species are salt sensitive whilst others require higher salt concentrations;
- Salinity (ppt) – is the salt concentration of water, measured directly as dissolved salts;
- Temperature (°C) – is a measure of the degree of hotness or coldness of water. It is a form of pollution and can impact on riverine biota and associated biological and chemical processes;
- pH – is a measure of acidity or alkalinity of water. Most freshwater and estuarine biota have a range of tolerances between 6.5 and 8; and

- Dissolved Oxygen (per cent saturation and $mg.L^{-1}$) – is a measure of the amount of oxygen dissolved in water. Dissolved oxygen is vital for many forms of riverine and estuarine biota including native fish and is also vital for the functioning of healthy aquatic ecosystems.

Measurements were generally collected between 15 and 30cm below the surface depending on the depth of water with the sampling depth recorded in the field. For each parameter, three replicate measurements were recorded approximately 10m apart from the access point to the site. Each parameter was then reported as the average (arithmetic mean) of the three measurements. The individual replicates are also reported to provide an understanding of the variation between individual readings (refer to **Appendix A**).

3.4. Existing surface water quality information

3.4.1. Nambucca Shire Council data

There are limited existing water quality data in the Nambucca and Bellinger catchments that aid in the description of existing water quality conditions. Nambucca Shire Council regularly sample two sites of relevance in the Nambucca River, the first is upstream of the Wastewater Treatment Plant and the other downstream. These sites also coincide with the Proposal. Water quality data at the two sites includes standard *in-situ* water quality parameters including dissolved oxygen, pH, turbidity, temperature, conductivity and salinity in addition to the following:

- Faecal Coliforms – an indicator of the faecal contamination of waters and thus the presence of human pathogens;
- Total Suspended Solids (TSS) – is a measure of the concentration of fine particles in the water and can consist of fine mineral particles, algae and micro-organisms and particles of organic matter. High TSS concentrations can reduce light available for aquatic organisms. They can also carry nutrients, metals and other pollutants;
- Nutrients – Nitrogen (N) and Phosphorus (P) are essential nutrients for life on earth. Nutrient pollution can lead to excessive growth of aquatic plants such as phytoplankton, cyanobacteria, macrophytes and algae. The types of nutrients monitored are total phosphorus (TP) and nitrate plus nitrite (NO_x).

A summary of water quality data for the Numbucca River is shown in **Table 3-2**.

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- **Table 3-2 Summary statistics for the Nambucca River (1991 – 2007)**

Site	Parameter	No. Results	Minimum	10th percentile	Mean	90th percentile	Maximum	Compliance (%)
Nambucca River: 200m upstream of river discharge point	Total Phosphorus ($mg.L^{-1}$)	177	0	0.001	0.056	0.15	0.3	53
	Faecal Coliforms (CFU)	172	0	1	29	81	307	-
	NO_x ($mg.L^{-1}$)	177	0.002	0.015	0.35	0.8	8	12
	Conductivity (mS/cm)	154	3.54	21.28	36.69	47.53	51.46	-
	Salinity (ppt.)	154	0.23	2.41	17.58	31.35	33.33	-
	Dissolved Oxygen ($mg.L^{-1}$)	137	3.1	5.16	6.73	8.13	16.8	72
	pH	152	3.74	7.35	7.74	8.26	9.34	87
	Turbidity (NTU)	154	0	2	599	10.74	27	88
Nambucca River: 200m downstream of river discharge point	Total Phosphorus ($mg.L^{-1}$)	178	0	0.01	0.06	0.15	0.84	51
	Faecal Coliforms (CFU)	171	0	0	28	79	585	-
	NO_x ($mg.L^{-1}$)	179	0	0.009	0.29	0.86	2.1	17
	Conductivity (mS/cm)	153	3.9	22.80	37.30	47.18	51.76	-
	Salinity (ppt.)	153	0.24	2.5	17.96	31.62	33.63	-
	Dissolved Oxygen ($mg.L^{-1}$)	135	0.9	5.22	6.72	7.92	16.8	75
	pH	152	6.54	7.44	7.89	8.38	11.28	91
	Turbidity (NTU)	153	0	2	6.22	10.72	28	90

Data for the Nambucca River 200m upstream and downstream of the discharge point indicates that:

- Mean total phosphorus concentrations were almost double the recommended ANZECC/ARMCANZ (2000) guideline of $0.03mg.L^{-1}$ for protection of aquatic ecosystems for both sampling sites. Overall, total phosphorus concentrations complied with the guideline 53 per cent and 51 per cent of sampling occasions upstream and downstream of the discharge point respectively. There was very little difference in TP concentrations between sites (aside from the maximum value) indicating that the water quality at the site upstream of the wastewater discharge is affected by tidal influences;
- Overall faecal coliform densities were low at both sites with mean densities of 29CFU/100mL upstream and 28 CFU/100mL downstream of the discharge point. Maximum faecal coliform densities recorded were significantly higher than both the mean and 90th percentile indicating that the high numbers are potentially due to wet weather events in the catchment rather than discharges from the treatment facility *per se*;
- Both NO_3 (nitrate) and NO_2 (nitrite) were measured. Results of these parameters were summed to determine NOx concentrations at each site. Oxidised nitrogen concentrations were generally higher than those recommended by ANZECC/ARCAMNZ (2000) ($0.015mg/L^{-1}$) with only 12 per cent of the 177 samples upstream and 17 per cent of the 179 samples downstream of the discharge point complying with the guidelines;

- Dissolved oxygen concentrations were predominantly measured in $mg.L^{-1}$ despite current ANZECC/ARCANZ (2000) guidelines being reported as percent saturation. Therefore in terms of compliance, the ANZECC (1992) guideline for DO concentrations >$6mg.L^{-1}$ have been applied. Mean DO concentrations complied with the guidelines with averages of approximately $6.7mg.L^{-1}$ at both sites. Overall, DO at the upstream site complied on 72 per cent of sampling occasions and on 75 per cent of occasions;
- The pH of estuarine systems should fall between 6.5 and 8 for the protection of aquatic ecosystems (ANZECC/ARMCANZ 2000). At both the Nambucca River sites, average pH levels were within these guidelines as indicated by mean levels of 7.74 and 7.89 recorded upstream and downstream of the discharge site respectively.
- Turbidity in the vicinity of the Nambucca River wastewater discharge point was generally good with 88-90 per cent of sampling occasions recording turbidity of less than 10NTU, and therefore within the recommended ANZECC/ARMCANZ (2000) guideline.

3.4.2. Route options assessment monitoring

Water quality information obtained during the route options assessment phase and relevant to the Proposal is discussed below, and shown in **Table 3-3**. All sites are located within Section 1 of the study area, however some of the sampling sites may have moved slightly since the route options assessment monitoring due to improved site access. These data represent the sample parameters specified in **Section 3.3** for wet and dry weather conditions. Samples were collected for three wet and three dry sampling events: 11-13 November 2003 (dry), 19-20 January 2004 (wet), 12-13 July 2004 (dry), 10 September 2004 (wet), 18 January 2005 (wet) and 3 February 2005 (dry). The mean of these six events was calculated for each water quality parameter.

- **Table 3-3 Mean water quality results from Route Options Assessment monitoring**

Site Name	Sample type*	pH	EC (mS/cm)	Salinity (ppt)	Turb (NTU)	DO (% sat)	Temp (ºC)
ANZECC (2000) criteria for protection of lowland aquatic ecosystems	-	6.5-8.5	0.125-2.2	N/A	<50	85-110	N/A
Williamson Creek upstream of existing highway (site 1a)	Dry	7.19	0.32	0.16	17.62	78.75	19.98
	Wet	7.20	0.37	0.16	17.75	47.83	18.65
Williamson Creek downstream of existing highway (site 1b)	Dry	7.08	0.33	0.16	11.82	70.37	19.61
	Wet	7.00	0.33	0.16	40.87	44.58	19.01
Warrell Creek downstream of existing highway (site 2b)	Dry	7.11	11.85	6.95	5.58	61.77	21.21
	Wet	7.31	17.60	10.29	4.88	57.80	22.95
Nambucca River	Dry	7.94	34.23	20.18	11.72	88.80	22.95

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Site Name	Sample type*	pH	EC (mS/cm)	Salinity (ppt)	Turb (NTU)	DO (% sat)	Temp (ºC)
ANZECC (2000) criteria for protection of lowland aquatic ecosystems	-	6.5-8.5	0.125-2.2	N/A	<50	85-110	N/A
upstream of the Proposal (site 3a)	Wet	7.84	43.05	27.66	10.78	74.23	22.61
Nambucca River downstream of the Proposal (site 3b)	Dry	8.00	35.05	23.39	6.55	88.78	22.64
	Wet	7.87	43.50	27.99	4.87	74.97	22.77
Deep Creek upstream of existing crossing (site 6a)	Dry	7.36	30.07	19.18	7.85	81.55	24.01
	Wet	7.50	30.72	19.68	12.28	76.05	21.96
Deep Creek downstream of existing Crossing site 6b)	Dry	7.27	30.02	19.19	8.73	83.62	23.75
	Wet	7.46	31.37	20.19	10.40	76.17	22.45
Kalang River upstream of the Proposal (site 9a)	Dry	7.72	30.17	19.99	19.35	94.77	22.17
	Wet	7.50	39.55	25.25	35.5	68.63	23.42
Kalang River downstream of the Proposal (site 9b)	Dry	7.75	31.52	19.57	17.5	95.12	22.01
	Wet	7.55	39.73	25.32	5.5	73.73	23.38
Bellinger River upstream of existing crossing (site 10)	Dry	7.38	23.03	18.07	15.87	90.52	22.39
	Wet	7.45	14.07	8.42	20.10	80.75	23.12

Data collected as part of the route options assessment phase demonstrates that:

- Mean pH levels at all sites met the ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems for lowland rivers and estuarine systems during both wet and dry weather;
- Mean turbidity at Williamson Creek complied with the ANZECC/ARMCANZ (2000) guideline of less than 50NTU for lowland river systems during dry and wet weather. Turbidity for estuarine systems is recommended to be less than 10NTU. During dry weather all sites exceeded 10NTU except for Warrell Creek, Deep Creek and the Nambucca River downstream of the Proposal. Following wet weather mean turbidity decreased at Warrell Creek, Nambucca River and Kalang River (downstream of the Proposal), and all complied except for the Nambucca River upstream of the Proposal. Mean turbidity at Deep Creek, Kalang River (upstream) and Bellinger River all increased following wet weather and exceeded guidelines;
- Dissolved oxygen (DO) concentrations failed to comply at Williamson Creek during dry and wet weather conditions. DO was less that the lower guide limit of 85 per cent saturation for lowland river systems at all times. At the estuarine sites, mean dissolved oxygen concentrations during dry weather complied with the ANZECC/ARMCANZ (2000) guideline of 80-110 per cent saturation at all sites except Warrell Creek. Following wet weather, mean

concentrations decreased and fell below 80 per cent saturation at all sites except the Bellinger River.

4. Groundwater

This section outlines the extent to which groundwater and surface water are connected in the study area, and provides information on the existing groundwater quantity, quality, use and users, and risks to groundwater from the Proposal.

4.1. Groundwater in the study area

Groundwater level measurements from within the study area (as detailed in **Section 4.2.1**) indicate that groundwater is generally below about 10 metres in depth (except at one bore in Section 1). The most likely places where groundwater is close to the ground surface, and therefore more at risk of contamination, is in streams, as base flow, around the rivers and in the wetlands. Research shows that, over time, all streams are connected with groundwater (Land and Water Australia, 2007). The extent to which groundwater and surface water are connected in a stream depends on the nature of the material between them. Chapter 18 – *Soil characteristics and erosion control* indicates that the soils on the floodplains and surrounding the waterways are fine-grained alluvial soils such as silty clays and sandy clays. Archaeological investigations also uncovered quartz gravel in some areas which would have a greater permeability. Compaction by livestock which was evident on much of the agricultural land along the Proposal, would also act to reduce groundwater permeability.

The NSW State Groundwater Dependent Ecosystems Policy (NSW Department of Land and Water Conservation, 2002) states that alluvial aquifer systems in the lower Nambucca and Bellinger Rivers have groundwater systems that are often in direct connection with surface water bodies like rivers and wetlands. These systems can be recharged quickly and can restore water levels when droughts break. The groundwater is likely to support base flows and hyporheic (region beneath and lateral to a stream bed, where there is mixing of shallow groundwater and surface water) ecosystems, wetlands, terrestrial vegetation and hypogean ecosystems. Active hypogean zones (beneath ground surface) have been found in tributaries of the Bellinger River (NSW Department of Land and Water Conservation, 2002). However, these alluvial groundwater systems tend to have relatively small amounts of water in storage. So, although these aquifers are responsive to natural recharge variability, significant changes to the water regime can lead to ecosystem damage (NSW Department of Land and Water Conservation, 2002).

4.2. Existing groundwater water quality information

Whilst there is a substantial number of groundwater bores located within the study area, water quality data pertaining to these bores are limited. In 1998, the then Department of Land and Water Conservation (now part of DECCW) undertook a risk assessment of groundwater bores located within the Nambucca Shire Local Government Area (LGA) which comprises a large proportion of the study area according to over extraction and /or contamination. This assessment identified that the alluvium downstream of Macksville was classified as medium risk mainly due to contamination risks and the remaining groundwater bores within the LGA were classified as low risk (Nambucca Shire Council, 2004). There have been other monitoring programs focussing on groundwater quality undertaken over time such as at previous and current landfill sites and in the proximity of Scotts Head Wastewater Treatment Works. Monitoring at all sites has indicated that there are no signs of contamination to groundwater.

4.2.1. Groundwater users

The former Department of Natural Resources (now part of DECCW) has a groundwater database which contains hydrogeological information. This database identifies 19 licensed bores within the study area when a search of the database was undertaken in 2004. The bores were dug between 1977 and 2002 and the majority of the bores in close proximity to the Proposal are predominantly located around Macksville and between Nambucca Heads and Valla Beach. The bores located around Macksville intersected shale and slates whereas the bores north of Nambucca Heads generally intersected clay, shales and slate. The depths of the bores varied between 4 metres and 58 metres, however depths generally ranged between 30-40m. The groundwater levels of these bores at the time of sampling (where available) range from 5 to 30 metres, salinity was good and bore yields up to 8.84 litres per second. The majority of bores are used for domestic supply with or without stock. Other uses include:

- **Section 1** – domestic irrigation uses in one bore and waste disposal at another bore near Macksville.
- **Section 2** – two bores used for industrial and one domestic industrial in this section and one bore used for waste disposal.
- **Section 3** – no additional uses recorded.
- **Section 4** – one bore used for recreation near Urunga.

There was no additional groundwater quality data relating to these bores.

4.2.2. Proposal groundwater investigation (quality and levels)

Golder Associates installed 21 standpipes within boreholes drilled as part of the geotechnical investigations for the Proposal. Groundwater levels were measured in 11 of these boreholes. No chemical analysis of the groundwater has been undertaken (refer **Table 4-1**).

