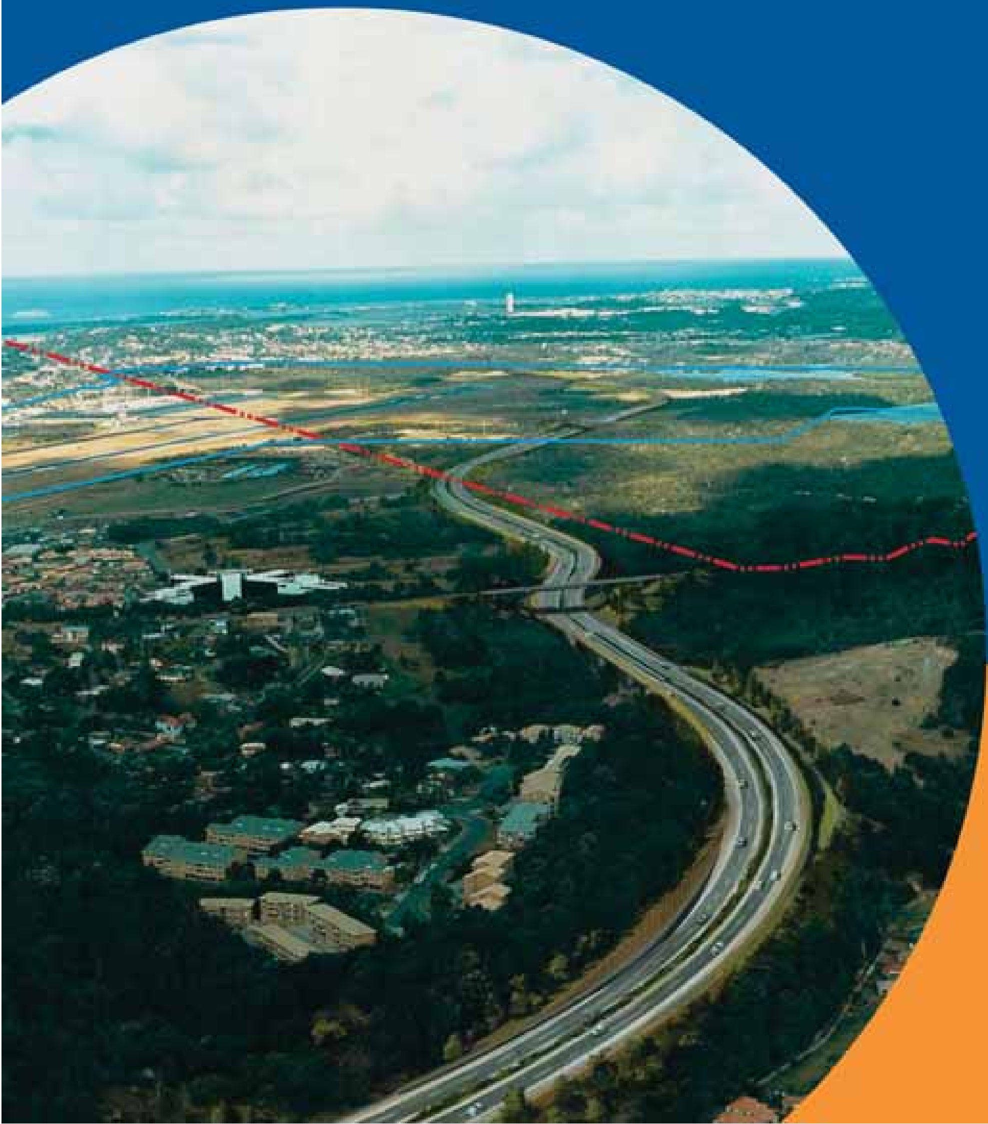
Australian Government
Department of Transport and Regional Services
RTA
Queensland Government
Department of Main Roads

TUGUN BYPASS

stewart road to kennedy drive



Technical Papers

December 2004

Tugun Bypass Environmental Impact Statement

Technical Paper Number 8
Surface Water Quality Assessment

Tugun Bypass Alliance

Client:	Queensland Department of Main Roads
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Glossary

Term	Meaning
Adsorption	A process by which metal ions or nutrients can react with or be held on a surface, particularly soil.
Aerobic	The presence of free oxygen.
Ambient	The background environmental condition.
Ammonium	A reduced form of inorganic nitrogen (NH_4).
Anaerobic	The absence of free oxygen.
Analysis	Method used to identify the amount of a substance.
Australian Height Datum (AHD)	Standard datum, with 0 m AHD corresponding approximately to mean sea level.
Average Annual Daily Traffic (AADT)	The average daily traffic flow at a location, averaged over a year.
Average Recurrence Interval (ARI)	The return period of a certain event. For example, a storm event having a 1 in 100 year ARI would occur once every 100 years.
Bacteria	A primitive group of ubiquitous, microscopic, single celled organisms lacking a nucleus.
Biochemical Oxygen Demand (BOD)	The amount of oxygen required by the aerobic mico-organisms (and processes) present in a water sample to oxidise any organic matter present to a stable inorganic form.
Catchment	The area of land which collects and transfers rainwater into a waterway.
Chlorophyll (Chl-a)	Major pigment that captures light for photosynthesis, found in cells of plants and bacteria. Used to indicate algal populations in water column.
Concentration	The strength or amount of substance in a known volume or mass.
Constructed Wetland	Permanently or periodically wet structural stormwater treatment device, incorporating planted vegetation and designed specifically to treat stormwater run-off.
Contamination	Alteration of a sample through mishandling, or pollution of an area through mismanagement or accident.
Denitrification	The conversion of the biologically available, oxidised form of nitrogen (NO_3) to nitrogen gas (N_2) which is biologically unavailable, by anaerobic bacteria.
Discharge	A term used to describe water flows at or from a given point.
Dissolve	The breakdown of a solid material into soluble parts.
Dissolved Oxygen (DO)	The amount of oxygen dissolved in solution. May be expressed in absolute terms (mg/L) or may be expressed at a percentage of the saturation value at the solutions temperature (percent Sat.).
Environmental Value	The uses, sensitivities or values of a natural asset, identified through the needs and wants of the community.
Eutrophication	Excessive enrichment of a water body with nutrients.

