18 Hydrology, water and soil management

This chapter discusses the water related issues associated with the Proposal including flooding / hydrology, water quality and groundwater. Issues relating to soil and specifically acid sulfate soils are also discussed in the chapter given the close relationship with water quality with regard to erosion and sedimentation and issues associated with acid leachate.

18.1 Existing environment

18.1.1 Hydrology and hydraulics

The Great Dividing Range is in close proximity to the coast in the Coffs Harbour region. While there are no major river systems within the study area, a number of small creek systems exist. The more prominent of the creek systems include Hayes Creek, Sugarmill Creek, Cunninghams Creek, Skinners Creek, Moonee Creek, Darkum Creek, Double Crossing Creek, Woolgoolga Creek and Arrawarra Creek. The location of these creeks is shown in Figure 18.1

As the coastal catchments are generally steep, relatively small in area and subject to high rainfall intensities, they can experience 'flash flooding' (flooding that peaks within six hours of the local heavy rainfall that caused it) and can be characterised by rapid rises of stream levels that are experienced for short periods of time. The more prominent creeks generally have a time to peak of approximately two hours with the duration of run-off lasting eight to twelve hours.

According to Coffs Harbour City Council (2003), there is a long history of flooding in the Coffs Harbour local government area. Significant flood events have occurred in 1917, 1938, 1950, 1963, 1974, 1977, 1989 and 1991.

Coffs Harbour City Council (CHCC) prepared a *Floodplain Risk Management Study* and associated flood risk map for the Moonee Creek system in November 2006, extending from Sapphire Beach to just north of Emerald Beach. One hundred year annual recurrence interval (ARI) flood events were shown on CHCC flood mapping to be concentrated around natural drainage lines and along the Moonee Creek floodplain to the east of the existing Pacific Highway

Source: Aerial Photography August 2000 (LPI NSW)

FIGURE 18.1 WATERCOURSES

alignment (refer Figure 18.2). The ARI annual recurrence interval is the long-term average number of years between the occurrences of a flood as big as (or larger) than the selected event. For example, floods with a discharge as great as (or greater) than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (Department of Natural Resources 2005).

Analysis of the existing flooding regimes on the existing Pacific Highway section of the Proposal (ie south from Woolgoolga) predicts that some culverts may not provide 100 year ARI immunity at present. The sections of the existing highway susceptible to overtopping are near Sugarmill Road and at Emerald Beach. Inundation of the existing highway at these locations is expected to occur in storm events greater than a 10 year ARI flood event and in these circumstances the existing highway can be inundated for periods of up to 12 hours.

The bypass section of the Proposal deviates away from the coastal floodplain areas, passing through smaller catchments that have more defined waterways. The topography along the bypass section is typically steeper than that along the upgrade section and consequently a floodplain model was not developed for the bypass section of the Proposal. Assessment of the individual streams along the bypass section has been undertaken using local hydrologic and hydraulic models to provide design discharges and water levels. This analysis shows that flows are typically confined to the individual waterways.

18.1.2 Water quality

There are in excess of 20 watercourse crossings in the study area. Major creeks include Hayes Creek, Sugarmill Creek, Cunninghams Creek, Skinners Creek, Moonee Creek, Double Crossing Creek, Woolgoolga Creek and Arrawarra Creek. Some of these 20 watercourses (including Sugarmill Creek) are in the catchment of designated SEPP 14 coastal wetlands, located in both upstream and downstream directions, and all drain into the Solitary Islands Marine Park.

The (then) Department of Environment and Conservation (2006) defined key objectives and indicators for measuring water quality as indicated in Table 18.1.

TABLE 18.1 WATER QUALITY OBJECTIVES AND SELECTED KEY INDICATORS (DECEMBER 2006)

WATER QUALITY OBJECTIVE	SELECTED KEY INDICATORS
Protection of aquatic ecosystems	Turbidity, dissolved oxygen and pH
Protection of primary contact recreation (ie. swimming, surfing)	Faecal coliform, enterococci, temperature and pH
Protection of secondary contact recreation (ie. boating, fishing)	Faecal coliform and enterococci

Coffs Harbour City Council has undertaken extensive water quality monitoring over a three-year period commencing in 2003 as part of environmental assessment work for a proposed sewage strategy, as well as subsequent additional monitoring. Water quality monitoring sites relevant to the Proposal extend from Pinebrush Creek (south of Sapphire) in the south to Arrawarra Creek in the north and are considered to give a good representation of the entire length of the proposed route.

The historical water quality data for the selected indicators shown in Table 18.1 have been compared with the Australia New Zealand Environment Conservation Council (2000) *Australian Water Quality Guidelines for Fresh and Marine Waters* (refer Table 18.2). The default low-risk guideline trigger values for a southeast Australian estuarine ecosystem in a slightly-moderately disturbed condition were used. Results are shown in brackets where relevant guidelines are exceeded.

Source: Coffs Harbour City Council web site

FIGURE 18.2 FLOOD MAP – SAPPHIRE TO EMERALD (COFFS HARBOUR CITY COUNCIL)

TABLE 18.2 QUANTITATIVE SUMMARY OF THE WATER QUALITY MONITORING DATA (JELLIFFE ENVIRONMENTAL 2003)