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Table 4-1 Depth of groundwater at boreholes in the study area

Borehole reference	Groundwater depth (metres below ground level)	Dates of sampling
Section 1		
1106	12.78	1/03/08
1108	0.70	1/03/08
1111	9.90-10.65	1/03/08 & 25/07/08
1116	2.95	25/07/08
Section 2		
2103	12.34	10/02/08
2108	12.35-13.03	2/10/07 & 6/10/07
2109	17.89-18.22	2/10/07, 10/02/08 & 1/03/08
Section 3		
3113	Dry (no groundwater encountered)	15/03/08
Section 4		
4101	17.00-19.75	22/09/07, 10/02/08, 15/03/08 & 25/07/08
4104	21.37-21.40	15/03/08 & 25/07/08
4112	15.75	10/02/08

A desktop assessment including a site visit was undertaken as part of the geotechnical investigations to identify potentially contaminating land uses along the Proposal which could result in soil or groundwater contamination. Based on the existing and historic land use in the area there is the potential for contamination from heavy metals, pesticides (OCP and OPP) and herbicides (phenoxy acid herbicides). Soil samples were taken in areas of both potential point source and diffuse pollution sources and tested for a range of contaminants including heavy metals and organic herbicides and pesticides. The soil samples returned results below laboratory reporting limits indicating very low to negligible levels of contaminants when compared to the National Environment Protection Council guidelines in the areas investigated. Therefore the risk to groundwater in these locations is considered to be low. Further details are provided in Chapter 18 – *Soil characteristics and erosion control.*

Golder Associates sampled selected boreholes and testpits from relatively low lying areas and near drainage depressions or creeks during the geotechnical investigation for the presence of acid sulphate soils (ASS). Seventeen samples were collected from 6 test pits (TP4323, TP4314, TP4315, TP4324, TP4326, and TP3308) and 4 boreholes (BH1108, BH3105, BH3106 and BH1117) at different depths. Of the 17 samples submitted for analysis, only 3 had no ASS

(TP4323, TP4324 and TP4314 1.0-1.1m). Chapter 18 – *Soil characteristics and erosion control* provides further details on the depths and locations of acid sulphate soils.

5. Assessment of water quality impacts

This section examines the existing water quality at sites associated with the Proposal and provides an assessment of the potential impact on locations where the Proposal traverses creeks and rivers. Where feasible, sites were chosen approximately 50-100m upstream and downstream of the Proposal crossing. As mentioned previously, sites upstream of the crossing are labelled ‘a’ while sites downstream are labelled ‘b’. The water quality results were compared with default trigger values for chemical and physical stressors for the protection of aquatic ecosystems for south-east Australia for slightly disturbed estuarine and lowland river ecosystems (ANZECC/ARMCANZ 2000). There are no default trigger values recommended for wetlands in south-eastern Australia. Highlighted results in the following tables indicate exceedences of these default trigger values.

5.1. Section 1 – Allgomera Deviation to Nambucca River

This is the southern-most section of the study area and the Proposal crosses Upper Warrell Creek, Butchers Creek, Rosewood Creek, Stony Creek, Williamson Creek, Warrell Creek and the Nambucca River. The Proposal also travels in close proximity to SEPP14 wetland N^{o} 388. The DECCW specifically requested ambient water quality conditions be assessed at this wetland. Water quality data for sites in Section 1 are presented in **Table 5-1** (shaded cells denote exceedence of relevant guidelines) and discussed in the following. Sites 1, 2, 3a & b, 4a & b, 5a & b, 6, 7 and 8a & b, are defined as lowland river sites, while sites 9a & b, 10a & b and SEPP 388 are defined as estuarine or wetland sites. Water quality has been assessed against relevant guidelines for each ecosystem type.

5.1.1. Upper Warrell Creek, Butchers Creek, Stony Creek and Rosewood Creek

Sites 1, 2, 6 and 7 currently receive run-off from the existing Pacific Highway or minor roads which were used to access the sampling locations. The water quality at these sites did not meet the ANZECC/ARMCANZ (2000) guidelines for dissolved oxygen during both dry and wet weather with mean concentrations at all sites failing to meet the lower limit of 85 per cent saturation. Sites in Butchers Creek (3a & b), Stony Creek (5a & b) and Rosewood Creek (4a & b) were sampled in July 2008 and also had low dissolved oxygen concentrations upstream and downstream of the Proposal and failed to meet the lower guideline limit.

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Table 5-1 Mean water quality results for sites in Section 1

Date	Water quality parameter	Site 1	2	3a	3b	4a	4b	5a	5b	6	7	8a	8b	ANZECC/ARMCANZ (2000) default trigger values for protection of lowland aquatic ecosystems	Site 9a	9b	10a	10b	SEPP 388*	ANZECC/ARMCANZ (2000) default trigger values for protection of estuarine aquatic ecosystems
24-25 Sep 2007 DRY	pH	5.75	5.84	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	6.26	6.45	6.66	6.19	6.5 – 8	6.95	6.94	8.13	7.43	No Data – not sampled	7.0 – 8.5
	Conductivity (µS/cm)	330.7	367.3							503.5	441.5	0.28	0.28	125 – 2200	1.5	1.99	34.8	35.7		N/A
	Turbidity (NTU)	2.20	20.30							5	3.60	6.2	4.7	<50	3.4	2.83	1.9	1.7		<10
	Dissolved Oxygen (% saturation)	57.13	24							77.27	64.10	59.1	60.2	85 – 110	58.9	67.5	87.4	89.3		80 – 110
	Temperature (°C)	17.17	18.5							19.2	19.15	17	17.3	N/A	20.4	22.9	18.9	13.8		N/A
22-24 Oct 2007 DRY	pH	7.46	7.175	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	7.245	7.09	7.34	7.41	6.5 – 8	7.59	7.55	8.14	8.15	7.78	7.0 – 8.5
	Conductivity (µS/cm)	330.3	315							503.5	258	0.29	0.3	125 – 2200	4.68	4.7	38.3	38.5	38.64	N/A
	Salinity (ppt)	0.15	0.28							0.24	0.1	0.12	0.13	N/A	4.85	2.61	24.3	24.4	24.48	N/A
	Turbidity (NTU)	50.70	21.1							49.45	28.50	51.8	47.9	<50	21.6	14.4	37.0	20.1	17.06	<10 (estuarine)
	Dissolved Oxygen (% saturation)	43.53	40.35							39.15	54.03	7.9	14.8	85 – 110	65.9	61.1	85.9	84.3	76.67	80 – 110
	Temperature (°C)	20.67	23.75							20.88	19.11	16.6	16.8	N/A	23.7	22.8	25.1	25.2	23.83	N/A
30 Oct 2007 WET	pH	7.30	7.47	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	7.123	7.21	No Data – site inaccessible	No Data – site inaccessible	6.5 – 8	7.51	7.39	7.94	8.01	7.64	7.0 – 8.5
	Conductivity (µS/cm)	312.7	320							261.3	525			125 – 2200	5.96	5.93	39.5	39.5	40.34	N/A
	Salinity (ppt)	0.13	0.14							0.11	0.235			N/A	3.24	2.61	25.1	25.2	25.86	N/A
	Turbidity (NTU)	13.77	12.77							18.83	23.35			<50	17.1	15.4	14.6	13.3	20.7	<10
	Dissolved Oxygen (% saturation)	13.93	24.73							39.97	4.00			85 – 110	70.6	44.0	62.4	62.9	49.87	80 – 110
	Temperature (°C)	21.02	22.15							22	20.75			N/A	27.0	25	23.9	24	23.09	N/A
8-9 Nov 2007 WET	pH	7.52	7.656	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	7.59	7.61	7.84	7.80	6.5 – 8	7.64	7.54	8.13	8.28	8.29	7.0 – 8.5
	Conductivity (µS/cm)	323	321.7							249.7	408	0.2	0.2	125 – 2200	7.85	6.19	42.2	42.1	42.79	N/A
	Salinity (ppt)	0.14	0.133							0.10	0.17	0.10	0.10	N/A	5.90	3.36	26.4	27.0	27.49	N/A
	Turbidity (NTU)	17.30	20							16.40	21.20	26.2	29.9	<50	14.4	12.8	15.1	14.6	14.7	<10
	Dissolved Oxygen (% saturation)	6.87	15.43							47.23	26.45	42.2	44.0	85 – 110	35.4	46.3	75.3	75.1	72.3	80 – 110
	Temperature (°C)	18.27	19.15							17.83	18.18	16.9	16.9	N/A	22.2	20.8	22.4	22.4	21.55	N/A
14-16 July 2008 DRY	pH	No Data – not sampled	No Data – not sampled	4.80	4.65	6.12	5.64	6.44	5.06	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	6.5 – 8	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled	No Data – not sampled
	Conductivity (µS/cm)			148	148	425	438	250	239					125 – 2200						
	Turbidity (NTU)			3.57	2.07	24	17.7	6.5	8.40					<50						
	Dissolved Oxygen (% saturation)			49.4	34.2	62.4	79.1	72.2	64.5					85 – 110						
	Temperature (°C)			14.6	14.5	14.2	14.7	15.1	15.5					N/A						

All sites are heavily impacted by macrophyte growth such as water lilies and ribbon weed as shown in Plates 1-4**.** The macrophytes are possibly responsible for the low DO concentrations, as the plants cover a large part of the water's surface preventing the transfer of oxygen from the air to the water. On the first sampling occasion the pH at sites 1, 2, 6 and 7 also failed to meet the lower limit of 6.5, although mean levels increased on subsequent sampling occasions. Wet weather did not seem to impact water quality of these systems, apart from a further decrease in DO concentrations following rainfall.

During dry weather sampling undertaken in July 2008, pH at all sites failed to comply with the lower guideline limit. In particular, Butchers Creek (3a & b) had a very low, acidic pH of 4.8 and 4.65 upstream and downstream of the Proposal respectively. The water at this site was also unusually clear which may be an indication that acid sulphate soils are present in the area and impacting on the water quality of Butchers Creek. The clay composition of the bed and banks at the site supports this theory.

Turbidity varied between sites and sampling occasions, with Upper Warrell Creek (1) the only site exceeding the limit of 50NTU on the 22-24 October 2007. At the time of sampling the creek did not appear to be flowing, was impacted by sedimentation and abundant filamentous algae and macrophytes which may have contributed to the high turbidity. It appears that following wet weather, the site began to flow, subsequently decreasing turbidity to more suitable levels and improving the overall water quality of the creek. This was also apparent to a lesser extent at sites 2 and 6. Generally, low turbidities were recorded at sites 3a & b, 4a & b and 5a & b during July 2008 and therefore complied with the ANZECC/ARMCANZ (2000) guidelines. However, 4a & b both had higher turbidities of 24 and 17.7NTU respectively at the time of sampling, possibly due to the significant amount of algae present in comparison to other sites.

All sites sampled are non-tidal and therefore had conductivities consistent with lowland river systems. Conductivities were slightly lower following wet weather due to the dilution of salts by rainwater.

Whilst increased flow following wet weather generally appeared to improve the water quality by re-oxygenating the waterway, this is probably due to the antecedent drought conditions and subsequently reduced flow in the creeks. Despite this minor improvement in water quality following wet weather, it is anticipated that these sites could be further impacted during the construction and operation of the Proposal without appropriate mitigation measures particularly as the sites generally have degraded banks with little vegetation to act as a buffer (**Plates 1-4**).

In addition, the Proposal includes a minor re-alignment of Stony Creek (near Rosewood Drive) between sampling sites 5a and 5b. This re-alignment would avoid the need for construction of a second culvert along this section of the creek. This re-alignment is proposed to take place during dry conditions to minimise impacts. The main impact of the re-alignment involves possible entrainment of loose sediment which would increase turbidity, probably only during the first rainfall event after construction. Turbidity at sites 5a and 5b was at the low end of the guideline range during dry weather. To minimise impacts and maintain lower turbidity readings during wet weather, appropriate erosion and sediment control measures would be adopted (**Section 7.4**).

- **Plate 1 Macrophyte growth in Warrell Creek at Browns Crossing (Site 1)**

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- **Plate 2 Macrophyte growth in Rosewood Creek (Site 7)**

- **Plate 3 Macrophyte growth in Stony Creek downstrean of the Proposal (site 5b)**

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- **Plate 4 Degraded banks, Warrell Creek at Browns Crossing (Site 1)**

5.1.2. Couches Creek

Under dry and wet weather conditions, the pH of Williamson Creek (sites 8a and 8b) generally met the ANZECC/ARMCANZ (2000) guideline between 6.5 and 8 for lowland river systems. The exception was site 8b, downstream of the existing crossing on 24-25 September 2007, which had mean pH levels slightly lower than 6.5.

The existing water quality conditions in Williamson Creek did not comply with the ANZECC/ARMCANZ (2000) guidelines for dissolved oxygen during either dry or wet weather conditions. At all times dissolved oxygen percent saturation was below the lower limit of 85 per cent saturation, and was as low as 8 per cent upstream and 15 per cent downstream of the existing crossing on the second (dry) sampling occasion due to very little flow and stagnant water conditions. Following wet weather, dissolved oxygen increased slightly but remained low at ~42 per cent saturation.

The turbidity of Williamson Creek varied between sampling occasions. On the first (dry) sampling event, mean turbidity was very low (<7NTU) at both sites, however increased significantly on the subsequent sampling event, also classified as dry. Turbidity on that occasion exceeded the upper limit of 50NTU at site 1a, and just complied at site 1b (47NTU). Following wet weather, turbidity decreased slightly to comply with the guidelines, possibly due to increased flow through the creek.

The conductivity of Williamson Creek remained within the limits for lowland river ecosystems (0.125 – 2.0 mS/cm), but decreased slightly following wet weather due to increased runoff entering the creek.

Williamson Creek is already impacted by the existing highway and farming land uses, which may be responsible for the poor water quality with respect to low dissolved oxygen and high turbidity. The creek has very low flow, is stagnant at times, abundant in filamentous algae, macrophytes and organic matter which may contribute to the low dissolved oxygen levels (refer to **Plate 5**). This could be affecting the ability of the system to support aquatic species such as fish. There is also the risk that the organic matter loads from algal growth and detritus could result in anaerobic conditions. The presence of filamentous algae also potentially indicates nutrient enrichment.

There is the potential for this site to be further impacted with the construction and operation of the Proposal, particularly with a further increase in turbidity (due to risk of increased suspended solids entering creek) and decrease in dissolved oxygen, without appropriate mitigation and control measures due to the limited amount of riparian vegetation cover and the shallow degraded banks of the creek (**Plate 6**). However, mitigation measures would be implemented to minimise construction impacts as outlined in **Section 7.4** of this working paper.

- **Plate 5 Williamson Creek under low flow conditions (site 8b)**

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- **Plate 6 Williamson Creek degraded shallow banks (site 8a)**

5.1.3. Warrell Creek

The existing Pacific Highway currently crosses Warrell Creek. The Proposal would result in a new crossing of Warrell Creek alongside the existing bridge, so sampling was undertaken upstream (site 9a) and downstream (site 9b) of the existing crossing. It should also be noted that whilst Upper Warrell Creek is classified as a lowland river (Sites 1 and 2), the section of Warrell Creek discussed in this sub-section is tidally influenced and has consequently been classified as estuarine (EPA, 1999a). The water quality was similar between the upstream and downstream sites, possibly due to the influence of tides.

Mean pH levels of 6.95 upstream and 6.94 downstream of the existing crossing on the first (dry) sampling event (24-25 September 2007) fell marginally below the lower limit of 7 for estuarine systems while pH levels increased on the second (dry) sampling event and complied with the ANZECC/ARMCANZ (2000) guidelines. Following wet weather, pH levels decreased slightly but remained within the 7 – 8.5 guideline range. A potential impact of the construction of the Proposal could be a decrease in pH levels if the 'high risk' ASS, which are present in the area, were to become exposed.

Warrell Creek is tidal at the sampling locations and conductivities are indicative of a high/incoming tides on three of the sampling occasions (22-24 October, 30 October and 8-9 November 2007. The higher conductivity coincided with higher pH levels which are expected in estuarine systems. The first sampling occasion was undertaken during low tide with conductivities of 1.5-2 mS/cm at both sites, and lower pH readings indicating that freshwater from upstream of the site was influencing water quality on the ebb tide.