Term	Meaning
Gross Pollution Trap	A sediment trap with a litter rack, usually located at the downstream end of the structure.
Heavy Metals	A subset of 'trace elements' which may include copper, zinc, lead, cadmium and mercury.
Macrophyte	Emergent wetland plant.
Monitoring	The procedure used to watch, observe and document changes through time and space.
Multiprobe (Water Quality Instrument)	A device used to simultaneously measure several water quality parameters in situ.
Nitrate	The most abundant oxidised form of nitrogen (NO_3).
Nitrification	The conversion, carried out by aerobic bacteria, of the reduced form of nitrogen, ammonium (NH_4), to the oxidised forms, nitrite (NO_2) and nitrate (NO_3).
Nitrite	An oxidised form of nitrogen (NO_2).
Nitrogen	An essential nutrient for all organisms forming a component of amino acids, protein, and genetic material.
Nutrient	Essential elements required by an organism for growth.
Oxidised Nitrogen (NOx-N)	The sum of nitrate nitrogen and nitrite nitrogen.
Particulates	The solid component in a water sample.
Phosphorus	An essential nutrient for all organisms forming a component of, for example, ATP and phospholipids.
Photosynthesis	The process carried out by plants and some bacteria in which light energy is harvested by pigments (mostly chlorophyll) and utilised to convert carbon dioxide and water into organic molecules and oxygen.
Run-off	That portion of rainfall that is not immediately absorbed into or retained by the soil e.g. overland flow.
Salinity	Salt content of seawater expressed in parts per thousand.
Sampling	The procedure used to collected a sample.
Sediment	Particulate matter at the bottom of the water column of rivers/bay, generally derived from soil on land.
Surfactants	Surface-active agents which are soluble and form oriented monolayers at the surface of a liquid. They have detergency, foaming, wetting, emulsifying and dispersing properties.
Suspended Sediment	Particles in suspension in flowing or static water.
Total Kjeldahl Nitrogen (TKN)	The sum of the concentration of nitrogen as ammonia plus the concentration of nitrogen as organic nitrogen.
Total Nitrogen (TN)	The total concentration of all nitrogen species present in solution (oxidised nitrogen, organic nitrogen and ammonia).
Total Petroleum Hydrocarbons (TPH)	The concentration of hydrocarbon in a sample that is determined by subtracting the fatty acids from the total grease concentration.

Term	Meaning
Total Phosphorus (TP)	The total concentration of all phosphorus species present in solution (particulate and dissolved).
Total Suspended Solids (TSS)	The total concentration of filterable solids present in suspension.
Turbidity	A measure of the ability of light to pass through water. The units of turbidity are Nominal Turbidity Units (NTU).
Water Column	The water from surface to bottom at a particular point.

1. Introduction

1.1 Summary of the Technical Paper

This technical paper examines the potential surface water quality issues associated with the implementation of a proposed transport corridor west of Tugun. The potential water quality impacts of the proposal are identified and discussed, with mitigation measures to address the potential impacts provided. Recommendations are also made regarding monitoring activities to be undertaken to assess the impacts of the proposal during construction and operation.

The waterways potentially affected by the proposal are Cobaki Creek and Broadwater, Currumbin Creek and Coolangatta Creek. Included in the potentially affected waterways are areas of NSW *State Environmental Planning Policy Number 14* Coastal Wetlands, which have high ecological significance.

The waters of Cobaki Broadwater exhibit salinities near that of ocean water during dry weather periods, have typically healthy dissolved oxygen and pH levels and show little stratification. Ortho-phosphorus and oxidised nitrogen concentrations have however, frequently exceeded *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000).

The lower reaches of Currumbin Creek in the vicinity of the proposal exhibit salinities near that of ocean water during dry weather periods and typically have healthy dissolved oxygen and pH levels. Nutrient levels in the creek appear to be low, though exceedances of the ANZECC (2000) default trigger values for oxidised nitrogen, total nitrogen and total phosphorus have been observed.

Monitoring results for Coolangatta Creek demonstrate large fluctuations in pH and nutrient levels in the creek, with exceedances of the ANZECC (2000) default trigger values recorded for zinc, aluminium, copper, lead, nickel, pH and total phosphorus on occasions.

During construction of the proposal, receiving water quality could be adversely affected by erosion, sedimentation and poor site-management practices. Potential pollutants include sediment generated in run-off at exposed areas, litter from construction packaging and waste material, hydrocarbons and toxicants from spills and leakages, and pH altering substances from acid sulfate soil disturbance.

During operation of the project, run-off from impervious surfaces may contain elevated levels of gross pollutants and litter, suspended solids, nutrients, biological oxygen demand (BOD), micro-organisms, heavy metals and oils and surfactants. The potential also exists for chemical spills to occur as a result of a traffic accident. This could have a toxic effect on the receiving environment.

A range of erosion and sediment control practices, as well as site management techniques, are proposed during construction of the proposal in order to mitigate potential water quality impacts. As part of these controls, sedimentation basins would be installed. The possible sites for these basins is discussed in this technical paper.

A series of measures comprising grassed swale drains, gross pollution traps and constructed wetlands is proposed for inclusion in the proposal. The possible sites of the constructed wetlands is discussed in this technical paper.

A system of water quality monitoring is proposed during construction and operation of the proposal in order to assess the performance of mitigation measures. Monitoring would be primarily conducted in the creeks crossing the route, with the impacts of the proposal assessed by comparing monitoring results to water quality objectives (determined from a baseline water quality study).

If the mitigation measures proposed in this report are implemented, the potential water quality impacts of the proposal are expected to be reduced to acceptable levels. By implementing the recommended monitoring regime during construction and operation of the proposal, impacts from the proposal would be accurately identified and further mitigation measures employed, if required.

Further, the requirements of the Queensland *Environmental Protection Act 1994* have been met by this document recommending an appropriate means of setting water quality guidelines consistent with ANZECC (2000), the *Environmental Protection (Water) Policy 1997* and the NSW *Environment Protection Authority Interim Water Quality Objectives* (2000). Consideration of the NSW Environment Protection Authority *Interim Water Quality Objectives* (2000) is consistent with the intent of the NSW *Water Management Act 2000*. Additionally the requirements of the *Environmental Protection (Water) Policy 1997* has been met by the specification of a stormwater treatment drain to ensure these water quality objectives will be met by the proposed project.

1.2 Reporting of Study Findings in the EIS

The studies for the Tugun Bypass environmental impact assessment commenced in 2000. In the subsequent four years the results of the various studies have been used to refine the concept design of the proposal. Further studies were also commissioned to ensure that all aspects of the various environmental issues were fully understood.

The long time period of the assessment has meant that the content of some of the earlier reports has been superseded by newer work. Changes to the design of the bypass have also been introduced to take account of these studies.

In the event that there is a contradiction between the technical papers and the text of the EIS, the EIS takes precedence as it reports the current understanding of issues, impacts and the concept design.

2. Existing Conditions

2.1 Catchment Overview

The proposed route alignment would not traverse any major watercourses, but would be located within the catchments of three waterways, namely Cobaki Creek and Broadwater, Currumbin Creek and Coolangatta Creek. The location of the route alignment with respect to these catchments is shown in Figure 2.1.

The catchment of Cobaki Broadwater is largely undeveloped at present, although some of the lower areas of the Tweed River catchment (to which the Broadwater is tidally connected) are highly urbanised. Extensive areas of NSW *State Environmental Planning Policy Number 14* wetlands occur in and around the Cobaki Broadwater in the vicinity of the alignment, as shown in Figure 2.1.