WATER QUALITY INDICATOR	ANZECC GUIDELINE	WATER MONITORING LOCATION						
		Arrawarra Creek	Darkum Creek	Woolgoolga Lake	Hearnes Lake	Fiddamans Creek	Moonee Creek (Park)	Moonee Creek (bridge)
Turbidity (NTU) [1]	0.5-10 (aquatic ecosystems)	(22.88)	10.00	6.00	(23.38)	3.00	(15.00)	(12.00)
Conductivity (mS/cm) [1]	No criteria available for estuarine ecosystems	43.12	30.00	43.50	28.54	26.00	51.70	38.10
Salinity (%) [1]	No criteria available for estuarine ecosystems	2.80	1.87	2.82	1.78	1.59	3.40	2.55
Dissolved oxygen (mg/L) [1]	> 6 mg/L (aquatic ecosystem)	(6.41)	5.89	(7.63)	(7.26)	(7.07)	(8.54)	(7.53)
pH [1]	7.0-8.5 (aquatic ecosystems)	7.96	7.86	8.38	8.07	(9.05)	(8.59)	8.31
	5.0-9.0 (primary contact recreation)	7.96	7.86	8.38	8.07	(9.05)	8.59	8.31
Temperature (°C) [1]	15-35 (primary contact recreation)	21.61	21.40	21.50	21.30	19.20	23.20	19.80
Faecal coliforms (cfu/100mL) [2]	median < 150 (primary contact recreation)	54.0	36.0	50.0	44.0	(189.0)	20.0	78.0
Enterococci (cfu/100mL) [2]	median < 1000 (secondary contact recreation)	54.0	36.0	50.0	44.0	189.0	20.0	78.0
	median < 35 (primary contact recreation)	(55.0)	(90.0)	(46.5)	17.0	(335.0)	(55.5)	(100.0)
	median < 230 (secondary contact recreation)	55.0	90.0	46.5	17.0	(335.0)	55.5	100.0

[1] Mean value of water quality results given. [2] Median value of water quality results given.

The major pollutants identified as exceeding Australia New Zealand Environment Conservation Council (2000) water quality criteria are dissolved oxygen, turbidity and enterococci. The worst affected sites were identified as Arrawarra Creek at Darlington Park, Fiddamans Creek and Woolgoolga Lake. Darkum Creek and Hearnes Lake were identified as exceeding the Australia New Zealand Environment Conservation Council (2000) water quality criteria in at least two or more parameters and were deemed "unacceptable" in these areas. Moonee Creek was generally in good condition having slightly elevated turbidity levels.

A summary of the qualitative water quality results obtained by council over the three year period commencing in 2003 for watercourses within the study area is presented in Table 18.3.

The qualitative analysis correlates with the quantitative analysis and shows a strong correlation between poor water quality and high rainfall events.

18.1.3 Soils including acid sulfate soils

The underlying geology and topography of the study area has given rise to varied conditions along the proposed alignment, resulting in a mosaic of soil landscapes through which the Proposal would pass (refer Figure 18.2). The soil landscape map and report (Milford 1999) provides an overview of the soil landscapes that the proposed alignment traverses, which is relevantly summarised

TABLE 18.3 QUALITATIVE WATER QUALITY SUMMARY FOR WATERCOURSES WITHIN THE STUDY AREA (JELLIFFE ENVIRONMENTAL 2003)

SAMPLING POINT	OVERALL CONDITION	IDENTIFIED ISSUES
Arrawarra Creek – Darlington Park	Critical	Occurrences of high faecal coliforms (positive correlation with rainfall), consistently high turbidity (correlating positively with rainfall and negatively with conductivity), some early indication of increasing temperature.
Darkum Creek	Unacceptable	Occurrences of high faecal coliforms (positive correlation with turbidity and rainfall), consistently high turbidity (correlating positively with rainfall and negatively with conductivity), mean dissolved oxygen concentrations low, some early indication of increasing temperature.
Woolgoolga Lake	Critical	Occurrences of high faecal coliforms (positive correlation with turbidity and rainfall), consistently high turbidity (correlating positively with rainfall and negatively with conductivity), some early indication of increasing temperature.
Hearnes Lake	Unacceptable	Consistently high turbidity (correlating positively with rainfall and negatively with conductivity), some early indication of decreasing temperature.
Fiddamans Creek	Critical	Occurrences of high faecal coliforms (positive correlation with turbidity and rainfall), consistently high turbidity (correlating positively with rainfall and negatively with conductivity), mean dissolved oxygen concentrations low.
Moonee Creek	Marginal	Consistently high turbidity (correlating positively with rainfall and negatively with conductivity), mean dissolved oxygen concentrations marginally acceptable (correlating negatively with temperature).

below. The landscape units all comprise bedded partially metamorphosed sedimentary rock that is reflected in the soil profiles.

Soil profiles

Megan landscape unit (approximately 41% of route)