Mean dissolved oxygen concentrations in Warrell Creek failed to meet the lower guideline limit of 80 per cent saturation for the protection of aquatic ecosystems on all sampling occasions. Following wet weather, mean dissolved oxygen concentrations further decreased at the downstream site to ~46 per cent saturation, and ~36 per cent saturation at the upstream site. This further decrease in dissolved oxygen could be due to the increase in suspended solids from increased runoff entering the creek. Turbidity levels on 3 of the 4 sampling occasions (one dry and two wet) were elevated both upstream and downstream of the proposed crossing of Warrell Creek subsequently exceeding the ANZECC/ARMCANZ guideline of 10NTU for estuarine ecosystems. It should be noted that turbidity levels were not too dissimilar between these sampling occasions, indicating that wet weather did not contribute significantly to increased turbidity during the sampling period.

Warrell Creek, which is located to the east and west of the existing Pacific Highway and adjacent to Scotts Head Road, is already impacted by road runoff (**Plate 7**). Warrell Creek at the sampling location has highly degraded banks due to cattle access and egress with the opposite (northern) bank containing a limited amount of casuarina riparian vegetation, both of which provide little buffer to poor water quality. Due to the tidal nature of the creek, water quality of the creek may also be impacted further upstream and downstream of the crossing than non-tidal creeks.

- **Plate 7 Warrell Creek looking towards existing crossing**

5.1.4. Nambucca River

The Proposal crosses the Nambucca River at Macksville, approximately 200m downstream of its confluence with Newee Creek and approximately 1.3km downstream of the existing Pacific Highway crossing of the Nambucca River. Water quality at sites 10a and 10b comply with the recommended ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems for pH and dissolved oxygen during dry weather. During wet weather, dissolved oxygen fell below the recommended guideline lower limit of 80 per cent saturation. This is not uncommon after heavy rain as storms wash large amounts of organic matter into streams, lowering dissolved oxygen concentrations due to the decomposition of the organic matter by bacteria.

Turbidity at both sites complied with the ANZECC/ARMCANZ (2000) guideline of less than 10NTU for estuarine systems on only one sampling occasion. Turbidity following wet weather slightly exceeded the guidelines with mean turbidities of ~14-15 NTU at both sites.

Whilst the Nambucca River generally has good water quality under dry weather conditions, it worsens slightly following wet weather, possibly due to an increase in runoff and sediment entering the waterway from River Street which runs adjacent to the Nambucca River. Water quality would be directly impacted due to the proximity to the road, although some vegetation is present which may provide a buffer by reducing sediment transport to the river.

The water quality of SEPP 14 Wetland N^o 388 was sampled during dry and wet weather. During dry weather pH levels were recorded at approximately 7.78, dissolved oxygen at 77 per cent saturation and turbidity was around 17 NTU. Following wet weather, pH levels and dissolved oxygen decreased to as low as 7.6 and 50 per cent saturation and turbidity increased to 20.7NTU. This is possibly a result of increased sediment in runoff from the adjacent Gumma Road.

5.2. Section 2 – Nambucca River to Nambucca Heads

The Proposal does not cross any waterways in section 2 however it runs adjacent to two SEPP14 wetlands, N^{o}s 383 and 386. SEPP N^o 383 is located approximately 20m to the west of the Proposal boundary and on the right bank of Newee Creek, whilst SEPP No. 386 is located alongside the Nambucca River approximately 800m to the east of the Proposal (**Figure 2-2**). At the time of sampling both wetlands did not have any water present to ascertain ambient water quality conditions, even under high tide conditions as shown in and **Plate 8** and **Plate 9**.

SEPP No. 386 would currently be impacted by runoff from the existing highway which runs adjacent to and in close proximity to the wetland. SEPP No. 383 has the potential to be impacted by local roads in close proximity to the wetland and the water quality of Newee Creek which flows through the wetland. Both wetlands are surrounded by disturbed and high risk ASS which would need to be managed appropriately during construction so that there is minimal impact on the wetlands.

- **Plate 8 SEPP 14 Wetland N^o 383 with no water during high tide**

- **Plate 9 SEPP 14 Wetland N° 386 with no water during high tide**

5.3. Section 3 – Nambucca Heads to Ballards Road

The Proposal crosses a number of lowland river and estuarine waterways between Nambucca Heads and Ballards Road. At the southern extent of Section 3 the Proposal crosses Boggy Creek (11), followed by Cow Creek (12a & b), Deep Creek (13a & b), a tributary of Oyster Creek (14a & b) and McGraths Creek. All these waterways were monitored both upstream and downstream of the crossing with the exception of Boggy Creek (not monitored upstream), Cow Creek (not monitored at downstream site on first sampling survey as it was inaccessible) and McGraths Creek (not monitored due to accessibility issues). Water quality results are displayed in **Table 5-2** and discussed in the following sections.

- **Table 5-2 Mean water quality results for sites in Section 3**

Date	Water quality parameter	Site							ANZECC/ARMCANZ (2000) default trigger values for protection of aquatic ecosystems
		11b	12a	12b	13a	13b	14a	14b	
24-25 September 2007 DRY	pH	6.21	6.70	Site inaccessible	7.04	6.66	5.96	6.34	6.5 – 8 (lowland river) 7.0 – 8.5 (estuarine)
	Conductivity (mS/cm)	0.39	0.21		7.1	8.69	0.26	0.24	0.125 – 2.2*
	Turbidity (NTU)	1.33	0.3		7.5	5.57	143	15.5	<50 (lowland river)

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Date	Water quality parameter	Site							ANZECC/ARMCANZ (2000) default trigger values for protection of aquatic ecosystems
		11b	12a	12b	13a	13b	14a	14b	
									<10 (estuarine)
	Dissolved Oxygen (% saturation)	31.4	85.2		81.3	87.6	28.7	49.8	85 – 110 (lowland river) 80 – 110 (estuarine)
	Temperature (°C)	16.3	19.4		22.9	22.4	17.5	18.3	N/A
22-24 October 2007 DRY	pH	7.11	7.22	7.30	7.75	7.76	7.42	6.99	6.5 – 8 (lowland river) 7.0 – 8.5 (estuarine)
	Conductivity (mS/cm)	0.49	0.25	14.2	26.8	34.8	0.27	0.26	0.125 – 2.2*
	Salinity (ppt)	0.24	0.1	8.24	66.1	21.6	0.11	0.11	N/A
	Turbidity (NTU)	102	17.9	27.6	11.6	13.7	89.5	71.8	<50 (lowland river) <10 (estuarine)
	Dissolved Oxygen (% saturation)	3.37	51.4	60.7	83.8	80.4	6.77	32.3	85 – 110 (lowland river) 80 – 110 (estuarine)
	Temperature (°C)	17.5	22.6	25.9	25.1	24.8	19.8	21.3	N/A
30 October 2007 WET	pH	7.20	7.34	7.60	7.88	7.96	7.19	7.30	6.5 – 8 (lowland river) 7.0 – 8.5 (estuarine)
	Conductivity (mS/cm)	2.9	5.07	42.8	42.7	43.6	0.24	0.23	0.125 – 2.2*
	Salinity (ppt)	1.60	2.47	27.5	42.7	28.1	0.09	0.09	N/A
	Turbidity (NTU)	43.9	30.7	29.9	18.7	16.6	36.6	63.2	<50 (lowland river) <10 (estuarine)
	Dissolved Oxygen (% saturation)	6.90	46.6	58.3	61.9	64.1	11.5	21.7	85 – 110 (lowland river) 80 – 110 (estuarine)
	Temperature (°C)	20.3	24.9	29.1	27.5	28.1	20.8	20.6	N/A
8-9 November 2007 WET	pH	7.74	8.21	7.50	7.88	7.79	7.32	7.26	6.5 – 8 (lowland river) 7.0 – 8.5 (estuarine)
	Conductivity (mS/cm)	0.4	0.2	16.3	12.7	11.9	0.22	0.17	0.125 – 2.2*
	Salinity (ppt)	0.19	0.11	9.58	7.33	6.78	0.11	0.08	N/A
	Turbidity (NTU)	30.6	17.2	19.9	18.8	22.1	27.8	27.3	<50 (lowland river) <10 (estuarine)
	Dissolved Oxygen (% saturation)	33.5	61.7	49.5	73.8	76.3	25.0	48.9	85 – 110 (lowland river) 80 – 110 (estuarine)
	Temperature (°C)	17.0	18.5	19.4	19.9	19.6	18.1	18.1	N/A

* Range of default trigger values for conductivity is only relevant for lowland rivers

5.3.1. Boggy Creek

Boggy Creek is classified as an intermittently closed and open lakes or lagoon (ICOLL) and known to fluctuate between saline and freshwater conditions. On three sampling occasions conductivities were indicative of a fresh water system and consequently the water quality of Boggy Creek has been compared with the ANZECC/ARMCANZ (2000) guidelines for lowland river ecosystems.

On 30 October 2007 conductivities indicated a more estuarine system (mean 2.9mS/cm) and the ANZECC/ARMCANZ (2000) guidelines for protection of estuarine aquatic ecosystems have been applied.

The pH of Boggy Creek (site 11 was slightly acidic on the first sampling occasion with a mean of 6.21 and consequently failed to meet the lower guideline limit of 6.5. On all subsequent sampling occasions the pH levels complied with the guidelines.

The water quality of Boggy Creek was generally poor downstream of the Proposal with very low mean dissolved oxygen concentrations, ranging between 3 per cent and 33 per cent saturation on all sampling occasions.

Turbidity complied on only two sampling occasions. On the dry sampling survey undertaken on 22-24 October 2007, Boggy Creek had a mean turbidity of 102NTU and it was noted that at the time of sampling there was little to no flow in the creek and an extensive cover of floating debris was observed which can contribute to high turbidity. Turbidity also exceeded the guideline of 10NTU for estuarine ecosystems on 30 October 2007 with a mean of 43.9NTU.

Overall this site generally had poor water quality, predominantly due to the low flow conditions and current impacts from the existing Pacific Highway. To the east of this monitoring site are high risk ASS. If disturbed, the water quality of Boggy Creek, particularly with respect to pH, could be further exacerbated and become more acidic. The site is generally well vegetated and it is anticipated that this vegetation, together with appropriate mitigation and control measures, would ensure the water quality does not further deteriorate with the construction and operation of the Proposal.

5.3.2. Cow Creek

Similar to Boggy Creek, Cow Creek fluctuates between fresh and estuarine waters at the upstream site (site 12a) and on the third sampling occasion, the conductivity of Cow Creek was indicative of an estuarine system and consequently the results have been compared with ANZECC/ARMCANZ (2000) guidelines for protection of estuarine systems. Cow Creek downstream of the Proposal (12b) was classified as estuarine at all times with conductivity greater than 14mS/cm which was recorded during low tide. The highest conductivity following high tide during dry weather was approximately 42mS/cm.

The water quality of Cow Creek upstream and downstream of the Proposal was similar, except that the downstream site failed to comply with relevant guidelines more frequently due to the more stringent guidelines imposed on estuarine ecosystems particularly with respect to turbidity. The turbidity at the upstream site failed to comply once on 30 October 2007. On this sampling occasion the site was classified as estuarine and therefore turbidity for protection of aquatic ecosystems should remain below 10NTU, as opposed to 50NTU for lowland (freshwater) river systems, however mean turbidity at the time was ~30NTU. Site 12b downstream of the Proposal exceeded the upper limit of 10NTU on all sampling occasions with the mean turbidity ranging between 19NTU and 30NTU.

The pH levels of Cow Creek complied at both sites following dry and wet weather except for site 12a on 8-9 November 2007. On this sampling occasion mean pH exceeded the upper limit of 8 for lowland river systems.

Dissolved oxygen in Cow Creek failed to comply on 3 of 4 sampling occasions due to low concentrations at both sites. On the first (dry) sampling event DO at site 12a complied with the ANZECC/ARMCANZ (2000) guidelines with a mean of ~85 per cent saturation, however, the percent saturation decreased significantly on all subsequent sampling occasions. On the second (dry) sampling occasion approximately 75 per cent of the creek was covered in floating debris which may have resulted in the low percent saturations at both sites. These percent saturations remained low following wet weather which is expected due to increased runoff and sedimentation.

The most likely impact of the Proposal on waterways during construction is increased sedimentation due to the disturbance of soils and potential for rainfall to wash sediments into the creek. These sites are already highly turbid, low in dissolved oxygen and bordered by agricultural land uses that provide little buffer. However, appropriate measures to mitigate against these construction impacts would be implemented. Details are provided in **Section 7** of this working paper.

5.3.3. Deep Creek

Deep Creek was sampled upstream (site 13a) and downstream (site 13b) of the Proposal and is classified as estuarine with mean conductivities ranging from 7mS/cm to 43mS/cm across the 4 sampling events. The pH of Deep Creek was slightly acidic on the first sampling occasion at the downstream site (site 13b) where it failed to comply with the 7-8.5 guideline range for protection of aquatic ecosystems. On all subsequent sampling occasions the pH increased and complied which indicates that despite being located in ‘high risk’ ASS the pH does not currently appear impacted upon, however should soil become exposed during construction, pH could be reduced significantly and should therefore be monitored and managed carefully.

Dissolved oxygen percent saturation complied during dry weather however decreased following wet weather and failed to comply with the lower limit of 80 per cent saturation. This is not uncommon following wet weather as runoff containing organic matter and sediments enter waterways which subsequently decreases dissolved oxygen concentrations. Supporting this are the higher turbidity readings at both the upstream and downstream sites following wet weather which exceeded the guideline of 10NTU. This guideline was also marginally exceeded during dry weather sampling on the 22-24 October 2007.

Deep Creek is currently impacted by the existing Pacific Highway and the Proposal at this location would be a duplication of this. The site is generally well vegetated although banks become exposed during low tide. Water quality results indicate the surrounding catchment appears to minimise some of the impact associated with wet weather and increased runoff which are likely to be exacerbated with the duplication of the existing highway.

5.3.4. Oyster Creek

The Proposal crosses a tributary of Oyster Creek (site 14a and 14b) in the northern part of Section 3. This tributary would already be impacted by the existing highway which traverses the creek in close proximity to site 14a. This tributary had conductivity indicative of a freshwater system and complied with the default trigger value for protection of lowland river aquatic ecosystems (ANZECC/ARMCANZ, 2000). The pH at sites 14a and 14b were slightly acidic on the first (dry) sampling occasion failing to comply with the lower limit of 6.5. On all subsequent sampling events pH fell within the limit of 6.5-8.

Dissolved oxygen percent saturations were consistently low both upstream and downstream of the Proposal during dry and wet weather ranging between 6.7 per cent saturation and 49 per cent saturation. Turbidity at the sites was also high failing to comply at the upstream site during both dry sampling occasions and at the downstream site during one dry and one wet weather sampling survey. This site is heavily impacted by lack of flow and the presence of macrophytes as indicated in **Plate 10**, both of which have the potential to reduce dissolved oxygen concentrations and increase the turbidity of the waterways.

Whilst increased flow at this site associated with increased runoff as a result of the construction and operation of the Proposal may potentially improve water quality, the increased flow could potentially be high in suspended solids and organic matter. This could further exacerbate water quality conditions particularly as the tributary has shallow banks with little vegetation. Careful management during construction would mitigate these potential impacts at these sites.

Plate 10 Tributary of Oyster Creek, suffering from low flow, high turbidity and macrophyte growth (Site 14b)

5.4. Section 4 – Ballards Road to Waterfall Way interchange

The Proposal in Section 4 commences north of Ballards Road and diverts to the west of the existing highway to traverse through Newry State Forest. It passes in close proximity to the commencement of Dalhousie Creek, and crosses the Kalang River in the vicinity of South Arm Road. The Proposal then passes to the west of SEPP 14 wetland No. 351 before passing to the east of Ridgewood Drive and the Raleigh Industrial area to rejoin the existing highway at Raleigh. Dalhousie Creek was not sampled due to inaccessibility and lack of flow. Both the Kalang River (sites 15a and 15b) and Bellinger River (site 16) were monitored at the proposed and existing crossing respectively, in addition to two SEPP14 wetlands which are in the vicinity (150m to 350m) of the Proposal but unlikely to be impacted during construction. The ambient water quality DECCW, however at the time of sampling no water was present in SEPP N^{o} 353 as shown in **Plate 12**.