Only *State Environmental Planning Policy Number 14* wetland Number 5a may be indirectly affected by the proposal through stormwater run-off. A section of the proposed road alignment located to the east of this wetland would be accommodated in tunnel. As a result, this section of the alignment would not drain directly into the *State Environmental Planning Policy Number 14* wetlands during the operational phase of the proposed development. However, construction works would occur in close proximity to the wetland areas.

Wetlands listed under *State Environmental Planning Policy Number 14* are regarded as having state significance. Estuarine wetlands are considered to be ecologically significant for the following reasons (Technical Paper Number12):

- estuaries are the habitat for part or all of the life-cycle for the majority of commercially and recreationally important fish species in eastern Australia;
- the shallow waters and intertidal habitats of estuarine wetlands are among the most important habitats for fisheries;
- estuarine wetlands provide habitat and food sources for a range of terrestrial and bird species such as conservation significant species and species listed under international agreements; and
- wetlands provide a retreat for fauna during drought, fire and other adverse conditions.

Due to the high ecological significance of estuarine wetlands, it is important that effective mitigation measures are included in the proposal to mitigate potential impacts.

The catchment of Currumbin Creek in the vicinity of the route alignment is highly urbanised. Run-off from the proposal would be conveyed to Currumbin Creek through minor drains where it would be discharged into the lower estuary in the vicinity of the creek mouth.

Coolangatta Creek is a highly disturbed urban stream existing in a catchment that is almost entirely urbanised. The creek exists in either piped form or as a concrete channel over most of its length, with the only section exhibiting potential for vegetation and bird life occurring where it crosses the property of Gold Coast Airport Limited. Downstream of the airport the creek is conveyed under the Tweed Heads Bypass and then through a 400 m long culvert to be discharged at the beach at Kirra.

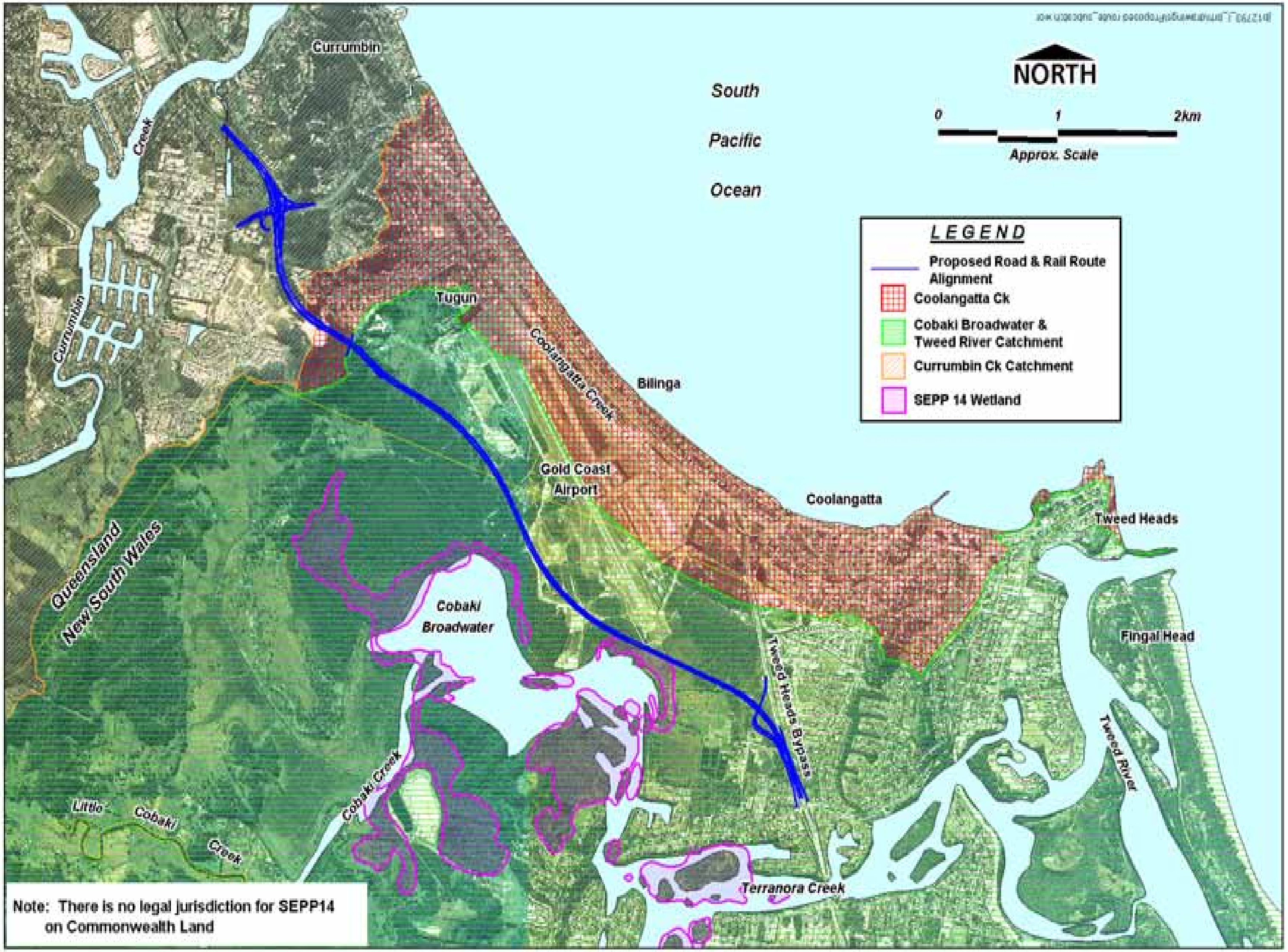


Figure 2.1: Waterways and Sub-catchments in the Vicinity of the Proposed Route Alignments

2.2 Existing Water Quality

2.2.1 Waterway Uses and Environmental Values

The ultimate receiving waters for run-off associated with the proposal are mainly Cobaki Creek and Broadwater, with some sub-catchments contributing flow to Coolangatta Creek and Currumbin Creek.

Cobaki Broadwater and Currumbin Creek provide:

- recreational amenity associated with boating, fishing, swimming and visual enjoyment by the public; and
- habitat for plants, fish, birds and mammals, including the presence of designated coastal wetlands defined under NSW *State Environmental Protection Policy Number 14*.

Coolangatta Creek occurs in an almost fully urbanised catchment and is either piped or channelised along most of its length. However, for a small section through the Gold Coast Airport it supports a variety of aquatic vegetation and bird life. The creek ultimately discharges to surf beaches used for swimming, fishing and providing visual amenity.

In accordance with protection of these existing environmental values, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) apply to Cobaki Creek and Broadwater, Currumbin Creek and Coolangatta Creek. In addition, the Airports (Environment Protection) Regulations 1997 limits apply to Cobaki Broadwater and Coolangatta Creek.

2.2.2 Historical Water Quality Data

Historical water quality data has been obtained for the receiving waters potentially affected by the proposed route. These data are discussed below for each of the major receiving waterbodies.