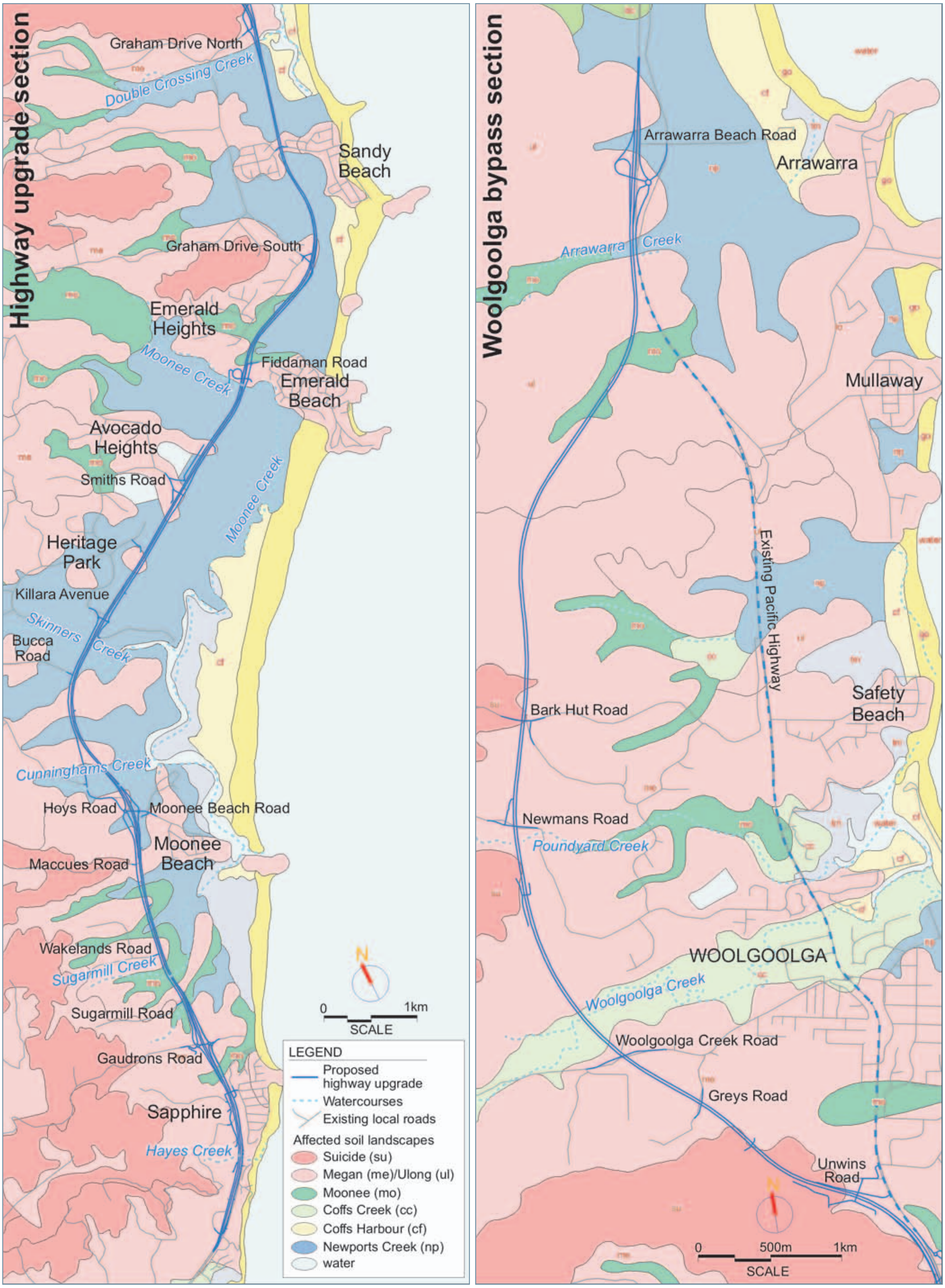
The bypass section passes mainly through the Megan landscape unit, which is described as an erosional landscape, comprising rolling low hills with moderately deep structured yellow, red and brown earths and associated soils typically on slopes of 5-20 per cent but up to 33 per cent where there is a transition to steeper hills of the Suicide landscape unit. The unit is mainly associated with Eucalypt forest, particularly through the Wedding Bells State Forest. However, within the study area it has been cleared and used for bananas and increasingly for residential subdivision. The soils are acid, locally stony, of low subsoil fertility and high erodibility.

Ulong landscape unit (approximately 19% of route)

Ulong is similar in nature and is associated with similar land forms as the Megan landscape unit. The Ulong landscape unit is present in isolated pockets along the upgrade section and from approximately Bark Hut Road to the northern extent of the Proposal at the Arrawarra interchange. The Ulong landscape unit is found on slightly flatter relief than Megan ie. undulating to rolling hills as opposed to rolling hills. As with Megan the soil is characterised by low wet strength silty clays generally greater than one metre thick, however Ulong is only moderately erodible.

Suicide landscape unit (approximately 4% of route)

On some steeper slopes there is a transition to the Suicide landscape unit, which is described as a colluvial landscape, comprising steep hills and dissected valleys. The soils are described as predominantly moderately deep to deep, well structured yellow earths with colluvial and red earth



Source: Soils landscapes 2001 (Department of Land and water Conservation)

FIGURE 18.3 SOIL LANDSCAPES

soils on steeper and lower slopes respectively. They are strongly acid and have low fertility, with a high erosion hazard. The unit is found in the Wedding Bells State Forest and also associated with Megan landscape unit in areas used for banana production.

South of Woolgoolga, the upgrade transects lower lying landscape units as follows:

Moonee landscape unit (approximately 7% of route)

A transferral landscape, comprises undulating rises, footslopes and drainage plains adjacent to steeper low hills and hills. The soils are moderately deep poorly drained humic mottled clays. They are strongly acid, slowly permeable, have high subsoil sodicity (proportion of sodium in the soil structure) and erodibility and are of low fertility. The lands are used mainly for grazing. The natural forest is often sub-tropical rainforest mixed with wet sclerophyll open forest. Remnants of the closed canopy rainforest are a feature of many rural residential and some agricultural holdings especially along small stream courses.

Newports Creek landscape unit (approximately 28% of route)

A swamp landscape, occupies low level to undulating coastal back-barrier floodplains on estuarine sediments. The soils are poorly drained deep yellow podzolics that are strongly to very strongly acid, locally strongly sodic or saline and subject to seasonal waterlogging and flooding. The unit has been used extensively after filling for residential subdivision and recreation.

Coffs Creek landscape unit (approximately 1% of route)