Water quality data for the Kalang River, Bellinger River and SEPP N^{o} 351 are presented in **Table 5-3** and discussed in the following sections. Both the Kalang and Bellinger Rivers are classified as estuarine and as such have been compared with the ANZECC/ARMCANZ (2000) default trigger values for protection of estuarine aquatic ecosystems. As mentioned previously, ANZECC/ARMCANZ (2000) have not recommended guidelines for water quality in wetlands, however water quality in general is discussed.

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■ **Table 5-3 Mean water quality results for sites in Section 4**

Date	Water quality parameter	Site				ANZECC/ARMCANZ (2000) default trigger values for protection of aquatic ecosystems
		15a	15b	16	SEPP 351	
24-25 September 2007 DRY	pH	7.78	7.7167	7.09	No data – not sampled	7.0 – 8.5
	Conductivity (mS/cm)	28.30	28.70	7.16		N/A
	Turbidity (NTU)	3.03	1.8	1.2		<10
	Dissolved Oxygen (% saturation)	83.1	88.23	82.37		80 – 110
	Temperature (°C)	21.4	20.6	19.8		N/A
22-24 October 2007 DRY	pH	7.86	7.87	7.69	6.78	7.0 – 8.5
	Conductivity (mS/cm)	35.7	35.93	14.8	419.33	N/A
	Salinity (ppt)	22.5	22.6	8.19	0.18	N/A
	Turbidity (NTU)	19.77	21.3	19.8	30.1	<10
	Dissolved Oxygen (% saturation)	75.5	75.4	77.6	17.8	80 – 110
	Temperature (°C)	24.3	25.26	23.07	19.9	N/A
30 October 2007 WET	pH	7.74	7.85	7.91	7.26	7.0 – 8.5
	Conductivity (mS/cm)	38.57	38.83	24.4	353.33	N/A
	Salinity (ppt)	24.51	24.72	14.84	0.156	N/A
	Turbidity (NTU)	21.57	21.73	12.53	37.7	<10
	Dissolved Oxygen (% saturation)	59.2	59.8	73.4	47.23	80 – 110
	Temperature (°C)	25.3	25.4	25.5	22.62	N/A
8-9 November 2007 WET	pH	7.9933	7.87	7.48	7.77	7.0 – 8.5
	Conductivity (mS/cm)	33.04	33.36	9.67	547	N/A
	Salinity (ppt)	20.74	20.86	5.42	0.25	N/A
	Turbidity (NTU)	14.633	13.23	27.07	15	<10
	Dissolved Oxygen (% saturation)	64.833	63.67	63.27	25.8	80 – 110
	Temperature (°C)	21.74	22.00	21.63	16.93	N/A

5.4.1. Kalang River

The Kalang River was monitored from the left bank upstream and downstream of the Proposal and the water quality of both sites was found to be similar due to tidal influences. The conductivity at both sites was relatively similar although slightly lower on the first sampling event which was undertaken during low tide. The Kalang River at this time would have been influenced by less saline water emanating from upstream. The pH of the Kalang River was similar across all sampling events with little change following wet weather and complied with the ANZECC/ARMCANZ (2000) guideline.

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Dissolved oxygen and turbidity levels indicate slightly poorer water quality failing to comply with relevant guidelines during one dry weather and both wet weather sampling events. The greatest risk to water quality of the Kalang River is the potential exposure of high risk ASS during construction of the Proposal and increased runoff and sedimentation with the operation of the Proposal.

The water quality of the Kalang River at the Proposal crossing could already be impacted during wet weather from runoff received from South Arm Road, a minor road that runs adjacent to the northern bank of the Kalang River, as well as the several unsealed roads along the southern bank.

5.4.2. Bellinger River

The Bellinger River (site 16) was also monitored for existing water quality conditions. This site is already crossed by the existing Pacific Highway and is therefore already potentially impacted. The pH of the Bellinger River complied during both dry and wet weather, remaining between the guideline of 7-8.5.

Dissolved oxygen percent saturations failed to comply on 3 of the 4 sampling occasions. Dissolved oxygen fell marginally below the lower limit of 80 per cent on the second (dry) sampling event but further decreased following wet weather as indicated by mean saturations of 73.4 per cent and 63.27 per cent following the third and fourth sampling events. Reduced dissolved oxygen concentrations are common following wet weather as runoff from surrounding areas high in suspended sediments and organic matter enters associated waterways. This is supported by the increased turbidity recorded following wet weather. Since the Proposal ceases just south of the Bellinger River, this site would not be impacted.

5.4.3. SEPP 14 No. 351

SEPP14 No. 351 generally had poor water quality with low dissolved oxygen percent saturations and high turbidity. The low dissolved oxygen concentrations during dry weather are most likely due to low flow in the wetland and increased runoff during wet weather. Either way, the low dissolved oxygen concentrations would be impacting on aquatic organisms present in the wetland as they are dependent on oxygen dissolved in the water for efficient functioning. The wetland receives runoff from an adjacent road and from a pipe that discharges into the wetland. These factors would contribute to the high turbidity and overall poor water quality of the wetland (**Plate 11**).

The Proposal passes through an area of high risk ASS adjacent to SEPP N° 351 which has the potential to cause significant impacts including low pH and dissolved oxygen if exposed and not appropriately managed. Whilst no water quality data were available for SEPP No 353 at this site, the site is already potentially impacted by pollution via runoff from a minor road in close proximity to the western edge (**Plate 12)**.

- **Plate 11 SEPP 14 Wetland N^{o} 351, poor water quality following wet weather**

- **Plate 12 SEPP 14 Wetland N^{o} 353 with no water**

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5.5. Summary of existing conditions in waterways

Section 1 of the Proposal crosses several Creeks. Butchers, Rosewood, Stony and Williamson Creeks are highly degraded creeks with excessive vegetation growth and poor water quality during both dry and wet weather. The estuarine reaches of Warrell Creek and the Nambucca River are in better condition, however water quality deteriorates in wet weather.

In Section 2, there are no waterway crossings, however the Proposal runs adjacent to two SEPP14 wetlands, but ambient water quality conditions were not determined as there was no water present for sampling.

In Section 3, the Proposal crosses Boggy, Cow and Deep Creeks and a tributary of Oyster Creek. All these waterways have poor water quality.

Section 4 is dominated by the Kalang River which has moderate water quality. The SEPP 14 wetlands to the east of the Proposal had poor water quality conditions in wet weather.

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6. Assessment of groundwater impacts

Risks to groundwater can be in the form of risks to quantity or quality, or both. The main risks to groundwater quality from this Proposal include risks of ASS leaching and accidental spills. Risks to groundwater quantity include compression of soft soils under embankments and the construction of in-stream structures and cuttings, all of which could disrupt current groundwater regimes. The risks are discussed in further detail below and in **Section 7** of this working paper and Chapter 18 - *Soil characteristics and erosion control.*

6.1. ASS risk to groundwater quality

ASS, whilst benign in waterlogged environments, can become exposed to the atmosphere during the construction process or through activities which lower the water table such as excavation, soil disturbance and dewatering operations. These activities cause sulphide minerals in the soil to oxidise and leach acidity, arsenic and metals into groundwater resulting in fish kills and loss of biodiversity in wetlands and waterways. The waterways with the potential to be affected due to a high probability of ASS include:

- Warrell Creek in the vicinity of sites 9a & b;
- Nambucca River surrounding sites 10a & b;
- Deep Creek surrounding sites 13a & b;
- Kalang River in the vicinity of sites 15a & b
- Bellinger River (surrounding site 16); and
- All sampled SEPP wetlands (No.383, 386, 388, 353 and 351).

It is also possible that ASS exist within other low lying areas, creeks or wetlands.

6.2. Risk of accidental spillage

Groundwater bores may be exposed to risk of impact from accidental spillages of fuels, oils and chemical agents. Such pollutants may infiltrate to the groundwater and adversely affect the water quality of bores. The vulnerability of these groundwater bores to pollution from accidental spillage is dependent upon the extent and permeability of the overlying strata and the proximity of potential spillage to a groundwater source. It is commonly found that groundwater bores with low yields are less likely to be impacted and given the limited number of bores where groundwater was encountered within the study area the likelihood of significant impacts to groundwater quality is low.

6.3. Risk to groundwater quantity

Groundwater barriers can form when in-stream structures are built, such as bridges, or when structures such as embankments are built on soft soil, which compresses and forms a less permeable layer of soil. The bridges that would be built would only impact groundwater movement in very localised areas and are therefore not considered to be a risk to groundwater flow. The issue of soft soils is discussed in Chapter 18 **-** *Soil characteristics and erosion control*. Since mitigation measures would be put in place to minimise the degree to which soft soils would compress, the construction of embankments should pose little risk to the formation of groundwater barriers.

Local groundwater drawdown can occur in areas where cuttings are constructed beneath the groundwater table. The drop in the groundwater table can impact flows and availability of water (flow rate and flow duration/frequencies) in springs, surface water systems and groundwater wells in the vicinity. Cuttings can also impact on groundwater dependent ecosystems (GDE's) and endangered ecological communities (EEC's). The Proposal cuts through topographically high zones along the route, which could alter the groundwater regimes feeding GDE's downgradient of the Proposal. Also, there are several EEC's identified within close proximity to the Proposal which could be affected should the groundwater regime change (Working paper 1 – *Flora and fauna*).

Aside from springs, GDE's and EEC's, there are a number of creeks and waterbodies that cross or run alongside the Proposal which may be impacted by proposed road cuttings (**Figure 2–1** to **Figure 2–4**). If the cuttings intersected and diverted groundwater upgradient of these creeks and waterbodies, baseflow could be limited. Furthermore, the groundwater supply to some of the wells that are used for domestic or stock purposes may diminish if they lie within the impact zone or drawdown "cone". The cuttings with the greatest potential risk of impacting surrounding ecosystems and groundwater sensitive areas are numbers 2.5, 2.14, 3.5, 4.2 and 4.10.

More discussion around GDC's and the risk of road cuttings and construction in general is provided in Working paper 1 – *Flora and fauna*. Generally, significant impacts would be mitigated against by following the proposed minimum design standards for drainage structures and by ensuring that site practices follow an appropriate environmental management plan.

Monitoring is another important mitigation measure for the protection of groundwater quality and quantity. Since relatively little is known about groundwater quantity, quality, use and users in the study area, it is important that monitoring of groundwater be undertaken prior to construction at key locations such as cutting sites and in bores close to waterways and wetlands. Monitoring should then continue throughout and after construction of the Proposal. More detail about groundwater monitoring is provided in **Section 7.4**.

7. Water quality impacts and environmental safeguards

The proposed upgrade of the Pacific Highway between Warrrell Creek and Urunga has the potential to impact the SEPP14 wetlands, surface water and groundwater quality in the following ways:

- Through erosion and sedimentation during the construction phase;
- Installation of in-stream structures in major water crossings including the Nambucca River, Kalang River and Warrell Creek;
- The exposure of high risk ASS; and
- By the generation of additional pollutants directly attributable to the highway from sources such as accidental spills.

Mitigation of these risks is especially important for the five SEPP 14 wetlands as well as small coastal streams and lagoons where flushing is minimal, such as Boggy, Cow and Oyster Creeks in Section 3. The impact of excess sediment, nutrients, acid, heavy metals and other chemicals on these ecosystems can be severe.

The following sections outline the potential water quality impacts during both construction and operation (**Sections 7.1– 7.2**), the water quality objectives (**Section 7.3**) and associated mitigation measures (**Section 7.4**).

7.1. Construction impacts

Construction of the Proposal, as with all road construction projects, presents a potential moderate risk to water quality. There are two main risks associated with construction of roads. The first risk is whilst the soils are exposed during earthworks. Unless soils are appropriately managed through erosion and sedimentation control measures there is the risk of suspended sediments and pollutants being washed into surrounding watercourses. The second risk is the disturbance of acid sulphate soils. Disturbance of ASS can result in increased dissolved metal contaminants, low pH levels and anoxic and hypoxic events in surrounding waterways. The waterways with the highest probability of ASS are Warrell Creek, Nambucca River, Deep Creek, Kalang River, Bellinger River, all five SEPP wetlands (No.383, 386, 388, 353 and 351 and other low-lying areas, creeks and wetlands. Chapter 18 - *Soil characteristics and erosion control* further discusses the location, effect and management of ASS. Other risks associated with the construction of this Proposal include:

Surface and groundwater quality impacts associated with construction of in-stream structures through removal of instream and streambank vegetation, disturbance of instream sediments, barriers to groundwater movement, possible localised turbidity, ground disturbance near drainage lines and hydrocarbon/chemical leaks and small scale spills from construction vehicles;

Groundwater and surface water contamination through export of sediment and associated pollutants such as heavy metals and nutrients via wind and water erosion or through heavy metals, toxic organics and surfactants used by machinery and other vehicles in the road building process;

Hydrologic and hydraulic disturbance through the changing of surface and subsurface flows and altering the volume and timing of water flows. There may also be an increase in surface runoff volumes if water is being used on site for dust suppression;

Impacts on groundwater recharge/discharge. The disturbance and ground clearing associated with construction of access roads, tracks and general vegetation clearing can alter groundwater recharge and introduce pollutants. The compaction of soils and cutting and filling associated with construction reduce groundwater recharge. This reduction in the depth of groundwater allows surface contaminants a shorter pathway to the water table making the groundwater table more vulnerable to pollution. Accidental spills, particularly in locations of highly permeable strata have the potential to contaminate groundwater;

Cuttings may intercept perched water tables or layers of relatively low permeability soil/rock. This could manifest as seepages possibly local instability of the batter face. There are a series of cuttings with the greatest potential risk of impacting surrounding ecosystems and groundwater sensitive areas including four in section 1 two deep cuttings in section 2, one in section 3 and two in section 4.

Dewatering impacts such as reduction in groundwater levels and reduced flow, particularly at locations where cuttings are proposed;

Intersection and interference with an aquifer which could obstruct groundwater flow and limit groundwater availability;

Exposure and discharge of groundwater as a result of excavation below the level of the water table, which creates the potential for off-site discharges of sediment-laden water; and

Accidental spills or leaks of oil, grease or fuel from work machinery and vehicles or from construction sites or compounds, and accidental spills of other chemicals that may be used during the course of construction.

7.2. Operational impacts

Road runoff

Once the upgrade of the Pacific Highway between Warrell Creek and Urunga is operational, the main risk to water quality would be an increase in surface runoff due to an increase in impervious surfaces and concentration of runoff by drains and kerbs.

The most important pollutants of concern relating to road runoff are:

- Suspended sediment from the paved surface;
- Heavy metals attached to particles washed off the paved surface;
- Oil and grease and other hydrocarbon products; and
- Anthropogenic litter.

In addition, nutrients such as nitrogen and phosphorus are also found in road runoff due to atmospheric deposition of fine soil particle.

The emphasis in stormwater quality management for road runoff is that of managing the export of suspended solids and associated contaminants – namely heavy metals, nutrients and organic compounds. (*Road Runoff and Drainage: Environmental Impacts and Management Options* Austroads 2001). Pollutants such as nutrients, heavy metals and hydrocarbons are usually attached to fine sediments (*Procedure for selecting treatment strategies to control road runoff*, Version 1.1, RTA, June 2003), therefore trapping suspended solids is the primary focus of the water quality management strategy for the operational stages of the Proposal.