Cobaki Creek and Broadwater

An extensive body of existing water quality information is available for Cobaki Creek and Broadwater. Surface water quality data available includes data collected by:

- NSW State Pollution Control Commission (1985);
- Tweed Shire Council (1989 - 1996);
- WBM Oceanics (1991); and
- NSW Environment Protection Authority (1996) for the *Northern Rivers Water Quality Assessment*.

Historical data collected from each of these sources are provided in Appendix A. The locations of monitoring sites are presented in Figure 2.2. Based on the available data set, the following key observations have been made regarding water quality in the study area:

- Under dry weather conditions, salinity is relatively constant in the Cobaki Broadwater and Cobaki Creek (approaching that of sea water). Following 24 hours of considerable rainfall, freshwater conditions have been observed in Cobaki Creek, with salinities in Cobaki Broadwater approximately 30 percent those of seawater (WBM Oceanics, 1991, event of 13 December 1991).

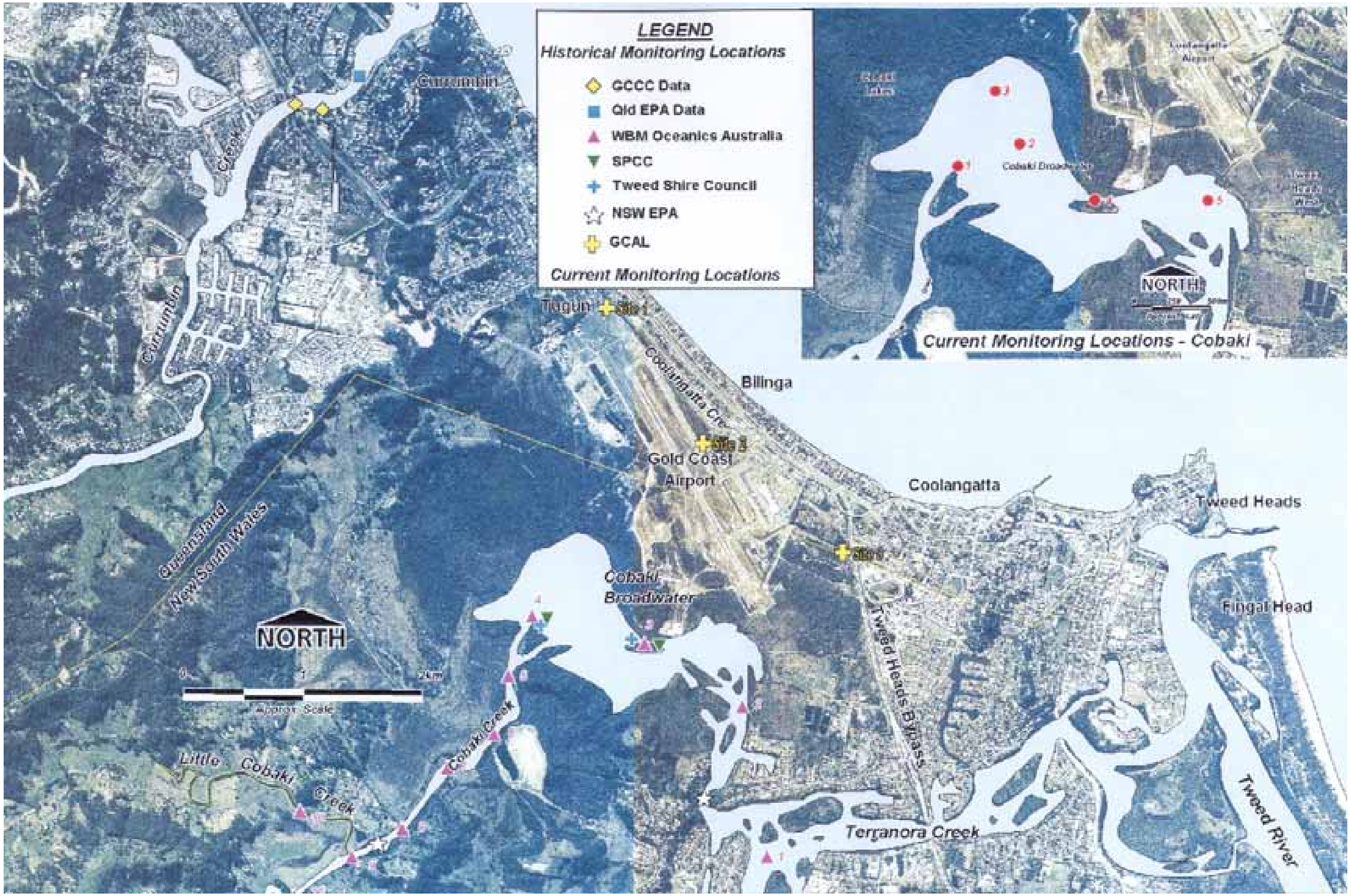


Figure 2.2: Water Quality Monitoring Locations

- Dissolved oxygen (DO) levels in Cobaki Broadwater typically range from 80 to 110 percent saturation, which is considered to be acceptable (i.e. when compared with ANZECC (2000) default trigger values for estuarine waters). Within Cobaki Creek however, symptoms of oxygen supersaturation and depletion are evident.
- pH values are relatively constant at acceptable levels during low freshwater flow periods, typically decreasing with passage upstream, possibly due to the exfiltration of low pH groundwaters. After significant rainfall, pH values in the creek and Broadwater were seen to reduce slightly (WBM, 1991, event of 13 December 1991).
- A peak in turbidity was noted in the data just upstream of the Broadwater. The re-suspension of fine sediments from the Broadwater on the flood tide would contribute to such characteristics, as would wind wave induced sediment re-suspension.
- The nutrients, total nitrogen (TN) and total phosphorus (TP) display little, if any, variational trend along Cobaki Creek. It should be noted that the State Pollution Control Commission data was collected at a time when the Tweed Heads West Sewage Treatment Works was discharging into Cobaki Broadwater. This has subsequently been shifted to Terranora Inlet as an ebb tide discharge. The State Pollution Control Commission data values are typically higher than those collected by Tweed Shire Council, WBM Oceanics, and the NSW Environment Protection Authority. This reflects the added nutrient levels in Cobaki Broadwater that previously occurred when the Tweed Heads West Sewage Treatment Works discharged to the Broadwater.
- A comparison of more recent water quality data (Tweed Shire Council and NSW Environment Protection Authority data) indicate that most water quality parameters have not changed to any great extent since the WBM Oceanics Australia data set was collected in 1991. One exception is that the levels of total nitrogen observed more recently appear to be slightly higher than the 1991 WBM Oceanics data set.

Currumbin Creek

Both Gold Coast City Council and the Queensland Environmental Protection Agency have monitored water quality in Currumbin Creek at a number of sites. Water quality data were obtained for sites in the vicinity of the discharge point from the drain crossing the proposed route, with the location of these sites shown in Figure 2.2.