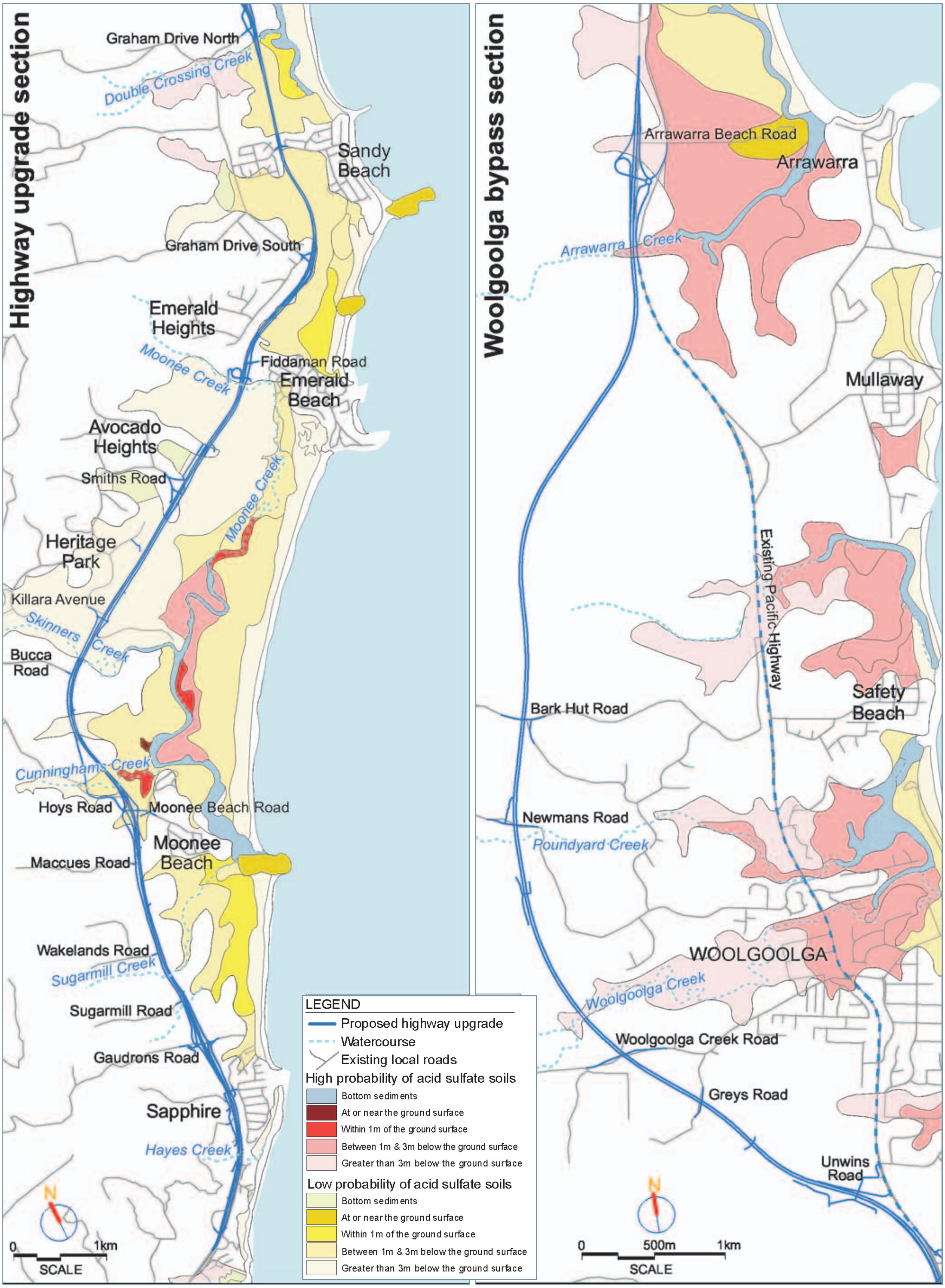
An alluvial landscape comprises of level to gently undulating floodplains and terraces in the lower catchments of coastal streams. The soils are variable but deep and poorly drained. In the study area this landscape unit is used for horse grazing and similar activities on small rural holdings. Elsewhere it is used after filling and drainage for industrial and commercial subdivision.

Table 18.4 summarises the landscape limitations for each soil landscape (extract from *Soils Landscape Report* (Milford H B 1999) which accompanies the *Coffs Harbour 1:100,000 Soil Landscape Series Sheet 9537*.

TABLE 18.4 LANDSCAPE LIMITATIONS FOR IDENTIFIED SOIL LANDSCAPES

	SLOPE STABILITY			DRAINAGE			EROSION			SOIL	
	Steep slopes	Mass movement hazards	Rockfall hazard	Flood hazard	Waterlogging	Permanenently high water tables	Seasonal waterlogging	High run-on	Water erosion hazard	Non-cohesive soils	Foundation hazard
Coffs Creek	L			W		W	W				L
Megan		L							L		L
Moonee						L	W		L		W
Newports Creek	W			W			W		L		W
Suicide	L	W						W	W		W
Ulong								L	L		

L = Localised occurrence, **W** = Widespread occurrence



Source: Soils landscapes 2001 (Department of Land and water Conservation)

FIGURE 18.4 ACID SULFATE SOILS

Acid Sulfate Soils

Acid sulfate soils comprise sediments and soils containing iron sulfate minerals such as pyrite, which become extremely acidic when drained and exposed to oxygen, and may generate acidic leachate following the oxidation of iron sulfide layers. The formation of acid sulfate soils typically occurs in low-lying coastal areas where iron rich sediments can interact with sulfate from seawater, organic matter and sulfate reducing bacteria. These conditions are usually limited to mangroves, salt marsh vegetation or tidal areas, and at the bottom of coastal rivers and lakes. However, flooding and stormwater erosion can redistribute acid sulfate soils throughout the estuarine floodplain.

Investigations of the likelihood and location of potential acid sulfate soils along the proposal were undertaken as part of the geotechnical investigations for the preferred route. These investigations included reviews of existing published information; field sampling and testing including laboratory tests to determine specific acid sulfate soils conditions and requirements for treatment at the site. Field sampling and laboratory analysis for acid sulfate rock was also undertaken.

Reference to the acid sulfate soil risk maps for Moonee Beach (Ref 9537S4 rev 2) and Woolgoolga (Ref 9537N4 rev 2) from the then Department of Land and Water Conservation suggest that areas of both high and low risk acid sulfate soils can be found within the study area. However acid sulfate soils are typically associated with soils below five metres Australian Height Datum (AHD) and hence are expected to be restricted to the low lying coastal areas. Acid sulfate soils in the study area are concentrated along the existing Pacific Highway alignment. In general the soils are classified as low acid sulfate soil potential with the exception of small areas north of Moonee Beach and some locations in the Sandy Beach to Woolgoolga area. The extent and risk of acid sulfate soils within the study area is shown on Figure 18.3.

Field and laboratory investigations were undertaken to define the extent of acid sulfate soil along the proposal. Test results confirm the presence of potential and actual acid sulfate soils at chainages 11.400 km to 22.600 km and 30.100 km to 31.350 km. The bypass section is located between 22.600 km and 30.100 km and exhibited no acid sulfate soil, which correlates with the section of the alignment that extends inland away from the low-lying coastal area.