The main impact on water quality of an increase in impervious surfaces includes the build up of contaminants (particularly heavy metals) on road surfaces, median areas and roadside corridors which, during wet weather, can be transported to surrounding watercourses or infiltrate into the groundwater system. Other potential impacts include:

- Increased flood risk due to the introduction of additional permanent physical obstructions in waterways (bridge piers) and increased volume highway runoff associated with introduction of additional impervious surfaces;
- Alteration of the water table and changes to local hydrology; and
- Impacts associated with maintenance practices such as herbicide use, mowing, road surface cleaning and reparation.

The water quality of surrounding creeks and streams during the operation of the highway has the potential to be affected in the following ways:

- Increased sediment loads can reduce light penetration through the water column, impacting aquatic flora and fauna;
- Decay of organic matter and some hydrocarbons can decrease dissolved oxygen levels;
- Increased nutrients (nitrogen and phosphorus) can stimulate the growth of algae and aquatic plants;
- Acidic pH, low dissolved oxygen, excess sulphate and iron stains due to exposed ASS.
- Heavy metals (including aluminium and iron) from vehicle wear, accident spills or ASS are toxic to aquatic biota and fish;
- Silting of waterways and associated smothering of aquatic flora and fauna; and
- Litter polluting waterways. Oil and grease are unsightly and can cause water quality problems.

Accidental spills

The risk of accidental spillage of hazardous materials either as a result of a collision or accidental spillage would always be present. Without satisfactory means of containment, the spillage of contaminants could pass rapidly into the drainage system and impact downstream ecosystems. Accidental spills of chemicals or petrol in accidents can cause severe damage to the ecology of waterways, and terrestrial ecosystem.

These water quality impacts would potentially impact aquatic biota by stimulating the growth of algae and aquatic plants through increased nutrients. Chemical spills, acid sulphate soils and heavy metals may be toxic to aquatic biota and fish. The majority of the waterways that are potentially impacted by the operation of the Proposal are already impacted by stormwater runoff from existing roadways and existing road maintenance activities. Impact mitigation measures are available and would be implemented as part of the Proposal design and operation so that adverse impacts are minimised as far as practical.

The potential for a spill of hazardous substances from a vehicle transporting dangerous goods along the upgraded section of the Pacific Highway is considered to be low in view of the following factors:

- Dangerous goods vehicle movements along the upgraded section of highway are expected to account for only 0.2 per cent of total daily traffic movements, hence the likelihood of an accident involving a truck containing dangerous goods is very low;
- The high road design standards proposed, which would reduce the potential for road accidents relative to the existing situation; and
- The stringent legislative controls on the transport of dangerous goods.

7.3. Water quality objectives

The water quality objective for the Proposal during the construction and operational phases is to protect sensitive waterways through the installation of devices which treat stormwater as close to its source as possible so that the Proposal changes the existing water regime to the smallest amount practicable. To achieve this objective measures have been incorporated into the drainage design to ensure pavement runoff passes though a water quality control measure before entering the receiving water, where possible.

Another water quality objective is to ensure that general pavement drainage incorporates methods for the retention of a minimum 20,000 litres of oil or chemical polluted run-off for the more sensitive water crossings.

7.4. Construction and operational phase environmental safeguards

To minimise the potential for adverse surface and ground water quality impacts, road construction works are subject to various controls, which are documented prior to commencement of the works in a Soil and Water Management Plan (SWMP) and an Acid Sulphate Soil Management Plan (ASSMP). A SWMP documents the controls that limit movement of sediment (ie erosion controls), and controls that remove sediment from runoff prior to discharge to downstream creeks and waterways (ie sediment controls). An ASSMP outlines strategies to manage the potential impacts where road construction works are likely to disturb ASS In addition to the SWMP and ASSMP, a groundwater monitoring plan is to be documented prior to, during and post-construction. More information about the inclusions of these plans is provided in the following sub-sections.

7.4.1. Proposed construction phase erosion and sediment controls

During the construction phase of the Proposal, there is potential for stormwater run-off from disturbed lands to be a major source of pollutants in downstream waterways. Overland flow can carry sediment and associated pollutants from disturbed and unprotected land surface areas into downstream waterways. In order to prevent this occurring on the Proposal, it is proposed to construct sediment basins as one of the control measures for the construction phase of the Proposal. Sediment basins are designed to intercept run-off containing sediments and retain the sediment and attached pollutants thereby protecting the downstream waterways.

Design Methodology

The recommended design criteria in "*Soils & Construction, Volume 1, 2004, and Volumes 2C and 2D, 2008 manuals*" (known as the Blue Book) have been used for sizing the proposed sediment basins. All creeks and waterways along the upgrade route have been considered in this assessment. Runoff from the construction areas would receive treatment at proposed sediment basins for all creeks and waterways except at less critical locations where the annual average soil losses were

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estimated to be less than 150m3/annum, as recommended in the "Blue Book". Class 1, 2 or 3 waterways (major, moderate to minimal fish habitat) were provided with sediment basins regardless of the 150m3/annum. Further design input parameters and assumption made are provided in **Table 7-1** below.

- **Table 7-1 Sediment basin design parameters for the Warrell Creek to Urunga upgrade**

Site constraints / characteristics	Value/rating used in the revised universal soil loss equation (RUSLE).
Rainfall Erosivity (ability of rainfall to cause erosion – Site specific)	R = 4500
2 year ARI, 6 hour rainfall intensity (I_2)	14.5 mm/hr
Rainfall Distribution Zone (to determine if special controls apply for various months of the year depending on soil loss classes)	Zone 1
Soil Erodibility (Subsoils)	High (k=0.04 assumed)
Typical slope gradient in works area	Variable along route, overall shallow to localised mild (0.5% to 5%) Site specific slopes have been adopted for each basin.
Calculated annual soil loss rate	Variable, ranges from 67 to 2070 tonnes/ha per year,
Soil loss class (Erosion Hazard)	Variable, ranges from Class 1 (Low) to Class 5 (high)
Soil texture Group/Type	Type D soils have been adopted for all sediment basins. ie. (fine and dispersible) >30% of particles are finer than 0.02mm.
5 day, 80th percentile rainfall depth	42.7 mm (Coffs Harbour)
Hydrologic sol group and Volumetric run-off coefficient (Cv)	Group D has been adopted based on predicted type of activity Cv= 0.69 (high run-off potential)
Catchment Area	Area of the total catchment draining to the sediment basin. Varies for each basin.
Disturbed Area	Actual disturbed area within the basin catchment area varies for each basin and for most cases is equal to total catchment area.
Percentage of the disturbed area on steeper slopes (embankments etc)	Varies for each catchment. Ranges from 10% to 65%.
Soil Cover Factor (C)	1
Soil Conservation Practices (P)	0.9
Assumed sediment yield time period	6 Months
Assumed slope length (distance between sediment fences on sloping areas)	L = 80m for most areas on site L =10m for steeper embankment (cut/fill) areas

Proposed sediment basins

Sediment basins require space allocation along the Proposal and they need to be contained within the road corridor. Whilst additional erosion and sediment controls within the disturbed construction areas can be accommodated without creating any space constraints, some of the larger proposed sediment basins can be difficult to fit within the allocated road corridor. It is therefore essential that

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the proposed sediment basins be designed and sized as accurately as possible at this stage and not deferred to the detailed design stages. The proposed sediment basins for the Proposal are tabulated on **Table 7-2** and shown on **Figures 6-1 to 6-21** of the Environmental Assessment Report.

Planning approval is being sought for works within the Proposal boundary. As such the sediment basins listed in **Table 7-2** have been designed to ensure that they fit within the boundary. If during detailed design further sediment basins are required which fall outside the boundary, separate approval may need to be sought.

A sediment basin is considered to be the "end of line" control. Details of the additional erosion and sediment controls on site would be provided at the detailed design stage as part of a comprehensive Soil and Water Management Plan. The key features of this plan must include:

- Diversion of external "clean" runoff around the construction area to reduce mixing of "clean" and "dirty" runoff and to consequently reduce the size of the required sediment basin;
- Diversion of all "dirty" runoff to the proposed sediment basin;
- Installation of sediment fences and straw bales to trap sediments;
- Installation of barrier fences to delineate the extent of site that can be disturbed;
- Installation of sediment traps and check dams, where required, especially in smaller catchments where a sediment basin has not been proposed;
- Stockpiling and reuse of all topsoil;
- Rehabilitation of disturbed are as quickly as possible; and
- Water quality monitoring at the outlet of the sediment basins.

Table 7-2 Proposed construction phase sediment basin size and location details

Basin Number	Approximate Chainage	Total Basin Volume Required (m3)	Total Length (m)	Total Width (m)	Basin Number	Approximate Chainage	Total Basin Volume Required (m3)	Total Length (m)	Total Width (m)
1 600		897	55	25	55	22620	561	46	23
2 830		155	34	18	56	22980	464	44	22
3 105	0	406	43	21	57	23090	1871	73	30
4 109	0	571	50	22	58	24130	289 49		18
5 150	0	586	50	22	59	24160	263 46		18
6 159	0	698	49	24	60	24360	899 55		25
7 267	0	969	58	25	61	24950	476 73		18
8 277	0	371	40	21	62	25000	220 41		18
9 305	0	361	40	21	63	25270	1245	62	27
10 321	0	686	48	24	64	26200	1715	68	30
11 374	0	1372	64	28	65	26260	786	54	24
12 394	0	1032	58	26	66	26570	1253	62	27
13 463	0	371	40	21	67	27240	357	40	21
14 463	0	371	40	21	68	27290	1258	63	27
15 525	0	917	56	25	69	27880	645	50	23
16 534	0	904	55	25	70	28570	523	47	22
17 630	0	1544	66	29	71	28590	872	55	25
18 656	0	1519	65	29	72	29700	763	52	24
19 732	0	235	43	18	73	30110	583	47	23
20 734	0	436	57	19	74	30330	1396	64	28
21 806	0	1627	68	29	75	30650	463	46	22
22 956	0	1412	65	28	76	30670	436	46	21
23 108	30	1112	58	27	77	30870	370	40	21
24 111	80	456	43	22	78	31530	1076	60	26

Basin Number	Approximate Chainage	Total Basin Volume Required (m3)	Total Length (m)	Total Width (m)	Basin Number	Approximate Chainage	Total Basin Volume Required (m3)	Total Length (m)	Total Width (m)
25 116	70	809	51	25	79	31580	632	49	23
26 116	90	402	43	21	80	31780	485	44	22
27 121	50	727	51	24	81	32150	932	57	25
28 125	20	775	53	24	82	32740	893	70	22
29 133	10	487	44	22	83	32740	893	70	22
30 136	50	403	43	21	84	33050	893	55	25
31 139	60	954	58	25	85	33430	435	46	21
32 140	70	571	46	23	86	33450	407	43	21
33 145	20	1293	64	27	87	33920	1060	58	26
34 150	50	1496	64	29	88	33940	677	52	23
35 157	60	781	53	24	89	34410	853	54	25
36 162	00	568	46	23	90	34640	544	48	22
37 162	30	422	42	22	91	35060	775	53	24
38 166	20	954	54	26	92	35400	450	42	22
39 166	60	1083	60	26	93	35730	971	55	26
40 171	80	519	46	22	94	36010	616	49	23
41 174	60	399	43	21	95	36490	1405	64	28
42 179	80	1075	60	26	96	36910	834	52	25
43 184	10	444	42	22	97	37160	877	55	25
44 189	10	554	45	23	98	37550	631	49	23
45 193	60	1452	66	28	99	37950	1053	58	26
46 194	00	850	53	25	100	38330	540	46	23
47 198	60	260	40	19	101	38600	650	50	23
48 203	10	613	49	23	102	39380	827	52	25

Basin Number	Approximate Chainage	Total Basin Volume Required (m3)	Total Length (m)	Total Width (m)	Basin Number	Approximate Chainage	Total Basin Volume Required (m3)	Total Length (m)	Total Width (m)
49 207	50	1761	70	30	103	39660	595	48	23
50 209	30	680	49	24	104	39680	480	44	22
51 211	20	533	48	22	105	40040	475	44	22
52 211	70	758	52	24	106	40490	490	45	22
53 216	60	1582	67	29	107	40540	1023	58	26
54 218	60	1076	60	26	108	41090	511	46	22

Note: Lengths and widths include an allowance of 10m for a maintenance access track, embankments and freeboard.

7.4.2. Proposed operational phase stormwater quality controls

The proposed permanent stormwater quality controls have been determined by preparing a water quality management strategy that aims to achieve the water quality objectives described in Section 7.4.

Water quality strategy (operational phase)

The proposed water quality measures incorporated into the drainage design of the Proposal in order to achieve the water quality objective include:

- Permanent Water Quality Basins;
- Vegetated Swales; and
- Permanent Spill Containment Basins.

These water quality control devices would mainly target suspended solids and their associated pollutants and would also provide a function for the required containment of accidental spills.

The water quality strategy for permanent spill containment basins is based on an assessment of the sensitivity of the water crossings and waterways along the Proposal (see **Figures 3-1- to 3-4**). The methodology adopted for providing spill containment was to ensure sensitive waterways are protected against potential spills occurring on the new pavement. The permanent water quality basins and permanent spill basins are the measures used to capture accidental potential spills. These measures have been proposed at the downstream end of drainage lines that discharge directly into the sensitive waterways identified.

Sensitive waterways requiring protection against accidental spills were identified according to the following criteria:

- Creeks and waterways with a Fisheries classification of 1, 2 and 3;
- Transverse culverts that provide for fish passage; and
- Transverse culverts that have SEPP 14 wetlands or an existing farm dam immediately downstream.

Proposed permanent water quality basins

Permanent water quality basins would provide the function of trapping the finer sediments and associated contaminants before stormwater is discharged into the receiving waterways. The basins would treat road pavement and batter runoff collected by the pavement drainage network. They operate by reducing flow velocities and promoting the settlement of suspended sediment contained in stormwater runoff. Measures are also incorporated into the design of the basins to enable the containment of accidental spills that have a density lower than water, such as petroleum hydrocarbons.

All permanent water quality basins would be converted from proposed sediment basins used during the construction phase. The location of basins takes into consideration site constraints such as the Proposal boundary, existing and proposed utilities, environmental and heritage exclusion zones, and significant trees. Basins that are to be used in both phases are designed according to the maximum size requirement, usually the construction phase requirement, and the one design would be maintained for both phases. At all locations where a basin was not proposed to treat runoff from the Proposal prior to discharge into the receiving waterways, other type of water quality controls such as vegetated swales would be proposed. There are circumstances where basins that have been used during the construction phase can be decommissioned and vegetated swales can replace them as water quality treatment measures. This is possible under certain conditions described below, in the following Section "Permanent Vegetated Swales"

Proposed permanent vegetated swales

Vegetated swales/table drains are used to treat and convey stormwater to the receiving waterways. Treatment is provided through the removal of suspended solids and their associated pollutants. Pollutant removal is facilitated by the interaction between the flow and the vegetation along the length of the swale. The vegetation acts to spread and slow velocities, which in turn aids the deposition of sediment.

Vegetated swales as a treatment measure are proposed at locations where pavement runoff is not being treated by a water quality basin (transformed from a previous construction phase sediment basin), or where a sediment basin has been decommissioned provided the grade of the table drain and the design flow velocity are within acceptable limits. Vegetation as a table drain lining can be applied where the grade of the table drain is generally between 0.5 per cent and 2 per cent, but grades up to 5 per cent can be used depending on the vegetation density. The locations where vegetated swales can be used would be identified at the design stage of the Proposal.

Proposed permanent spill containment basins

The spill containment basins are designed to capture liquid spills of a maximum 20,000L via a reverse graded 'Ellis' pipe arrangement, or a baffle type underflow arrangement. Following containment, the pollutant would be pumped out and the spill disposed of in an appropriate manner. The spill basins are designed to contain spills in dry weather or light rainfall events. Due to the capacity of the 'Ellis' pipe, the spill basin becomes less effective during times of heavy rainfall as spills lighter than water would flow over the spillway.