The Gold Coast City Council data are more recent, covering the period from 1991 to 1996 with approximately monthly sampling intervals. The Queensland Environmental Protection Agency data cover the period 1973 to 1982 with an irregular sampling frequency. The average and standard deviation for each of the parameters monitored by both Gold Coast City Council and the Queensland Environmental Protection Agency are provided in Tables 2.1 and 2.2 respectively, where they are compared with both the south-east Queensland ANZECC (2000) default trigger values for physical and chemical stressors for slightly disturbed (estuarine) ecosystems and primary contact recreation guidelines.

Where no guideline is provided in the table (represented by n/a), either no guideline exists for that parameter in this waterway type (estuarine) or the guideline cannot be directly compared to the dataset. For example, a guideline exists for suspended solids which state ‘less than 10 percent change in seasonal mean concentration’. As the seasonal mean concentration for this waterway is not known, no guideline is provided for suspended solids in the table.

As the whole dataset has not been presented (only means and standard deviations), exceedances of the guideline values are not identified (shaded) in the table but are discussed in Section 2.2.4.

Table 2.1: Gold Coast City Council Monitoring Data (Currumbin Creek)

	Temp. (deg-C)	Cond. (mS/cm)	DO (mg/L)	pH	TSS	TN	TP	Faecal Coliforms (org./100mL)	Turbidity NTU
Average	22.1	48.5	6.6	8.1	14.0	0.20	0.04	133	2.0
(± Std. Dev.)	(±2.5)	(±9.0)	(±0.7)	(±0.3)	(±18.2)	(±0.08)	(±0.02)	(±564)	(±0.8)
ANZECC (2000)	n/a	n/a	>6 NB	7.0-8.5	n/a	0.3	0.03	150	0.5-10

For notes on parameters and acronyms included in tables please refer to the glossary

Table 2.2: Queensland Environmental Protection Agency Monitoring Data (Currumbin Creek)

	Organic-N (mg/L)	NH3-N (mg/L)	NOx-N (mg/L)	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Faecal Coliforms (org./100mL)	Turbidity (NTU)
Average	0.25	0.06	0.03	0.35	0.05	10.8	706	5.9
(± Std. Dev.)	(±0.19)	(±0.06)	(±0.04)	(±0.21)	(±0.02)	(±8.8)	(±1801)	(±6.9)
ANZECC (2000)	n/a	n/a	0.015	0.3	0.03	n/a	150	0.5-10

For notes on parameters and acronyms included in tables please refer to the glossary

Coolangatta Creek

Gold Coast Airport Limited collects water quality data from various locations along Coolangatta Creek in the vicinity of the proposed alignment, where the creek traverses the airport property. Apart from areas within the airport, the creek is piped or channelised along most of its length.

The following two monitoring sites, as shown in Figure 2.2, were deemed the most useful to establish the quality of water within Coolangatta Creek for the purposes of this investigation:

- the entry point to the airport site (Site 1); and
- the exit point from the airport site (Site 8).

Monitoring at these locations is undertaken regularly, with a representative sample of the results of the monitoring presented in Table 2.3. Results are compared against south-east Queensland ANZECC (2000) default trigger values for physical and chemical stressors for slightly disturbed (lowland river) ecosystems and toxicant trigger values for 95 percent level of species protection (freshwater). Concentrations greater than the guidelines are shaded for easy identification.

Table 2.3: Gold Coast Airport Limited Monitoring Results - Coolangatta Creek

Analyte	ANZECC (2000)	Site 1: 9/02	Site 1: 8/99	Site 1: 8/98	Site 1: 8/96	Site 8: 9/02	Site 8: 8/98	Site 8: 8/96
Aluminium (µg/L)	55		150	120			220	
Ammonia (µg/L)	900	220		<50	20	180	<50	10
Arsenic (µg/L)	n/a	3		2		4	6	
Cadmium (µg/L)	0.2	<1		<2		<1	<2	
Copper (µg/L)	1.4	1	<5	<5		2	6	
Lead (µg/L)	3.4	3		<5		1	<5	
Mercury (µg/L)	0.6	<0.5		<1		<0.5	<1	
Nickel (µg/L)	11	<1	<5	<5		1	<5	
Zinc (µg/L)	8	29	26	17		32	14	
pH	6.5-8.0	7.2	6.5	6.44	7.1	6.5	6.9	6.8
Conductivity (uS/cm)	n/a	380		380	509	1,900	7,900	4,350
Faecal coliforms (org./100mL)	150/100ml				100			400
Suspended solids (mg/L)	n/a	4	33	18		9	9	
Total dissolved solids (mg/L)	n/a		240	230	320		5,400	2,900
Turbidity (NTU)	n/a			11	4.9		3.6	5.2
Nitrate (µg/L)	n/a	290		600	600	20	190	5,000
Nitrite (µg/L)	n/a	10		<50		10	<50	
Organic Nitrogen (µg/L)	n/a			4,000			<50	
Phosphorus-ortho (µg/L)	5	60	280	160		<10	<50	
Phosphorus-total (µg/L)	30		300	230	120		<50	<20

For notes on parameters and acronyms included in tables please refer to the glossary

Where no trigger value is provided in the table (represented by n/a), either no guideline exists for that parameter in this waterway type (freshwater) or the guideline cannot be directly compared to the dataset. It should be noted that in some situations the detection limit used in analysing for some parameters was not lower than the guideline value. In situations where the result is less than the detection limit (signified by '<') no exceedance of the guideline value is identified.

2.2.3 Field Investigations

Field investigations were conducted on 28 September 2000 by WBM Oceanics Australia personnel to collect water quality data within Cobaki Broadwater for comparison with the historical data set. Physical water quality parameters were recorded in situ using a calibrated Yeo-kal 611 water quality instrument and water samples were collected according to the methods of *Australian Standard AS/NZS 5667.1:1998* and sent to a NATA registered laboratory for analysis. The location of the field water quality monitoring sites are presented in Figure 2.2 (see inset).

The results of field investigations are presented in Table 2.4 and Table 2.5 where they are compared to the south-east Queensland ANZECC (2000) default trigger values for physical and chemical stressors for slightly disturbed (estuarine) ecosystems, with results not meeting the guidelines shaded for easy identification. Where no guideline is provided in the table (represented by n/a), either no guideline exists for that parameter in this waterway type (estuarine) or the guideline cannot be directly compared to the dataset.