18.1.4 Groundwater

A review of the Department of Natural Resources registered groundwater bore database indicates that groundwater yields from bores in the Coffs Harbour area are generally less than one litre per second and the majority of the water bearing zones are within the fractured bedrock. The exceptions are bores within the alluvial deposits to the east of the existing highway alignment where shallow bores in sands and gravels produce yields as high at 22 litres per second.

Groundwater levels were measured during drilling operations undertaken in the area as part of geotechnical investigations for the preferred route. It should be noted that groundwater levels can rise or fall following protracted periods of wet weather or a long dry season. No piezometers were installed during the geotechnical fieldwork and therefore long term monitoring of groundwater levels and flow regimes has not been undertaken.

At most geotechnical investigation sites where auger drilling and test pit excavation was undertaken groundwater was not encountered within the residual soils that were present. The use of drilling fluids during coring operations precluded measurement of groundwater levels following completion of the borehole.

Groundwater was encountered in a number of sites positioned at low-lying areas where fill embankments are proposed. This groundwater was in the form of standing water or seepage at depths of between 0.1 metres and 11.9 metres below ground level. Groundwater was encountered at depths of between 1.88 metres and 2.8 metres below ground level in three proposed cut areas (discrete areas) along the proposed alignment. These discrete cut areas were in the vicinity of Headlands Road at Sapphire, the proposed interchange at south Woolgoolga and approximately one kilometre north of Woolgoolga Creek. At Cunninghams Creek, Skinners Creek, Double Crossing Creek and Woolgoolga Creek (proposed bridge work locations), groundwater was encountered in the form of seepage and perched water tables at depths of between 0.7 metres and 3.5 metres below ground level.

18.2 Potential impacts of the Proposal

18.2.1 Hydrology and hydraulics

The Proposal crosses a number of streams which flow predominantly east towards the coast. In this regard the Proposal has the potential to affect the hydraulic behaviour of the watercourses and their associated floodplains. The two main objectives of the proposed drainage arrangements are to:

- Provide flood immunity on at least one carriageway of the highway for a 100 year ARI flood event.
- Minimise changes to existing flood behaviour.

The design of all bridge and drainage structures along the alignment caters for the 100 year ARI flood event. The structures introduced to cater for this event would be designed such that they would not substantially alter peak water levels, discharge or velocity distributions either upstream or downstream of the Proposal. Hydrologic and hydraulic analyses have been tailored specifically to assist in development of the drainage arrangements for the Proposal design and also to determine potential changes in drainage and flooding behaviour that could be attributed to the Proposal.

Assessment methodology

A brief description of the hydraulic assessment approach undertaken as part of the development of the Proposal is provided below:

Hydrologic modelling was undertaken to determine design flow conditions. Hydrologic (RAFTS) models of the contributing catchments were developed to derive design flows for each waterway crossing along the upgrade and bypass sections of the Proposal. Critical durations and peak discharge predictions were identified for each catchment. Flow hydrographs and peak discharge estimates were determined and used in the hydraulic analyses.

The following hydraulic models were constructed to form a base-case for the assessment:

- Two dimensional hydraulic modelling was used to represent the floodplain areas crossed by the Proposal (Moonee Creek, Fiddamans Creek and the Hearns Lake area downstream of Double Crossing Creek). These models were used to predict water level, discharge and velocity distributions across the floodplains.
- One dimensional hydraulic modelling was used to represent the more defined watercourses crossed by the Proposal. This modelling used the MIKE11, Hec-Ras and CulvertMaster modelling packages as appropriate for the bridge and culvert crossings.

Where a section of the existing highway was found to have insufficient flood immunity (ie less than 100 year ARI flood immunity), it is proposed that existing culvert arrangements be augmented (applicable to the upgrade section only). The culvert augmentations have been designed to achieve flood immunity for the Proposal in a 100 year ARI flood event without increasing peak discharge and hence peak water levels downstream.

Where the existing highway currently has immunity in a 100 year ARI flood event, the existing drainage structures would be lengthened to accommodate the widened formation (also applicable to the upgrade section only). At these locations, analysis was undertaken to determine if lengthening of the existing drainage structures would affect peak water levels upstream of the Proposal.

In the bypass section of the Proposal, one-dimensional hydraulic models of the waterways were developed. At waterway crossings along the bypass section, the Proposal has been designed to cater for the 100 year ARI flood event with minimal upstream and downstream effects.

Proposed culvert works

On the upgrade section of the Proposal, the majority of existing culverts and transverse drainage structures were found to achieve the required flood immunity (100 year ARI), with large capacity pipe and box culverts providing substantial freeboard to the existing highway pavement.

Culvert extensions (upgrade section)

Where required, existing culverts would be extended as part of the Proposal to pass under the new highway carriageway and / or the adjacent local access road. As the extended culverts would cater for the same flood flows as the existing culverts, analysis undertaken predicts that the extended culverts would have a negligible affect on flood behaviour (including flood levels, flow velocity and extent and duration of inundation) upstream or downstream of the highway.

Culvert augmentations (upgrade section)

In the locations where overtopping of the existing highway (100 year ARI event) is anticipated, the Proposal provides for augmentation of existing culverts (provision of additional culvert cells) to achieve the required flood immunity. The upgrade requirements to provide this level of immunity for the existing highway section and the resulting flood flow characteristics, including change in head water depth upstream of these culverts, is provided in Table 18.5.

TABLE 18.5 AUGMENTATION OF EXISTING CULVERTS TO ACHIEVE 100 YEAR ARI DESIGN[1]

CULVERT	CHAINAGE	TYPE	ADDITIONAL CELLS[1]	SIZE (mm)	PROPOSED HEADWATER DEPTH (m)	CHANGE IN HEADWATER DEPTH[2] (m)	PROPOSED FREEBOARD[3] (m)
C8B	10.380 km	Pipe	2	1800	4.5	-0.2	0.5
C9A	10.988 km	Pipe	1	1350	2.4	-0.4	0.2
C19A	18.080 km	Pipe	2	600	1.9	-0.9	0.5
C20A	18.310 km	Box	2	2440 x 1220	1.9	-0.7	0.4
C22A	18.893 km	Pipe	1	900	1.3	-0.6	0.5
C23A	19.469 km	Pipe	1	600	1.3	-0.1	0.3
C26A	22.475 km	Pipe	2	750	1.4	-0.8	0.4

1 The culvert augmentation requirements would be further defined during the detailed design phase of the project.
2 Negative (-ve) denotes decrease in headwater depth.
3 Proposed freeboard to highway upgrade levels.