Where possible, the pavement drainage discharging to the sensitive waterways is to be designed such that it utilises permanent water quality basins already proposed. Additional permanent spill basins can be provided at any discharge points immediately upstream of the sensitive waterways not already protected by a permanent water quality basin where spill containment would already be incorporated into the basin.

Based on an assessment of the sensitivity of the water crossings and waterways along the Proposal (see **Figures 3-1- to 3-4**) permanent basins providing spill protection are proposed for those locations presented in **Table 7-3**.

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Table 7-3 Sensitive waterways with provision for spill containment

Chainage (m)*	Name of crossing	North/South	Sensitivity classification	freshwater or estuarine
Section 1				
750	Warrell Creek (upstream)	S	Category 1	Freshwater
	Warrell Creek (upstream)	N	Category 1	Freshwater
1560	Butchers Creek	S	Category 2	Freshwater
	Butchers Creek	N	Category 2	Freshwater
2710	Rosewood Creek	S	Category 2	Freshwater
	Rosewood Creek	N	Category 2	Freshwater
3820	Stony Creek	S	Category 2	Freshwater
	Stony Creek	N	Category 2	Freshwater
5290	Williamson Creek	S	Category 2	Freshwater
	Williamson Creek	N	Category 2	Freshwater
6430	Warrell Creek (downstream)	S	Category 1	Estuarine
	Warrell Creek (downstream)	N	Category 1	Estuarine
10,480	Nambucca River	S	Category 1	Estuarine
	Nambucca River	N	Category 1	Estuarine
Section 3				
20,850	Boggy Creek	S	Category 2	Freshwater
	Boggy Creek	N	Category 2	Freshwater
21,760	Cow Creek	S	Category 2	Freshwater
	Cow Creek	N	Category 2	Freshwater
23,040	Deep Creek	S	Category 1	Estuarine
	Deep Creek	N	Category 1	Estuarine
26,530	Oyster Creek (Tributary of)	S	Category 2	Freshwater
	Oyster Creek (Tributary of)	N	Category 2	Freshwater
Section 4				
30,070	McGrath creek	S	Category 3	Freshwater
	McGrath creek	N	Category 3	Freshwater
35,790	Kalang River	S	Category 1	Estuarine
	Kalang River	N	Category 1	Estuarine

Note: Section 2 of the Proposal does not cross any waterways.

7.4.3. Soil and water management plan

The SWMP would be prepared during the detailed design stages in accordance with the principles and practices outlined in:

- Landcom (2006), *Managing Urban Stormwater: Soils and Construction*, Volume 2 Book 4, Main Road Construction; and
- RTA (2000) *RTA Road Design Guide*, Section 8 "Erosion and Sedimentation".

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The soil and water management sub-plan would include hydrology, water quality and groundwater management measures identified in this environmental assessment. It would include:

- A list of the construction activities that could cause sedimentation or pollution of watercourses.
- Describe management method to minimise the discharge of sediment or water pollutants from the site including a strategy to minimise the area of bare surfaces during construction.
- Preparation of detailed construction work method statement for in-stream works in consultation with the Department of Environment and Climate Change and Department of Primary Industries.
- Document hydrology, groundwater and surface water quality management measures.
- Specify construction procedures that minimise water flow velocities and avoid excess velocities such as implementation/construction of level spreaders, check dams, bank and channel linings.
- Specify erosion control measures and structures to minimise soil erosion and prevent discharges of sediment and other water pollutants from work sites in accordance with the principles and practices documented in:
- Locate construction compounds and storage facilities away from wetlands and water courses.
- Specify control measures for storage, handling and disposal of fuels and other chemicals, including procedures for containment and clean-up of accidental spills.
- Include details of progressive site stabilisation and revegetation procedures.
- Management procedures for installation of instream structures.
- Specific erosion and sediment controls to be included during construction and operation to provide additional protection to the fisheries and oyster leases within the Nambucca River and Kalang River.

The erosion and sediment control measures that would be incorporated into the SWMP are outlined below.

Erosion control measures and structures

Sediment would be generated during the construction of the proposed highway as the existing ground surfaces are disturbed. It is therefore important that erosion control measures and structures be incorporated to prevent sediment from entering the surrounding creeks and streams and the groundwater system. The following preventative measures and practices would ensure effective erosion control:

- Minimise the area of disturbance;
- Install erosion and sediment control structures before commencement of site disturbance and construction works;
- Location of soil stockpiles on flat areas of the site, away from erosion hazard areas;
- Design batters on stable slopes and limit their height and slope of soil stockpiles;
- Seeding of disturbed areas for temporary soil stabilisation;
- Shaping of land to minimise slope lengths and gradients and improve drainage;
- Employment of appropriate measures to prevent wind blown dust entering waterways;

- Specify construction procedures that minimise water flow velocities and avoid excess velocities such as implementation/construction of level spreaders, check dams, bank and channel linings;
- Construction of sediment fences on the upstream slopes of the buffer area;
- Designated areas for plant and construction material storage within the site compound;
- Ensuring all chemicals and fuels associated with construction are store in roofed and bunded areas;
- Creation of diversion banks at the upstream boundary of construction activities to ensure diversion of upstream run-off around exposed areas;
- Creation of catch drains at the downstream boundary of construction activities where practicable to ensure containment of sediment-laden run-off and diversion toward treatment areas to prevent flow of runoff to downstream undisturbed areas; and
- Provision for catching runoff and pollutants from bridges and the road itself in environmentally sensitive areas (see next sub-section 'Sediment Control Measures').

7.4.4. Acid sulphate soil management plan

The Acid Sulphate Soil Management Advisory Committee (ASSMAC) has provided advice in the planning, assessment and management of activities in areas containing ASS and detailed this information in the Acid Sulphate Soil Manual (ASSMAC 1998). The ASSMP prepared for this Proposal would outline:

- How management of excavated material, its temporary storage, treatment and use would be implemented;
- What leachate and sediment control procedures and protocols should be implemented;
- Contingency measures in the event of unexpected acid related incidents; and

Mitigation measures would include:

- Avoidance or minimising the disturbance of ASS by not digging up ASS or lowering the water table;
- Monitoring of water quality downstream of acid sulphate soil risk areas to allow early identification of potential risks from acid sulphate leachate to ensure that mitigation measures are implemented in a timely manner;
- If ASS are disturbed, acid generation potential should be minimised, associated with increased runoff as a result of the construction and operation of the Proposal any acid produced should be neutralised, acid waste leaving the site should be prevented and acid resistant construction materials should be used preferentially; and
- Cover ASS with clean fill so as not to cause further disturbance.

The RTA's policy is to develop and maintain both structural and non-structural measures to minimise water pollution during operation of roads. The RTA recommends structural measures such as detention basins, gross pollutant traps, grass channels, created wetlands and accidental spill interception and containment structures. Non-structural measures include community involvement in reducing roadside littler and developing an ownership for good vehicle maintenance practices (RTA 2000).

7.4.5. Groundwater monitoring

The main safeguards to protect groundwater quantity and quality involve mitigation of impacts from accidents and spills, mitigation of impacts from cuttings, and groundwater monitoring. The Working paper 1 – *Flora and fauna* provides some detail about mitigation measures for the protection of groundwater dependent ecosystems. In terms of protecting water quality from accidents and spills during construction, storage of potentially harmful materials would be undertaken away from watercourses and within impermeable, bunded facilities. Spill contingency equipment would also be stored in close proximity. During operation the concept design includes scope for inclusion of spill contingency measures, which capture accidental spillages to ensure that they are not released directly to the environment. Safeguards for cuttings and monitoring are described separately below.

Cuttings

If seepages in the batter face of road cuttings develop due to interception of a permeable layer of soil/rock, sub-horizon drains should be installed to relieve the water pressure in the batter. If seepages develop from interception of a perched water table, engineering mitigation measures need to be installed to transfer the seepage water into the groundwater ecosystem immediately downslope of the cut. These measures should involve collecting the seepage water from the cut face just above the level of the road and piping it under the cut/fill platform to the downslope side of the highway. The water could either be returned to the ground through absorption trenches, or held in water quality ponds to be tested and possibly treated before being discharged back into the surface water system.

Monitoring

Four NSW policies exist which aim to protect groundwater from unsustainable degradation. These policies are: the *NSW Groundwater Policy Frameworks* Document, the *NSW Groundwater Quantity Management Policy*, the *NSW Groundwater Quality Protection Policy* and the *NSW Groundwater Dependent Ecosystems Policy*. The principles outlined in these policies require the protection of groundwater quantity and quality for the towns and ecosystems that depend on it. However, to protect groundwater, adequate knowledge about the location, quantity, quality and flow patterns is needed. Currently information is largely lacking for the alluvial aquifers underlying the three catchments, of Bellinger, Nambucca and Deep Creek. Groundwater monitoring before, during and after construction would help fill these information gaps.

Materials stored and handled during construction would be managed in accordance with procedures outlined in the Construction Environmental Management Plan to ensure that the risks of pollution are minimised. In addition no significant pollution sources have been identified along the route through investigations conducted to date, therefore at this stage no groundwater monitoring is proposed prior to

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construction. In the event that potential contamination hotspots or potential pollution sources are identified during the detailed design process, the first mitigation measure for groundwater would comprise of monitoring prior to construction to identify the likely impacts associated with embankment and cutting sites, particularly those cuttings which are most likely to impact environmental features such as springs, creeks and GDE's/EEC's (refer to Sections 5 and 6). Several monitoring sites should also be established adjacent to waterways and wetlands so that baseline data can be collected. Thirdly, monitoring sites should be established at locations with a high probability of ASS occurring (refer to Section 6). Monitoring of selected cuttings and other sites should commence well in advance of construction to provide a data set that represents natural variability over space and time. Groundwater monitoring should comprise the following:

- Installation and monitoring of groundwater wells (potentially nested, or multi-level) prior to road construction;
- Hydraulic tests (falling head) to estimate hydraulic conductivities of the shallow and possible deep aquifer systems that the cuts may intersect; and
- Groundwater sampling and analysis for at least total dissolved solids, pH, and heavy metals and hydrocarbon compounds.

Once pre-construction monitoring has been undertaken, the management principles outlined in the four groundwater policies can be followed. Groundwater monitoring should continue to be carried out during construction and operation of the Proposal to:

- Identify whether baseflow to creeks is provided by the groundwater systems;
- Compare results from measurements of pore water pressure with predicted settlement rates. This would also provide an advanced prediction of ongoing settlement; and
- Determine whether the cuttings are having an adverse impact on water quality.

Groundwater monitoring should be conducted in association with both visual observations and quantitative measurements of surface water flows at creeks and wetlands and an assessment of the condition of ECC's.

8. Conclusion

Overall the water quality of waterways in the Warrell Creek to Urunga study area was slightly better under dry weather conditions than following wet weather, although the smaller tributaries (predominately those classified as lowland rivers) had poor water quality during dry weather due to very low flow and/or stagnant water conditions at the time of sampling. Poor water quality during dry weather was generally due to high turbidity and low dissolved oxygen and pH concentrations which failed to meet the ANZECC/ARMCANZ (2000) trigger values for slightly disturbed estuarine and lowland river ecosystems. Following wet weather, the water quality at all sites deteriorated due to increased turbidity and lower dissolved oxygen levels. The extent to which the waterways were affected by wet weather appears dependent on the surrounding catchment and the amount of riparian vegetation. Sites with well vegetated banks and permeable catchment surfaces are less affected by rainfall and runoff as the sediment can become trapped by the vegetation thereby reducing the amount of runoff entering the waterways.

All rivers and creeks in the study area would be impacted as they are all crossed by the Proposal, however the severity of this impact is dependent on the resilience of the waterbody and the mitigation measures that would be implemented. Sites that are well vegetated and only slightly degraded are more resilient than those with little vegetation and moderate degradation. No SEPP14 wetlands would be directly impacted as the Proposal runs adjacent to them, however potential exists for indirect impacts through the operation of the Proposal, their proximity to high risk ASS during construction and to potential changes in local hydrology.

The Proposal in Section 1 of the study area first crosses a number of creeks including Upper Warrell, Butchers, Rosewood, Stony and Williamson Creeks which have demonstrated poor existing water quality during both dry and wet weather conditions. Under dry weather conditions these sites are generally impacted by low flow, excessive aquatic macrophyte growth, high turbidity and low dissolved oxygen and pH concentrations. Following wet weather dissolved oxygen appears to decrease further. These sites are generally highly degraded and appropriate mitigation measures would need to be implemented to ensure that water quality is not further exacerbated.

Butchers Creek water quality is also currently potentially impacted by ASS. Appropriate mitigation measures for construction and operation of the Proposal in the vicinity of actual and potential acid sulphate soils should be implemented. The estuarine reaches of Warrell Creek and the Nambucca River appear to have better water quality probably due to the larger volumes of water and tidal influences. Following wet weather, water quality in these systems deteriorates with high turbidity and low dissolved oxygen concentrations and therefore appropriate mitigation measures would also be required during construction at these sites.

The two waterways, Warrell Creek and Nambucca River have the potential to be impacted by in-stream structures which directly and indirectly impact on water quality. Direct water quality impacts are associated with excavation works in or near drainage lines and from construction of the bridge over the waterway. Indirect water quality impacts result from water contamination due to sedimentation, erosion, changes to quality of road runoff during construction and operation and potential pollutants from vehicles. If these potential impacts are not appropriately managed they have the potential to result in the eutrophication of receiving waters and production of contaminated runoff.

Section 2 of the Proposal does not cross any waterways but runs adjacent to two SEPP14 wetlands which were both dry at the time of sampling. ASS mitigation measures would be implemented as part of the Acid Sulphate Soil Management Plan to minimise the potential for impact from disturbance of high risk acid sulphate soils around these wetland areas.

In Section 3 the Proposal could adversely affect Boggy Creek, Cow Creek, Deep Creek and a tributary of Oyster Creek as all these waterways are crossed by the Proposal and these sites already display poor water quality. It is important, therefore, that appropriate mitigation and control measures are implemented for both construction and operational phases of the Proposal.

Section 4 of the study area is dominated by the Kalang River which the Proposal crosses several kilometres upstream of the existing highway crossing. Both the upstream and downstream reaches of the Kalang River would be impacted due to its tidal nature. Two SEPP14 wetlands could also be indirectly affected by alteration of the water table, disturbance of ASS and changes to local hydrology. Appropriate mitigation and control measures would be necessary to avoid impacts on water quality. Similar to Warrell Creek and the Nambucca River in Section 1, the Kalang River also has the potential to be impacted by the construction and operation of in-stream structures.

The construction of cuttings below the groundwater table has the potential to impact on the existing groundwater regime, and locally draw the groundwater table down. As a consequence, there is the potential for the drawdown to impact on springs, surface water systems, nearby structures and the potential for negative impacts on groundwater dependent ecosystems and communities. There is the potential for long term impacts on groundwater, creeks and waterways during operation of the Proposal where cuttings have intersected the watertable.

In addition to the cuttings, the disturbance and ground clearing associated with construction of access roads, tracks and general vegetation clearing can alter groundwater recharge and introduce pollutants. The compaction of soils and cutting and filling associated with construction reduce groundwater recharge. This reduction in the depth of groundwater allows surface contaminants a shorter pathway to the water table making the groundwater table more vulnerable to pollution. Accidental spills, particularly in locations of highly permeable strata have the potential to contaminate groundwater.