Table 2.4: Chemical Water Quality Results (28 September 2000)

Site	TSS (mg/L)	NH_3-N (mg/L)	Oxidised-N (mg/L)	TKN (mg/L)	TN (mg/L)	PO_4-P (mg/L)	Chl-a (µg/L)
1	34	0.05	0.02	0.10	0.12	0.02	<5
2	27	0.05	0.02	0.30	0.32	0.02	<5
3	20	0.05	0.01	0.20	0.21	0.02	<5
4	14	0.04	0.02	0.10	0.12	0.02	<5
5	10	0.03	0.01	<0.10	0.11	0.02	<5
ANZECC (2000)	n/a	n/a	0.015	n/a	0.3	0.015	5

For notes on parameters and acronyms included in tables please refer to the glossary

Table 2.5: Physical Water Quality Results (28 September 2000)

Site	Time	Depth	Temp (deg C)	Turbidity (NTU)	Salinity (g/L)	Cond (mS/cm)	pH	Redox (mV)	DO (mg/L)	DO (%sat)
1	8:45	0.3	22.36	26.4	37.01	55.8	7.92	109	6.2	88.1
2	9:10	0.3	22.36	21.1	36.95	55.7	7.91	98	6.1	86.9
		0.5	22.36	22.2	36.96	55.7	7.91	97	6.1	87.0
3	9:00	0.3	22.48	17.7	37.00	55.8	7.89	101	6.1	87.7
4	9:25	0.3	21.99	5.2	36.85	55.6	7.98	102	6.1	86.7
		1.0	21.91	5.8	36.84	55.6	7.98	102	6.1	86.6
		2.0	21.89	5.3	36.86	55.6	7.98	102	6.1	86.6
		3.0	21.91	5.6	36.87	55.6	7.98	102	6.1	86.5
		4.0	21.99	5.2	36.87	55.6	7.98	103	6.1	86.7
		5.0	21.90	6.1	36.87	55.6	7.98	103	6.1	86.6
		6.0	21.91	5.7	36.87	55.6	7.98	103	6.1	86.6
5	9:40	0.3	21.69	4.9	36.84	55.5	8.03	112	6.3	89.1
		1.0	21.71	5.2	36.83	55.5	8.03	111	6.3	88.9
ANZECC (2000)			n/a	0.5-10	n/a	n/a	7.0-8.5	n/a	n/a	80-110

For notes on parameters and acronyms included in tables please refer to the glossary

2.2.4 Assessment of Existing Water Quality

Cobaki Broadwater

The following observations can be made regarding water quality in Cobaki Broadwater from the historical data and the measurements taken during field investigations for this study:

- dissolved oxygen levels were typically within the range specified by ANZECC (2000) default trigger values of 80–110 percent saturation;
- pH levels were typically above neutral (pH 7.0), though levels did appear to drop slightly following significant run-off;
- salinity levels during dry weather flows were generally high (>30 g/L), though levels did appear to decrease to low levels following significant run-off;
- turbidity and total suspended solids levels were seen to vary according to preceding rainfall conditions. During this monitoring episode, turbidity concentrations exceeded the upper ANZECC (2000) default trigger at Sites 1, 2 and 3. Although turbidity concentrations in exceedance of 10 NTU (ANZECC 2000) have been reported throughout the period of historical monitoring, generally speaking, concentrations were typically low to moderate, indicating good water clarity. Wind induced re-suspension of bed sediments and input of turbid inflows from the upstream catchment are likely to account for much of the elevated turbidity levels; and
- ortho-phosphorus (PO_4) concentrations at all sites exceeded ANZECC (2000) guideline levels, as did oxidised nitrogen (NO_x) at three of five sites and total nitrogen concentration at one site. Exceedances are only minor in this regard. The

low chlorophyll-a concentrations observed during the monitoring episode conducted for this study (28 September 2000) confirms these nutrient levels do not appear to be causing undesirable levels of phytoplankton growth.

Currumbin Creek

The following observations can be made regarding water quality in Currumbin Creek from the historical monitoring data collected by Gold Coast City Council and Queensland Environmental Protection Agency:

- salinity levels appear to be consistently high (approaching those of seawater) in the lower estuary, as indicated by the high average conductivity and low standard deviation;
- average dissolved oxygen and pH levels were within acceptable limits;
- faecal coliform levels showed high variation (as described by standard deviation) which is likely to be attributable to high rainfall events when sewer overflows can occur and catchment loads are highest;
- turbidity and total suspended solid levels were low, as would be expected in a highly saline environment; and
- average concentrations exceeded ANZECC (2000) default trigger values for NO_x, total nitrogen and total phosphorus by relatively small amounts in most instances.

Coolangatta Creek

The following points may be made regarding water quality in Coolangatta Creek based on the historical monitoring data collected by Gold Coast Airport Limited:

- of the metals analysed, aluminium and zinc levels were greater than the ANZECC (2000) default trigger values for toxicity (95 percent species protection - freshwater) for all sites and monitoring episodes;
- copper concentrations were observed at concentrations greater than the ANZECC (2000) default trigger values for toxicity (95 percent species protection - freshwater) on some monitoring occasions.
- minor fluctuations above and below the desirable pH range were observed;
- phosphorus concentrations (both total and ortho) were greater than the ANZECC (2000) default trigger values for all episodes at Site 1. Phosphorus concentrations were below the analytical detection limit at Site 8; and
- ANZECC (2000) default trigger values do not exist for individual nitrogen species, however a total oxidised nitrogen concentration of 60 µg/L applies to lowland rivers. Results indicate that when combined, oxidised nitrogen levels far exceed this on several occasions. It is noted that the highest concentrations are generally observed at the most upstream site, which indicates that Gold Coast Airport Limited operations are not contributing large nitrogen inputs to Coolangatta Creek.

Summary

In summary, the waters of Cobaki Broadwater and Currumbin Creek generally appear to exhibit good water quality that would normally be expected to support healthy ecosystems. The waters of Coolangatta Creek exhibit a greater variation in water quality levels, which may be attributed in part to the sporadic nature of freshwater inflows and lack of regular flushing.

3. Potential Water Quality Impacts

3.1 General Considerations

During the construction phase, receiving water quality may be adversely affected as a result of erosion and sedimentation, whereby sediment-laden stormwater run-off is transported from exposed construction areas to the receiving environment.

During the operational phase, stormwater run-off from impervious surfaces would have elevated pollutant concentrations. This is particularly relevant at interchanges and merging lanes, where braking and acceleration is most common and the associated deposition of pollutants onto the road surface is likely to be greatest. The potential also exists for chemical spills to occur as a result of traffic accidents, with harmful materials transported to receiving waters via the stormwater drainage system. The probability of such spills occurring is assessed in Technical Paper Number 16.

The potential impacts on receiving water quality from the proposed road route are discussed in detail for the construction and operational phase of the proposal in the following sections.

3.2 Construction Phase

During the construction phase, potential impacts on receiving water quality could include:

- sedimentation and elevated turbidity levels from poor erosion and sediment control during site disturbance and the movement of construction vehicles;
- litter accumulation from construction packaging and waste material;
- hydrocarbon and toxicant contamination from spills and leakages;
- changes in pH levels associated with disturbance of acid sulfate soils; and
- disturbance of material associated with the Tugun Landfill.

Sediment is generated when rain or run-off contacts exposed areas or stockpiles of earth, suspending and transporting sediment to receiving waters located downslope. Once in the receiving waters, sediment may affect the aquatic environment in a number of direct and indirect ways. Direct impacts include reduction in light penetration (limiting growth of aquatic plants), clogging of fish gills, alterations to geomorphology, smothering of benthos and reduced visibility for predatory species. Indirect impacts of sediment can occur due to the long-term accumulation and desorption of attached pollutants such as nutrients and heavy metals.