As indicated in Table 18.5, proposed culvert augmentation works would reduce peak water levels upstream from the Proposal.

Augmentation of culvert arrangements has the potential to increase discharges and hence water levels downstream of the culvert. However, the culvert augmentations have been designed to achieve flood immunity for the Proposal in a 100 year ARI flood event without increasing peak discharge and hence peak water levels downstream.

The two dimensional MIKE 21 models generated for the floodplain areas do not predict any significant alterations to the current discharge distributions, flow velocities or peak water levels across the floodplain downstream of the Proposal. Similarly, the one dimensional models generated for the confined watercourses do not predict any significant alterations to the current discharge distributions, flow velocities or peak water levels in the non-floodplain areas downstream of the Proposal.

In summary, the proposed culvert augmentations are predicted to decrease flood levels upstream of the Proposal without significantly altering downstream flood behaviour.

New culverts (bypass section)

On the bypass section of the Proposal, the alignment crosses the upper catchments of the creek systems. Many of the proposed creek crossings on the bypass section are located in deep fill areas. All culverts on the bypass section have been designed to provide a minimum freeboard of 0.7 metres to the highway in the 100 year ARI flood event and to cater for these flood events with minimal changes to the level and extent of flooding, inundation periods and flood flow velocities upstream and downstream of the Proposal. In developing the design, predicted upstream water levels were compared to existing property levels. Considerable freeboard is maintained to nearby residences in a 100 year ARI flood event and any afflux (however minor) would be limited to the immediate vicinity of the watercourses.

In summary, the proposed culvert extensions and augmentations on the upgrade section of the Proposal are predicted to have a minor (if any) impact on existing flood behaviour. Peak flood levels would be reduced immediately upstream of augmented culverts. Any other changes to the level and extent of flooding, inundation periods and flood flow velocities are predicted to be minor and localised. Culverts proposed along the bypass section of the Proposal have been designed to pass the 100 year ARI design event discharges with sufficient freeboard to the proposed pavement levels and with manageable culvert velocities (and hence head loss and afflux). Freeboard is provided to upstream residences in the both the upgrade and bypass sections.

Proposed bridges

A hydraulic analysis of each of the bridged waterway crossings on the highway has been undertaken to determine flooding characteristics for both the existing and proposed bridge structures. Peak flow, water level and velocity estimates for the proposed bridge locations are provided in Table 18.6 for the 20 year, 100 year and 2000 year ARI design events.

TABLE 18.6 DESIGN FLOOD DETAILS AT PROPOSED BRIDGES

BRIDGE CROSSING	20 YEAR ARI			100 YEAR ARI			2000 YEAR ARI		
	Flow (m^3/s)	Flood level (m AHD)	Velocity (m/s)	Flow (m^3/s)	Flood level (m AHD)	Velocity (m/s)	Flow (m^3/s)	Flood level (m AHD)	Velocity (m/s)
Cunninghams Creek	51	2.8	1.5	71	3.1	1.7	116	3.9	2.3
Skinners Creek	66	4.7	1.6	94	5.3	1.8	154	6.5	2.4
Double Crossing Creek	65	3.6	0.8	89	4.0	1.0	143	4.7	1.3
Woolgoolga Creek	155	14.4	1.8	206	14.8	2.0	314	15.5	2.4
Poundyard Creek (arch culvert)	23	33.6	2.5	30	33.8	2.4	N/A	N/A	N/A
Arrawarra Creek	52	5.6	2.3	74	6.1	2.7	119	6.9	3.2

Upgrade section bridge works

In the upgrade section, the Proposal includes replacement of the existing highway bridges at Cunninghams Creek, Skinners Creek and Double Crossing Creek and the existing bridge on Hoys Road at Cunninghams Creek. The new / replacement structures would have longer spans with higher waterway clearance to the underside of bridge deck than the existing bridge structures.

As is the case for the augmented culvert designs, the larger "under-bridge" areas are not predicted to alter discharge distributions or reduce flood attenuation upstream of the existing highway. No increases in peak water level are therefore predicted downstream of the proposed works (refer Table 18.7).

Bypass section bridge works

The proposed bridge works in the bypass section have been designed to minimise impacts on flood behaviour. The deck of the new three span bridge structure proposed for Woolgoolga Creek on the bypass section of the Proposal is to be located well above the level of the 1 in 2000 year flood event and the piers have been located to minimise potential impacts on the watercourse. The proposed arch culvert at Poundyard Creek would span the natural channel as well as the predicted extent of inundation.

Potential hydraulic impacts of the proposed bridge works

Existing and predicted flood levels upstream and downstream of the proposed highway bridge structures in a 1 in 100 year flood event are provided in Table 18.7.

TABLE 18.7 EXISTING AND PREDICTED FLOOD DETAILS AT PROPOSED BRIDGES

BRIDGE CROSSING	UPSTREAM FLOOD LEVEL			DOWNSTREAM FLOOD LEVEL		
	EXISTING (m AHD)	PROPOSED (m AHD)	CHANGE IN FLOOD LEVEL (m)	EXISTING (m AHD)	PROPOSED (m AHD)	CHANGE IN FLOOD LEVEL (m)
Cunninghams Creek	3.02	3.08	0.06	2.58	2.58	0.00
Skinners Creek	5.25	5.27	0.02	3.97	3.97	0.00
Double Crossing Creek	4.00	4.04	0.04	3.76	3.76	0.00
Woolgoolga Creek	14.67	14.76	0.09	14.21	14.21	0.00
Poundyard Creek (arch culvert)	33.76	33.78	0.02	32.57	32.57	0.00
Arrawarra Creek	5.94	6.05	0.11	4.32	4.32	0.00

As illustrated in Table 18.7, the hydraulic modelling predicts that any increase in peak water levels upstream of the proposed bridges would be less than 0.11 metres and that there would be no change in peak water levels downstream of the bridges. A review of the potential impact of the predicted increases in upstream flood levels on existing properties has been conducted. Excluding residences proposed to be acquired for the Proposal, the nearest residence upstream of any of the proposed bridges is approximately 170 metres north of Skinners Creek. This residence has a minimum clearance of approximately one metre from the predicted 100 year ARI flood level. Residences upstream of other bridge sites are outside the area of any likely influence of the proposed structures.