9. References

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Appendix A Water Quality Results

- **Table 9-1 Water Quality Results for the first sampling occasion conducted on 24 – 25 September 2007 (Dry weather)**

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)
W1	25-09-07	1	5.73	367	0.37	17.9	2.10	5.65	59.1
		2	5.85	315	0.32	16.9	2.20	5.49	54.6
		3	5.68	310	0.31	16.7	2.30	5.4	57.7
		Mean	5.75	331	0.33	17.2	2.20	5.51	57.1
W2	25-09-07	1	5.8	328	0.33	18.2	10.3	3.64	35.7
		2	5.93	367	0.37	20.0	42.5	3.00	28.7
		3	5.8	407	0.41	17.3	8.1	0.59	7.6
		Mean	5.84	367	0.37	18.5	20.3	2.41	24.0
W3	25-09-07	1	6.22	293	0.29	20.2	3.6	7.6	82.0
		2	6.51	310	0.31	20.0	4.0	7.5	88.2
		3	6.06	297	0.30	17.4	7.4	6.3	61.6
		Mean	6.26	300	0.30	19.2	5.0	7.14	77.3
W4	25-09-07	1	6.61	465	0.47	19.5	3.5	5.7	63.4
		2	6.28	418	0.42	18.8	3.7	6.6	64.8
		Mean	6.45	442	0.44	19.2	3.6	6.2	64.1
1a	25-09-07	1	6.68	298	0.30	19.3	4.6	7.5	77.4
		2	6.65	274	0.27	16.1	5.6	4.2	50.3
		3	6.65	265	0.27	15.6	8.4	5.3	49.6
		Mean	6.66	279	0.28	17.0	6.2	5.7	59.1
1b	25-09-07	1	6.29	296	0.30	16.5	5.0	5.3	55.8
		2	5.66	283	0.28	17.4	4.6	5.9	56.9
		3	6.62	273	0.27	18.0	4.5	5.9	67.9
		Mean	6.19	284	0.28	17.3	4.7	5.7	60.2
2a	25-09-07	1	6.78	1693	1.69	20.3	3.1	5.2	60.8
		2	7.17	1091	1.09	20.7	3.6	5.2	55.2
		3	6.89	1719	1.72	20.1	3.5	5.7	60.8
		Mean	6.95	1501	1.50	20.4	3.4	5.4	58.9

Site Number	Date	Replicate	pH	Electrical Conductivity (μS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)
2b	25-09-07	1	7.05	1926	1.93	23.1	6.2	5.6	74.4
		2	7.04	1886	1.89	23.0	1.1	6.4	60.7
		3	6.73	2150	2.15	22.7	1.2	5.0	67.5
		Mean	6.94	1987	1.99	22.9	2.8	5.6	67.5
3a	25-09-07	1	8.10	35300	35.3	18.5	2.4	8.5	88.4
		2	8.12	34000	34.0	19.0	1.6	7.9	87.5
		3	8.18	35200	35.2	19.1	1.7	8.0	86.3
		Mean	8.13	34833	34.8	18.9	1.9	8.1	87.4
3b	25-09-07	1	7.04	35900	35.9	19.4	2.1	8.2	92.2
		2	7.18	36200	36.2	20.0	0.6	8.0	87.0
		3	8.07	35000	35.0	20.0	2.4	7.9	88.6
		Mean	7.43	35700	35.7	19.8	1.7	8.1	89.3
4b	25-09-07	1	6.08	395	0.39	16.7	1.6	3.42	35.0
		2	6.00	369	0.37	16.4	1.2	2.0	20.3
		3	6.56	393	0.39	15.8	1.2	3.71	38.8
		Mean	6.21	386	0.39	16.3	1.3	3.04	31.4
5a	24-09-07	1	6.78	218	0.22	19.7	0.0	7.4	82.2
		2	6.71	214	0.21	19.2	0.0	7.9	85.1
		3	6.60	211	0.21	19.3	0.9	8.0	88.4
		Mean	6.70	214	0.21	19.4	0.3	7.75	85.2
5b	Not sampled – no access								
6a	24-09-07	1	7.43	8620	8.62	22.8	3.1	6.92	79.3
		2	7.46	4640	4.64	22.8	10	6.25	78.0
		3	6.23	8040	8.04	23.1	9.4	7.75	86.6
		Mean	7.04	7100	7.10	22.9	7.5	6.97	81.3
6b	24-09-07	1	6.56	8000	8.00	21.9	4.3	8.36	88.8
		2	6.58	8000	8.00	22.6	7.9	7.29	88.9
		3	6.85	10090	10.09	22.8	4.5	7.45	85.0
		Mean	6.66	8697	8.69	22.4	5.6	7.70	87.6
7a	24-09-07	1	6.68	265	0.27	17.6	145	2.59	25.2
		2	6.65	258	0.26	17.1	150	2.87	32.0

Site Number	Date	Replicate	pH	Electrical Conductivity (μS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)
		3	4.54	243	0.24	17.9	136.3	2.87	29.0
		Mean	5.96	255	0.26	17.5	143.8	2.78	28.7
7b	24-09-07	1	6.04	251	0.25	17.2	16.6	3.00	31.1
		2	6.39	237	0.24	19.2	16.1	6.70	74.3
		3	6.59	227	0.23	18.5	13.8	3.60	44.1
		Mean	6.34	238	0.24	18.3	15.5	4.40	49.8
9a	24-09-07	1	7.67	27900	27.9	21.5	3.8	7.41	85.7
		2	7.81	28300	28.3	21.3	2.7	7.62	81.4
		3	7.87	28700	28.7	21.3	2.6	7.33	82.2
		Mean	7.78	28300	28.3	21.4	3.0	7.45	83.1
9b	24-09-07	1	7.74	27800	27.8	20.7	1.6	7.80	96.2
		2	7.66	29700	29.7	20.5	1.6	7.30	85.3
		3	7.75	28600	28.6	20.7	2.2	7.50	83.2
		Mean	7.72	28700	28.7	20.6	1.8	7.54	88.2
10	24-09-07	1	6.99	6490	6.49	20.0	1.2	6.99	89.1
		2	7.09	7220	7.22	19.9	1.2	7.34	76.8
		3	7.19	7790	7.79	19.6	1.2	7.38	81.2
		Mean	7.09	7167	7.17	19.8	1.2	7.24	82.4

■ Table 9-2 Water Quality Results for the second sampling occasion conducted on 22 – 24 October 2007 (Dry weather)

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
W1	22-10-07	1	7.74	335	0.30	20.61	68.5	4.0	43.8	0.15
		2	7.37	328	0.30	20.59	47.8	4.0	43.5	0.15
		3	7.27	328	0.29	20.82	35.8	3.9	43.3	0.14
		Mean	7.46	330	0.30	20.67	50.7	4.0	43.5	0.15
W2	22-10-07	1	7.20	299	0.25	23.29	24.0	3.4	39.5	0.25
		2	7.15	331	0.30	24.20	18.2	3.4	41.2	0.30
		Mean	7.18	315	0.28	23.75	21.1	3.4	40.4	0.28
W3	22-10-07	1	7.29	494	0.49	21.73	64.9	3.2	64.1	0.23
		2	7.20	513	0.48	20.02	34.0	1.5	14.2	0.24
		Mean	7.25	501	0.49	20.88	49.5	2.4	39.2	0.24
W4	23-10-07	1	7.23	260	0.20	19.16	15.6	5.3	57.4	0.10
		2	7.02	257	0.20	19.09	55.5	4.7	50.6	0.10
		3	7.03	257	0.20	19.07	14.4	5.0	54.1	0.10
		Mean	7.09	258	0.20	19.11	28.5	5.0	54.0	0.10
1a	23-10-07	1	7.00	300	0.25	16.72	68.5	1.2	11.9	0.12
		2	7.61	300	0.25	16.78	43.7	0.6	5.5	0.12
		3	7.41	284	0.25	16.39	43.3	0.7	6.3	0.13
		Mean	7.34	295	0.25	16.63	51.8	0.8	7.9	0.12
1b	23-10-07	1	7.50	297	0.26	16.20	64.5	1.5	15.1	0.13
		2	7.42	298	0.26	15.98	53.3	1.3	13.1	0.13
		3	7.31	295	0.25	16.36	25.9	1.8	16.2	0.13
		Mean	7.41	297	0.26	16.18	47.9	1.5	14.8	0.13
2a	23-10-07	1	7.59	4683	4.87	23.64	17.3	5.5	65.8	4.87
		2	7.61	4685	4.84	23.59	24.4	5.6	66.5	4.84
		3	7.56	4671	4.83	23.73	23.1	5.4	65.5	4.83
		Mean	7.59	4680	4.85	23.65	21.6	5.5	65.9	4.85
2b	23-10-07	1	7.51	4699	4.85	22.11	16.5	5.1	60.9	2.61
		2	7.58	4700	4.89	23.11	13.7	5.2	61.1	2.61
		3	7.57	4700	4.85	23.17	13.1	5.2	61.4	2.60
		Mean	7.55	4700	4.86	22.80	14.4	5.2	61.1	2.61

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
3a	22-10-07	1	8.13	8000	38.41	25.06	54.5	6.2	86.1	24.39
		2	8.14	8000	38.30	25.06	25.8	6.2	85.8	24.31
		3	8.14	8000	38.22	25.02	30.8	6.2	85.9	24.32
		Mean	8.14	8000	38.31	25.05	37.0	6.2	85.9	24.34
3b	22-10-07	1	8.14	8000	38.45	25.29	30.2	5.9	83.7	24.42
		2	8.15	8000	38.47	25.19	20.1	5.9	84.3	24.44
		3	8.15	8000	38.46	25.13	17.8	6.1	85.6	24.45
		Mean	8.15	8000	38.46	25.20	22.7	6.0	84.5	24.44
4b	24-10-07	1	7.10	442	0.39	17.76	113.3	0.5	3.7	0.20
		2	7.04	438	0.40	17.09	106.9	0.3	2.8	0.20
		3	7.18	577	0.51	17.49	85.9	0.6	3.6	0.31
		Mean	7.11	486	0.43	17.45	102	0.5	3.4	0.24
5a	23-10-07	1	7.37	237	0.18	23.74	13.1	5.3	62.5	0.10
		2	7.15	246	0.19	22.05	26.3	3.7	42.2	0.09
		3	7.14	252	0.22	21.87	14.4	4.4	49.6	0.11
		Mean	7.22	245	0.20	22.55	17.9	4.5	51.4	0.10
5b	23-10-07	1	7.12	8000	12.69	25.90	20.3	4.5	58.9	7.42
		2	7.72	8000	12.27	25.83	29.6	4.8	61.4	6.93
		3	7.07	8000	17.75	25.89	33.0	4.8	61.8	10.36
		Mean	7.30	8000	14.24	25.87	27.6	4.7	60.7	8.24
6a	22-10-07	1	7.75	8000	26.83	25.21	9.0	6.3	83.8	16.43
		2	7.76	8000	26.72	25.10	9.9	6.1	83.1	16.34
		3	7.75	8000	26.94	25.07	15.8	6.3	84.6	16.52
		Mean	7.75	8000	26.83	25.13	11.6	6.2	83.8	16.43
6b	22-10-07	1	7.76	8000	35.88	24.78	15.4	5.9	80.7	21.70
		2	7.76	8000	34.37	24.84	13.3	5.9	79.8	21.54
		3	7.76	8000	34.29	24.92	12.3	6.0	80.7	21.55
		Mean	7.76	8000	34.85	24.85	13. 7	5.9	80.4	21.60
7a	23-10-07	1	7.8	271	0.24	19.06	140.5	0.8	5.9	0.12
		2	7.38	269	0.23	19.57	24.2	0.8	9.3	0.11
		3	7.08	263	0.23	20.78	103.9	0.5	5.1	0.11

Site Number	Date	Replicate	pH	Electrical Conductivity (μS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
		Mean	7.42	268	0.23	19.80	89.5	0.7	6.8	0.11
7b	23-10-07	1	7.11	260	0.24	19.20	109	1.9	20.0	0.12
		2	6.90	258	0.22	22.30	50.5	3.0	34.4	0.11
		3	6.96	257	0.22	22.43	55.9	3.6	42.5	0.11
		Mean	6.99	258	0.23	21.31	71.8	2.8	32.3	0.11
9a	22-10-07	1	7.86	8000	35.61	24.27	15.0	5.6	75.1	22.43
		2	7.86	8000	35.73	24.37	21.6	5.6	75.3	22.53
		3	7.87	8000	35.78	24.30	22.7	5.7	76	22.54
		Mean	7.86	8000	35.71	24.31	19.8	5.6	75.5	22.50
9b	22-10-07	1	7.86	8000	35.90	25.23	27.0	5.4	74.0	22.57
		2	7.86	8000	36.10	25.62	19.5	5.3	74.0	22.70
		3	7.90	8000	35.80	24.93	17.4	5.8	78.3	22.54
		Mean	7.87	8000	35.93	25.26	21.3	5.5	75.4	22.60
10	22-10-07	1	7.68	8000	14.14	23.01	15.6	6.4	77.6	8.17
		2	7.68	8000	14.21	23.15	33.8	6.3	77.7	8.21
		3	7.70	8000	14.20	23.05	10.1	6.4	77.5	8.19
		Mean	7.69	8000	14.18	23.07	19.8	6.4	77.6	8.19
SEPP 351	24-10-07	1	6.69	420	0.37	20.42	47.3	2.2	22.3	0.18
		2	6.90	422	0.38	18.91	27.2	0.6	5.70	0.19
		3	6.74	416	0.37	20.66	15.8	2.3	25.4	0.18
		Mean	6.78	419	0.37	20.00	30.1	1.7	17.8	0.18
SEPP 388	22-10-07	1	7.80	8000	38.47	23.74	16.7	5.6	77.0	24.43
		2	7.79	8000	38.62	23.86	14.4	5.7	77.7	24.57
		3	7.75	8000	38.84	23.9	20.1	5.4	75.3	24.44
		Mean	7.78	8000	38.64	23.83	17.1	5.6	76. 7	24.48

Table 9-3 Water Quality Results for the third sampling occasion conducted on 30 October 2007 (Wet weather)

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
W1	30-10-07	1	7.40	315	0.26	21.00	13.5	1.2	13.8	0.10
		2	7.26	311	0.26	21.10	13.5	1.4	14.1	0.10
		3	7.25	312	0.26	21.00	14.3	1.3	13.9	0.10
		Mean	7.30	313	0.26	21.02	13.8	1.3	13.9	0.10
W2	30-10-07	1	7.49	321	0.29	22.19	12.4	2.5	27.7	0.14
		2	7.45	318	0.25	22.14	11.8	2.5	28.5	0.14
		3	7.47	321	0.29	22.13	14.1	1.7	18.0	0.14
		Mean	7.47	320	0.28	22.15	12.8	2.2	24.7	0.14
W3	30-10-07	1	7.23	263	0.22	21.91	18.2	3.9	42.9	0.11
		2	7.03	259	0.22	22.01	18.0	3.5	39.3	0.11
		3	7.11	262	0.22	22.08	20.3	3.4	37.7	0.11
		Mean	7.12	261	0.22	22.00	18.8	3.6	40.0	0.11
W4	30-10-07	1	7.24	526	0.47	20.64	23.8	0.4	3.4	0.24
		2	7.18	524	0.47	20.85	22.9	0.5	4.6	0.23
		Mean	7.21	525	0.47	20.75	23.4	0.5	4.0	0.24
1a	30-10-07	1								
		2								
		3								
		Mean								
1b	30-10-07	1								
		2								
		3								
		Mean								
2a	30-10-07	1	7.51	5803	6.01	27.07	17.4	5.6	72.2	3.27
		2	7.51	5765	5.95	27.01	13.9	5.5	70.1	3.23
		3	7.51	5720	5.93	27.05	20.1	5.4	69.5	3.22
		Mean	7.51	5763	5.96	27.04	17.1	5.5	70.6	3.24
2b	30-10-07	1	7.33	4682	4.83	24.95	15.2	3.8	46.6	2.60
		2	7.38	4734	4.90	24.99	14.1	3.2	39.4	2.63
		3	7.45	4715	4.87	24.99	16.9	3.8	46.1	2.61