Spills of fuels or chemicals may result from poor equipment maintenance or poor housekeeping practices associated with fuel/chemical storage on the construction site. Litter may result when insufficient waste storage devices are provided. An Erosion and Sediment Control Plan would be prepared as part of the contractor's environmental management plan prior to the commencement of construction. The plan would detail measures for reducing the incidence of sediment, litter or chemical pollution reaching receiving waters during the construction phase.

Acid sulphate soils may be exposed during excavation. These soils and the leachate produced from stockpiles of such material would require appropriate treatment. This issue is dealt with in Technical Paper Number 5.

A section of the proposed transport corridor will pass through an area of the Tugun Landfill and would require some excavation of the material previously disposed of at the site. The characteristics of the landfill material and the measures which must be taken to manage this excavation process in order to mitigate potential impacts is discussed in Technical Paper Number 6.

3.3 Operational Phase

3.3.1 Stormwater Run-off

During the operational phase, pollutant export from impervious surfaces has the potential to affect receiving water quality adversely. Wong *et al.* (2000) identify the following pollutants as potentially occurring in run-off from impervious areas:

- gross pollutants and litter;
- sediment and suspended solids;
- nutrients (primarily phosphorus and nitrogen);
- pollutants creating a biochemical oxygen demand (BOD);
- problematic micro-organisms;
- metals; and
- toxic organics, oils and surfactants.

Problematic micro-organisms are typically associated with animal waste and sewer overflows, while the rest may be largely attributed to run-off from transport related functions (Wong *et al.* 2000). The pollutants from road run-off of most concern in terms of ecological impacts are suspended solids, heavy metals and petroleum hydrocarbon compounds (Wong *et al.* 2000). The sources and potential impacts of each of the identified pollutants from road run-off are discussed below.

Gross Pollutants and Litter

Gross pollutants and litter include human-derived litter, vegetation and coarse sediment. In urban catchments, organic material (typically garden waste) has been found to be the largest contributor to gross pollutant export (Wong *et al.* 2000), though in the case of highway run-off, human-derived litter would be expected to contribute a much larger proportion of the load. The main source of litter in highway run-off is the dumping of waste from cars using the highways. Coarse sediment and vegetation may be generated by direct deposition onto the road surface by trucks carrying uncovered loads or by maintenance activities adjacent to the highway and in the drainage system.

Gross pollutants may affect the receiving environment in a number of ways, as well as reducing the drainage capacity of the stormwater system. Gross pollutants are typically unsightly and reduce the visual amenity of waterways. They may physically affect aquatic habitats and organisms, such as entangling birds in plastic and may also contribute to the contamination of receiving waters due to other pollutants associated with the gross pollution.

Sediment and Suspended Solids

Sediment accumulates on road surfaces during dry periods as a result of vehicle movements and atmospheric deposition, and is mobilised to the stormwater system and the receiving environment as suspended solids by subsequent storm events.

Suspended solids may directly affect the receiving environment in the following ways:

- physically coating aquatic plants, reducing light availability and consequently limiting growth;
- fouling invertebrate and fish gills;
- reducing food availability for aquatic grazers;
- reducing visibility due to turbidity, affecting aquatic predatory species; and
- changing stream habitat, particularly sedimentation of riffles (Wong *et al.* 2000).

Suspended solids are also typically a source of nutrients. Excessive suspended solid pollution may lead to increased nutrient levels in the receiving environment, leading to increases in the numbers of plants that can utilise high nutrient concentrations, such as emergent macrophytes and algae (Wong *et al.* 2000).

Toxic pollutants such as heavy metals may be attached to suspended solids, using the particulate material as a transport medium to the receiving environment. The close association of heavy metals with suspended solids was demonstrated by Pitt *et al.* (1995), with the relevant results presented in Table 3.1. These results show significantly higher concentrations of cadmium, copper, chromium and lead in non-filtered samples than in filtered samples.

Table 3.1: Summary of Typical Metal Concentrations in Street Run-off

Metal	Mean Metal Concentration (mg/L)	
	Non-filtered Samples	Filtered Samples
Cadmium	37	0.3
Copper	280	3.8
Chromium	9.9	1.8
Zinc	58	31
Lead	43	2
Nickel	17	-

Source: (Pitt *et al.* 1995)

Nutrients

Nutrients may enter the stormwater system through a number of sources including sediment, nitrous oxide deposition from vehicle exhausts, organic waste and ash (Wong *et al.* 2000). Excessive nutrient levels may lead to eutrophication of the receiving environment. This may result in excessive macrophyte and/or algal growth.

Excessive growth of plants and algae contributes a high organic load to the waterway, which may deprive the water column of oxygen during night-time respiration and through decomposition of decaying material. Some forms of algae may also release toxins into the water column, making it unsuitable for recreation and possibly leading to fish kills.

Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand is made up of all oxygen-consuming processes within the waterbody. It includes 'natural' oxygen consumption through the decay of organic matter and also the oxygen-demanding reactions associated with some pollutants. The oxidation of hydrocarbons and ammonia and reduction of metals contribute to the biochemical oxygen demand of the receiving waters.

An excessive biochemical oxygen demand may result in depletion of dissolved oxygen in the waters. This may cause the death of aquatic organisms and may also result in the release of nutrients and metals from the bed sediments due to anoxic or anaerobic conditions.

Heavy Metals

Heavy metals are the major source of toxicity in urban run-off, with the key metals in order of highest toxicity being cadmium, copper, chromium, lead, zinc and nickel (Petersen and Batley 1992). They are typically present in both dissolved and particulate form, though most metal species are mainly transported in run-off as attached pollutants to suspended solids.

Once in the receiving environment, the toxicity of metals and their split between dissolved and particulate forms depends on environmental factors such as pH, temperature and redox potential (Wong *et al*. 2000). Heavy metals may affect organisms through both immediate lethal effects and also sub-lethal effects. Sub-lethal effects occur when the concentration of a heavy metal is not sufficient to kill an organism, but is sufficient to disadvantage it in some way. These sub-lethal effects may lead to long-term impacts on the receiving environment through changes to community structure and ecosystem health (Wong *et al*. 2000).

Toxic Organics, Oils and Surfactants

These substances are generally found in road run-off due to vehicle leaks, poor vehicle maintenance and general vehicular activities. The impacts include toxic effect (toxic organics), reduced visual amenity (oils and surfactants) and increased chemical oxygen demand (all).

South-east Queensland Data

Information on highway run-off pollutant concentrations in south-east Queensland has been presented by Drapper et al (2000). Data was collected from 21 monitoring locations for traffic volumes of between 3,500 AADT (Average Annual Daily Traffic) and 50,000 AADT (commercial vehicle percentage two percent to 10 percent), and included run-off from pavement surfaces of asphalt and concrete. Run-off samples were collected in an in situ sampler, which collected the first 20 litres of run-off leaving the surface. It was estimated that the entire run-off event would be collected for 75 percent of expected storms. The range of median pollutant concentrations recorded across the monitoring sites is presented in Table 3.2, where the results are compared to south-east Queensland ANZECC (2000) default trigger values for physical and chemical stressors for slightly disturbed (lowland river) ecosystems and toxicant trigger values for 95 percent level of species protection (freshwater).