Conclusions

In summary, cross drainage along the length of the Proposal would be facilitated at culvert locations and at bridges that, in accordance with the objectives of the Pacific Highway Upgrade Program, provide flood immunity for at least one highway carriageway for a 100 year ARI flood event.

Existing flooding behaviour upstream and downstream of the Proposal would not be substantially altered. The most substantial changes would be decreased flood levels upstream of the augmented culverts along the upgrade section. No additional residences would be affected by the 100 year ARI flood event as a result of the Proposal and any impacts on adjacent properties would be minor and limited to the immediate vicinity of the watercourses.

18.2.2 Soils and surface water quality

Construction phase

Soil characteristics including erodibility, contamination and acidity are inextricably linked to water quality. The landuse type surrounding a watercourse or water body (ie.. vegetated / undeveloped compared to industrial land use) also influences its water quality to various extents. Exposure of some soils may induce a higher risk to water quality than others. The potential water quality impacts discussed below are provided in this context.

The majority of the upgrade section would traverse through the Newports Creek landscape unit. In particular, the Newports Creek landscape unit occupies the area of Cunninghams Creek, Skinners Creek and Arrawarra Creek affected by the Proposal. As well as these locations, Double Crossing Creek and Moonee Creek both form a local north / south division between Ulong and Newport Creek landscape units. The Moonee landscape unit covers the upgrade section that crosses Sugarmill Creek. The Newports Creek landscape unit is typically a poorly drained acidic soil subject to seasonal waterlogging. The Ulong landscape unit is only moderately erodible whilst the Moonee landscape has high erodibility.

The majority of the bypass section traverses the Megan landscape unit and closer to the foot of the Great Dividing Range, the Suicide landscape unit. Both Poundyard Creek and Hayes Creek (in the upgrade section) transect an area of the Megan landscape unit. Woolgoolga Creek to the north is located within an area of Coffs Creek landscape unit. The Megan landscape unit occurs in low rolling hillsides and is considered to be a highly erosive environment. As the landscape becomes steeper, there is a transition to the Suicide landscape unit which also has a high erosion hazard. The Coffs Creek landscape unit is poorly drained and experiences seasonal waterlogging.

Construction of the Proposal would result in considerable disturbance to soils. The disturbance and exposure of soils, in particular within or immediately adjacent to drainage lines and waterways, is recognised as one of the potential main environmental risks to the integrity of local water quality.

During periods of rainfall, erosion of exposed areas would have the potential to be exacerbated and sediment-laden runoff and associated pollutants could potentially enter downstream waterways leading to increased turbidity and therefore a reduction in quality of aquatic habitat.

The Proposal would require some in-stream (channelisation) works at Arrawarra Creek . The Proposal also requires removal of a number of existing bridge structures which would also potentially impact on water quality (at least in the short term). These existing bridge structures are:

- Pacific Highway crossing over Cunninghams Creek.
- Hoys Road crossing over Cunninghams Creek.
- Pacific Highway crossing over Skinners Creek.
- Pacific Highway crossing over Double Crossing Creek.

The Proposal also includes ancillary works (refer Section 8.4), all of which expose soils during construction. This increases the risk of erosion and therefore the sedimentation of waterways.

Mitigation and management measures to address potential issues associated with soil erosion and water quality are addressed in Section 18.3.

Operation phase

The existing highway has few, if any, water quality controls where it crosses existing watercourses. The water quality management measures proposed as part of the concept design would therefore result in an overall net improvement to water quality generally along the length of the upgrade section.

Notwithstanding, it is recognised that the Proposal would result in a net increase in stormwater runoff due to the increase in surface area of impermeable materials (the proposed highway carriageways, bridges and local access road network).

The proposed design provides for stormwater to be directed to newly constructed water quality control structures for treatment prior to release into the creek systems. These structures would also function as chemical spill containment structures and would be designed to retain non-soluble and less dense pollutants such as hydrocarbons through the use of a permanent pond of water. The exact location of water quality control structures would be determined during detailed design and take into account local environmental and community issues.

The proportionate increase in the area of impervious surfaces within the bypass section would be substantially greater than the upgrade section as it currently has rural land uses and undeveloped forested land. The increase in area of imperviousness has a direct relationship to the volume and velocity of stormwater that would need to be controlled and treated. The Proposal would include appropriately designed water quality control structures to minimise release of any untreated stormwater from the road corridor for this section.

It is noted that specific concerns have been raised by the community over the effects of the Proposal on the waterways in the area, and in particular potential for downstream impacts on the Solitary Islands Marine Park. Stringent mitigation and management measures (refer Section 18.3) are proposed during construction in recognition of the particular sensitivities. With these in place, coupled with monitoring, impacts on water quality are expected to be very minor if not negligible.

18.2.3 Acid sulfate soils

The majority of the Proposal would pass through areas considered to have negligible or low probability of acid sulfate soils. However, isolated areas such as Arrawarra Creek, localised sections north of Arrawarra Creek, Woolgoolga Creek and the area immediately east of the existing highway at Cunninghams Creek, exhibit high probability of acid sulfate soils. There is also a high probability of acid sulfate soils occurring within the bottom sediment in Double Crossing Creek to the immediate east of the existing highway.