Site Number	Date	Replicate	pH	Electrical Conductivity (μS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
		Mean	7.39	4710	4.87	24.98	15.4	3.6	44.0	2.61
3a	30-10-07	1	7.88	8000	39.65	23.88	16.9	4.5	62.1	25.22
		2	7.96	8000	39.46	23.89	13.9	4.6	62.6	25.13
		3	7.98	8000	39.41	23.95	13.1	4.6	62.5	25.08
		Mean	7.94	8000	39.51	23.91	14.6	4.6	62.4	25.14
3b	30-10-07	1	8.00	8000	39.54	23.97	14.4	4.6	60.6	25.19
		2	8.01	8000	39.53	23.97	13.3	4.6	62.9	25.16
		3	8.01	8000	39.42	23.99	13.1	4.6	63.2	25.13
		Mean	8.01	8000	39.50	23.98	13.6	4.6	62.2	25.16
4b	30-10-07	1	7.29	4323	4.29	20.45	42.2	0.9	7.9	2.30
		2	7.24	1780	1.18	20.55	68.3	0.7	8.1	0.93
		3	7.08	2832	2.87	20.01	21.4	0.4	4.7	1.56
		Mean	7.20	2978	2.78	20.34	44.0	0.7	6.9	1.60
5a	30-10-07	1	7.51	2409	2.23	25.51	43.3	4.3	51.8	1.30
		2	7.49	1998	2.07	24.98	25.1	4.4	52.5	1.07
		3	7.02	8000	10.92	24.05	23.6	3.1	35.5	5.05
		Mean	7.34	4135	5.07	24.85	30.7	3.9	46.6	2.47
5b	30-10-07	1	7.70	8000	42.44	28.85	31.3	4	62.6	27.15
		2	7.60	8000	42.96	29.71	29.7	4.5	61.8	27.56
		3	7.51	8000	43.25	28.86	28.9	3.3	50.4	27.63
		Mean	7.60	8000	42.88	29.14	30.0	3.9	58.3	27.45
6a	30-10-07	1	7.83	8000	43.70	27.45	15.8	4.1	59.5	43.70
		2	7.90	8000	41.88	27.51	22.9	4.4	64.7	41.88
		3	7.92	8000	42.54	27.46	17.3	4.2	61.6	42.54
		Mean	7.88	8000	42.71	27.47	18. 7	4.2	61.9	42.71
6b	30-10-07	1	8.01	8000	43.48	28.07	14.6	4.5	67.1	28.07
		2	7.97	8000	43.87	28.23	18.8	4.4	64.6	28.23
		3	7.90	8000	43.56	27.90	16.5	4.5	60.6	27.90
		Mean	7.96	8000	43.64	28.07	16.6	4.5	64.1	28.07
7a	30-10-07	1	7.24	245	0.19	20.76	48.6	0.9	10.1	0.09
		2	7.16	241	0.19	20.79	35.6	1.1	11.4	0.09

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
		3	7.17	241	0.19	20.82	25.7	1.2	13.0	0.09
		Mean	7.19	242	0.19	20.79	36.6	1.1	11.5	0.09
7b	30-10-07	1	7.41	238	0.19	20.52	69.4	1.9	21.0	0.09
		2	7.29	236	0.19	20.44	65.1	1.8	19.5	0.09
		3	7.21	234	0.19	20.69	55.2	2.3	24.7	0.09
		Mean	7.30	236	0.19	20.55	63.2	2.0	21.7	0.09
9a	30-10-07	1	7.66	8000	38.38	25.36	20.6	4.3	59.6	24.40
		2	7.76	8000	38.53	25.35	22.5	4.2	58.8	24.41
		3	7.80	8000	38.81	25.33	21.6	4.2	59.3	24.72
		Mean	7.74	8000	38.57	25.35	21.6	4.2	59.2	24.51
9b	30-10-07	1	7.85	8000	38.53	25.39	21.4	4.30	59.4	24.57
		2	7.85	8000	38.98	25.36	21.8	4.30	60.1	24.80
		3	7.85	8000	38.98	25.38	22.0	4.30	59.9	24.79
		Mean	7.85	8000	38.83	25.38	21.7	4.3	59.8	24.72
10	30-10-07	1	7.86	8000	23.94	25.49	12.9	5.5	72.7	14.57
		2	7.90	8000	24.01	25.50	13.1	5.5	73.1	14.60
		3	7.97	8000	25.24	25.59	11.6	5.6	74.5	15.36
		Mean	7.91	8000	24.40	25.53	12.5	5.5	73.4	14.84
SEPP 351	30-10-07	1	7.50	357	0.32	22.70	34.3	5.0	46.6	0.16
		2	7.20	355	0.32	21.45	58.5	3.1	36.9	0.16
		3	7.07	348	0.31	23.72	20.3	4.8	58.2	0.15
		Mean	7.26	353	0.32	22.62	37.7	4.3	47.2	0.16
SEPP 388	30-10-07	1	7.51	8000	39.09	22.80	19.9	3.4	46.2	25.12
		2	7.70	8000	41.25	23.35	23.1	3.7	51.1	26.35
		3	7.70	8000	40.68	23.14	19.1	3.9	52.3	26.11
		Mean	7.64	8000	40.34	23.10	20.7	3. 7	49.9	25.86

Table 9-4 Water Quality Results for the fourth sampling occasion conducted on 8 – 9 November 2007 (Wet weather)

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
W1	9-11-07	1	7.61	323	0.28	18.28	16.3	0.80	7.40	0.14
		2	7.49	323	0.28	18.28	17.8	0.60	6.40	0.14
		3	7.45	323	0.28	18.26	17.8	0.60	6.80	0.14
		Mean	7.52	323	0.28	18.27	17.3	0.67	6.87	0.14
W2	9-11-07	1	7.92	318	0.27	19.57	15.2	1.30	13.9	0.13
		2	7.62	313	0.27	19.24	26.1	1.40	15.0	0.13
		3	7.43	334	0.27	18.64	18.7	1.70	17.4	0.14
		Mean	7.66	322	0.27	19.15	20.0	1.47	15.4	0.13
W3	9-11-07	1	7.83	249	0.21	17.91	16.3	4.50	48.0	0.10
		2	7.54	250	0.21	17.78	15.8	4.50	46.7	0.10
		3	7.40	250	0.21	17.80	17.1	4.50	47.0	0.10
		Mean	7.59	250	0.21	17.83	16.4	4.50	47.2	0.10
W4	9-11-07	1	7.73	410	0.35	18.18	21.8	2.60	27.2	0.17
		2	7.49	406	0.35	18.18	20.6	2.40	25.7	0.17
		Mean	7.61	408	0.35	18.18	21.2	2.50	26.5	0.17
1a	9-11-07	1	7.99	235	0.21	17.08	31.3	5.00	52.1	0.09
		2	7.78	240	0.21	16.90	23.6	3.60	37.5	0.10
		3	7.74	240	0.18	16.87	23.6	3.60	37.0	0.10
		Mean	7.84	238	0.20	16.95	26.2	4.07	42.2	0.10
1b	9-11-07	1	7.97	240	0.21	16.96	27.8	4.30	44.8	0.10
		2	7.75	240	0.21	16.94	31.9	4.10	42.6	0.10
		3	7.69	236	0.17	16.92	30.0	4.30	44.6	0.10
		Mean	7.80	239	0.20	16.94	29.9	4.23	44.0	0.10
2a	9-11-07	1	7.74	6681	6.99	21.33	14.3	3.50	40.3	8.82
		2	7.63	7104	7.50	21.59	13.9	3.20	36.4	4.09
		3	7.54	9008	9.08	23.54	15.0	2.60	29.6	4.80
		Mean	7.64	7598	7.86	22.15	14.4	3.10	35.4	5.90
2b	9-11-07	1	7.53	5903	6.16	20.82	13.1	4.50	49.9	3.35
		2	7.56	5891	6.16	20.73	12.4	4.10	41.3	3.34
		3	7.54	6010	6.25	20.93	12.9	4.50	47.8	3.40

Site Number	Date	Replicate	pH	Electrical Conductivity (μS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
		Mean	7.54	5935	6.19	20.83	12.8	4.37	46.3	3.36
3a	8-11-07	1	8.00	41340	41.34	22.40	16.3	5.60	74.5	26.46
		2	8.17	41280	41.28	22.44	15.2	5.70	75.9	26.44
		3	8.21	41210	41.21	22.48	13.9	5.70	75.6	26.37
		Mean	8.13	41277	41.28	22.44	15.1	5.67	75.3	26.42
3b	8-11-07	1	8.25	42070	42.07	22.29	13.5	5.50	73.7	27.00
		2	8.28	42140	42.14	22.37	14.6	5.60	75.1	27.04
		3	8.28	42120	42.12	22.35	14.8	5.60	74.8	27.05
		Mean	8.27	42110	42.11	22.34	14.3	5.57	74.5	27.03
4b	9-11-07	1	8.25	423	0.40	17.05	35.3	3.10	31.4	0.15
		2	7.52	435	0.36	17.04	28.3	3.50	34.1	0.20
		3	7.46	461	0.44	17.02	28.3	3.40	35.0	0.22
		Mean	7.74	440	0.40	17.04	30.6	3.33	33.5	0.19
5a	9-11-07	1	8.53	260	0.20	18.57	19.5	5.80	61.0	0.12
		2	8.14	260	0.20	18.53	16.7	5.80	61.1	0.10
		3	7.96	264	0.20	18.52	15.5	6.00	63.1	0.10
		Mean	8.21	261	0.20	18.54	17.2	5.87	61.7	0.11
5b	9-11-07	1	7.44	14860	14.86	19.24	20.9	4.40	51.2	8.49
		2	7.49	17410	17.41	19.46	19.7	4.20	48.4	10.5
		3	7.57	16670	16.67	19.45	19.1	4.40	49.0	9.75
		Mean	7.50	16313	16.31	19.38	19.9	4.33	49.5	9.58
6a	9-11-07	1	7.92	12970	12.97	19.89	18.4	6.40	73.6	7.45
		2	7.87	12670	12.67	19.93	20.6	6.50	74.3	7.28
		3	7.86	12620	12.62	19.83	17.4	6.40	73.5	7.25
		Mean	7.88	12753	12.75	19.88	18.8	6.43	73.8	7.33
6b	9-11-07	1	7.70	11760	11.76	19.60	22.1	6.70	75.9	6.69
		2	7.81	11840	11.84	19.57	19.7	6.80	76.9	6.77
		3	7.85	12060	12.06	19.60	24.4	6.70	76.1	6.88
		Mean	7.79	11887	11.89	19.59	22.1	6.73	76.3	6.78
7a	9-11-07	1	7.73	277	0.24	18.18	25.7	1.80	18.9	0.12
		2	7.13	252	0.21	18.16	28.7	2.40	23.7	0.10

Site Number	Date	Replicate	pH	Electrical Conductivity (μS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
		3	7.09	238	0.21	17.97	28.9	3.30	32.4	0.10
		Mean	7.32	256	0.22	18.10	27.8	2.50	25.0	0.11
7b	9-11-07	1	7.29	216	0.17	18.05	29.8	4.60	48.0	0.08
		2	7.27	213	0.17	17.95	25.9	4.50	47.2	0.08
		3	7.22	211	0.17	18.37	26.1	4.00	51.7	0.08
		Mean	7.26	213	0.17	18.12	27.3	4.37	49.0	0.08
9a	9-11-07	1	7.99	32960	32.96	21.60	15.4	5.00	63.1	20.78
		2	7.99	33070	33.07	21.89	15.0	5.30	66.4	20.67
		3	8.00	33090	33.09	21.73	13.5	5.10	65.0	20.78
		Mean	7.99	33040	33.04	21.74	14.6	5.13	64.8	20.74
9b	9-11-07	1	7.77	33820	33.82	22.04	13.5	4.80	62.0	21.19
		2	7.90	32820	32.82	21.94	13.1	5.20	66.5	20.42
		3	7.94	33450	33.45	22.01	13.1	4.80	62.5	20.96
		Mean	7.87	33363	33.36	22.00	13.2	4.93	63.7	20.86
10	9-11-07	1	7.43	9470	9.47	21.63	27.8	5.30	62.6	5.31
		2	7.48	9500	9.50	21.65	22.9	5.50	63.8	5.33
		3	7.52	10050	10.05	21.60	30.5	5.50	63.4	5.63
		Mean	7.48	9673	9.67	21.63	27.1	5.43	63.3	5.42
SEPP 351	9-11-07	1	8.15	523	0.48	17.07	17.4	2.70	28.2	0.24
		2	7.68	563	0.52	16.88	12.6	2.40	25.2	0.26
		3	7.48	555	0.52	16.85	15.0	2.30	24.0	0.26
		Mean	7.77	547	0.51	16.93	15.0	2.47	25.8	0.25
SEPP 388	8-11-07	1	8.37	43040	43.04	21.63	14.8	5.90	78.8	27.68
		2	8.28	42490	42.49	21.45	13.7	5.30	71.4	27.27
		3	8.22	42850	42.85	21.58	15.6	5.10	66.7	27.51
		Mean	8.29	42793	42.79	21.55	14.7	5.43	72.3	27.49

Table 9-5 Water Quality Results for sampling undertaken during July 2008 (Dry Weather)

Site Number	Date	Replicate	pH	Electrical Conductivity (µS/cm)	Electrical Conductivity (mS/cm)	Temperature (°C)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Salinity (ppt)
W2a	16-07-08	1	4.93	147	0.17	14.72	1.8	5.2	51.3	0.08
		2	4.78	148	0.17	14.56	7.5	5.0	48.7	0.08
		3	4.70	148	0.17	14.58	1.4	4.8	48.2	0.08
		Mean	4.80	148	0.17	14.62	3.6	5.0	49.4	0.08
W2b	16-07-08	1	4.75	148	0.17	14.6	1.0	3.1	30.9	0.08
		2	4.65	148	0.17	14.44	2.2	3.4	33.3	0.08
		3	4.55	148	0.17	14.42	3.0	3.8	38.4	0.08
		Mean	4.65	148	0.17	14.49	2.1	3.4	34.2	0.08
W3a	15-07-08	1	6.55	251	0.29	14.97	4.6	7.3	72.2	0.14
		2	6.35	249	0.29	15.25	10.5	7.3	72.9	0.14
		3	6.41	250	0.29	15.13	4.4	7.2	71.4	0.14
		Mean	6.44	250	0.29	15.12	6.5	7.3	72.2	0.14
W3b	15-07-08	1	5.27	240	0.28	15.85	10.7	6.2	63.0	0.14
		2	5.04	237	0.29	15.17	8.0	6.4	64.0	0.14
		3	4.86	241	0.28	15.57	6.5	6.6	66.6	0.14
		Mean	5.06	239	0.283	15.53	8.4	6.4	64.5	0.14
W4a	14-07-08	1	6.10	429	0.48	13.68	30.2	5.0	49.5	0.24
		2	6.16	418	0.46	15.44	21.6	8.1	77.7	0.23
		3	6.09	429	0.49	13.50	20.2	6.3	60.0	0.24
		Mean	6.12	425	0.48	14.21	24.0	6.5	62.4	0.24
W4b	14-07-08	1	5.72	442	0.49	13.63	19.6	8.7	83.1	0.24
		2	5.62	435	0.47	14.94	20.3	7.9	77.4	0.23
		3	5.57	437	0.46	15.44	13.3	7.8	76.8	0.23
		Mean	5.64	438	0.47	14.67	17.7	8.1	79.1	0.23