Without careful management and control, acid sulfate soils can pose a potential environmental risk if the pyretic material is exposed to oxidation leading to the generation of acid runoff. The pollution potential of acidic drainage is high, particularly if it is allowed to enter nearby watercourses as it can result in the lowering of pH in the water, which in turn can deplete dissolved oxygen, mobilise metals such as aluminium, reduce rates of photosynthesis, and significantly affect aquatic flora and fauna. Potential acid sulfate soils are harmless to the environment as long as they remain waterlogged.

Off-site effects of the exposure of potential acid sulfate materials to oxygen can also include flushing of extremely acid and aluminium rich toxic water during rain. Acid water contamination can have potentially serious implications for aquatic ecology and commercial fisheries, including fish kills and fish disease outbreak. In addition, corrosion of concrete and steel by acids and salts can cause serious problems for infrastructure and require significant expenditure on maintenance of public structures.

18.2.4 Groundwater

The proposed alignment has the potential to cause drawdown of the groundwater table, as well as potential reductions in groundwater flow, around major cuttings. In areas of potential or known acid sulfate soils, lowering of the water table could also potentially allow oxygen to reach groundwater, which could result in the oxidation of sulfide minerals. This process generates acid which, on rewatering, could migrate as acidic groundwater, potentially affecting groundwater receptors (surface water and other areas where groundwater seeps to the surface).

Localised drawdown of very shallow water perched within residual soils could also occur around cuttings. These effects however, are generally very localised. Further detailed groundwater investigations would be undertaken at the detailed design stage and appropriate measures (design and mitigation / management) would be implemented to manage these potential impacts.

There is also the potential for the quality of the groundwater recharge to be adversely affected by fuel spillages and other soluble contaminants, or possibly from the disturbance of contaminated soils and/or acid sulfate soils as identified above and thus adversely affecting groundwater quality and groundwater-dependent ecosystems.

Proposed management measures to address these potential impacts are described in Section 18.3.

18.3 Proposed management measures

18.3.1 Hydrology and hydraulics

A fundamental feature of the Proposal design has been to minimise impacts on the existing flood regime. Cross-drainage infrastructure including bridges and culverts have been designed to be minimise any potential changes to afflux (ie. increase in flood levels upstream of the crossing). Adequate cross-drainage infrastructure (in terms of both location and capacity) would be provided to maintain natural flow paths. The design would also ensure that embankments would not obstruct flood flows during major storm events.

Where possible the location of proposed low points associated with the new Highway would coincide with low points with the existing Highway.

The design would include appropriate grade / drainage to minimise the opportunity for sediment to accumulate in the drainage structures.

18.3.2 Soil and surface water management

In general soil, surface water management measures would come in three primary forms:

(i) Management of activities during construction aimed at minimising the production of elevated levels of suspended solids and pollutants in site runoff.

(ii) Physical design measures aimed at settling out sediment from runoff during construction and operation.

(iii) Management during operation.

Water quality control structures would be positioned at numerous locations along the Proposal, generally adjacent to culverts at transverse creek lines, both upstream and downstream of the highway formation. The structures would be located so as to provide for the catchment and temporary storage of run-off from all cut batters and associated berms and benches. Runoff from the road pavement would be directed to the structures via pipes and pits that would be constructed through the road cuttings. The location and sizing requirements for the water quality control structures would be further refined during the detailed design of the project.

The RTA will ensure that water quality control structures are designed and located in accordance with the provisions of the draft *Managing Urban Stormwater: Soils and Construction, Volumes 1 and 2, Book 4, Main Road Construction* (DECC 2006) and are constructed, operated and maintained to meet the requirements of the RTA's *Code of Practice for Water Management – Road Development and Management*.

Water quality management measures are specified in the draft Statement of Commitments (Appendix A), which are:

(i) Water quality will be monitored upstream and downstream of the project site during construction to determine the effectiveness of mitigation strategies.

(ii) Where feasible and reasonable, the area of soil exposure during construction will be minimised.

(iii) There will be progressive revegetation of earthworks areas and stabilisation and restoration works.

(iv) Specific construction methods will be developed and implemented for in-stream works in consultation with relevant government agencies to limit water quality impacts.

(v) Site-specific construction methods and water management controls will be developed and implemented where the Proposal crosses the Solitary Islands Marine Park in consultation with relevant government agencies to limit water quality impacts.

(vi) Water quality will be monitored specifically at locations where in-stream works are proposed and where the Proposal crosses the Solitary Islands Marine Park to determine the effectiveness of water management controls.

Some of the sediment control basins established during construction would likely be converted to permanent water quality basins for the operation of the Proposal. Permanent stream protection measures and other waterway structure requirements would also be established. Water quality during operation would be managed through the application of standard management measures and design requirements for construction and operation phase water quality control structures will be determined on the basis of a site-specific investigation that considers the sensitivity of the receiving environment and the proximity of the discharge point to receiving waters.

These mitigation and management measures, along with the proposed design features are considered appropriate to manage the potential water quality issues identified as being associated with the construction and / or operation of the Proposal.

18.3.3 Acid sulfate soils

The potential engineering and environmental consequences of building on acid sulfate soil materials was taken into account in developing the concept design for the Proposal. This would be further considered at the detailed design stage, with appropriate environmental management measures implemented during construction.

Given the presence of potential acid sulfate soils along the Proposal, the following commitments have been identified (refer Appendix A) to manage identified acid sulfate soil impacts:

(i) Areas of Potential Acid Sulfate Soils and actual Acid Sulfate Soils will be identified and oxidisation of acid sulfate soil material will be limited, any exposed acid sulfate soil will be neutralised and surface water drainage and buffer acid runoff will be controlled.

(ii) Containment strategies will be identified and implemented to ensure that all acidic leachate associated with the oxidation of acid sulfate soil is contained for treatment or removal and is prevented from entering downstream watercourses.

18.3.4 Groundwater

The potential for changes in the groundwater table in response to significant construction activities that have a likelihood of impact will be investigated. Where a potential for change is identified, the significance of the change and any resultant impacts will be determined and where necessary, measures to manage the changes will be designed and implemented in consultation with relevant government agencies.