It can be seen from this information that the ANZECC (2000) guidelines for total kjeldahl nitrogen (TKN), total phosphorus, copper, zinc and lead were exceeded, while no absolute guideline level currently exists for total petroleum hydrocarbons (TPH) and total suspended solids. It should also be noted that the monitoring results presented in Table 3.2 are dissolved pollutant fractions only, and the total concentrations (particularly in the case of metals), for which the ANZECC (2000) default trigger values apply would be expected to be higher. Values which exceed ANZECC (2000) guideline levels have been shaded for easy identification.

Table 3.2 Median Dissolved Pollutant Concentration Ranges in Road Run-off in South-east Queensland

Pollutant	Median Range (µg/L)	ANZECC (2000) Guideline Value (µg/L)
Total Kjeldahl Nitrogen	1,600-10,050	500 (total nitrogen)
Total Phosphorus	190-2,000	50
Total Petroleum Hydrocarbons	46-1,695	n/a
Acid-extractable Copper	30-280	1.4
Acid extractable Zinc	160-1,450	8
Acid-extractable Lead	50-450	3.4
Total Suspended Solids	60,000-1,825,000	n/a

For notes on parameters and acronyms included in tables please refer to the glossary.

Source: (Drapper *et al.* 2000)

3.3.2 Spills Containment

In addition to the pollutant export associated with stormwater run-off, receiving water quality may also be affected by spills caused by accidents involving chemical transport vehicles (including petrol tankers). Due to the proximity of the Cobaki Broadwater, any spillage of chemicals on the highway has the potential to enter the receiving waters through the stormwater drainage network.

The sensitive nature and proximity of the receiving environment (including *State Environmental Planning Policy Number* 14 and other significant wetlands) means that the consequences of any chemical spill may be significant, potentially resulting in the death of plant and animal species coming in contact with the spill. Provision for the capture of chemical spills would therefore be included in the design of the highway stormwater drainage system. This is discussed further in Section 4.2.

3.3.3 Stream Hydrology

It can be seen from Figure 2.1 that the catchments of the streams crossing the proposed road route are large compared to the road and rail surface areas themselves. The effect on flows in the streams from the creation of impervious surfaces associated with the proposal would therefore be minor. Further, the impact of the proposal on the hydrology of the streams would also be minimised by installing culverts at locations where streams would naturally cross the routes, wherever possible.

In accordance with the NSW Fisheries (1999) *Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures*, the stream crossings to the north and south of the proposed tunnel have been designed as box culverts and sized to maintain existing low flows and peak flows and facilitate fish passage as much as practicable.

3.4 Impact Assessment

The receiving waters potentially affected by the proposal have been shown to have high environmental values, which must be protected. In particular, extensive areas of *State Environmental Planning Policy Number 14* wetlands are present in the Cobaki

Broadwater area, with the proposed routes coming within close proximity to these sensitive areas.

In the absence of appropriate mitigation measures, the project would have an adverse impact on water quality during both the construction and operational phases through uncontrolled stormwater run-off and possible spills of chemicals and fuels.

It would therefore be necessary to incorporate appropriate mitigation measures as part of the proposal to protect receiving water quality. These measures would include erosion and sediment controls during construction and stormwater treatment measures and spills containment measures during operation. The mitigation measures proposed for the proposal are discussed in more detail in Chapter 4.

4. Water Quality Impact Mitigation Measures

4.1 Construction Phase

The primary stormwater pollutant of concern during the construction phase is suspended sediment and associated attached pollutants. The main mitigation strategy to address this pollutant would be the implementation of erosion and sediment controls as part of an Erosion and Sediment Control Plan as a component of the Soil and Water Management Plan.

Due to the high environmental values of the potentially affected receiving waters (particularly the Cobaki Broadwater), sedimentation basins would be installed as part of the controls to settle sediment prior to discharge to the receiving environment. Preliminary geotechnical investigations (Technical Paper Number 5) indicate that the proposed route is dominated by coarse-grained sandy soils, which would rapidly settle from run-off if treated by conventional sediment control devices (such as sedimentation basins).

Details of the full range of erosion and sediment controls that would be implemented are documented below, and have been divided into pre-construction, construction and post-construction activities.

The design of erosion and sediment controls for the proposal would be undertaken, during detailed design, prior to commencement of construction. The production of detailed erosion and sediment control plans would be undertaken during the construction phase. All erosion and sediment controls (including sedimentation basins) would be designed consistent with the requirements of *Managing Urban Stormwater - Soils and Construction* (NSW Department of Housing 1998) and *Soil Erosion and Sediment Control - Engineering Guidelines for Queensland Construction Sites* (Institution of Engineers – Queensland 1996)

4.1.1 Pre-Construction Erosion and Sediment Control

Before construction activities begin, the following measures would be implemented to ensure that minimal disturbance and minimal adverse water quality impacts result. These measures would be adopted in a staged approach and would be implemented prior to construction beginning on the proposal. Detailed design of sediment and erosion controls would be undertaken during detailed design prior to the commencement of construction. This would include:

- baseline water quality monitoring in potentially affected waterways undertaken to determine the 'pre-construction condition' of local waterways for subsequent assessment of construction impacts (refer to Section 4.3);
- designation and delineation of buffer strips adjacent to waterways, where possible. Once designated, these buffer strips should be assessed for effective filtering ability. Where necessary the filter strips will be rehabilitated to provide further buffering capacity. These buffer strips would remain vegetated and would filter sediment from construction site run-off. No construction plant or operations would occur within this buffer zone;
- designation of areas for construction plant and material storage. These areas should be removed from waterways and run-off from these areas would be directed to a holding

pond in case of spillages. Run-off from upstream areas should be diverted around these designated storage areas and kept separate from the holding pond;

- placement of refuse containers at numerous strategic locations across the site for collection of litter and solid building waste;
- designation and marking of transport routes across undisturbed portions of the site to ensure minimal unnecessary vegetation disturbance;
- education of site personnel regarding sediment and erosion control measures implemented on site; and
- implementation of a programme of equipment and machinery management and maintenance.

4.1.2 Construction Erosion and Sediment Control

Detailed design of all erosion and sediment controls would be completed prior to construction. Erosion controls would be used wherever possible on-site in preference to sediment controls. All run-off from disturbed areas would be directed through sediment controls before discharging into waterways. Measures to mitigate water quality impacts during construction would include:

- on-going education of site personnel of their responsibilities with respect to erosion and sediment control;
- installation of silt fences downstream of disturbed areas and along the top edge of buffer zones. Silt fences should be located continuously along contours and should treat areas less than 0.6 ha per 100 m of silt fence. A maximum slope length of 60 m would also ensure optimal performance (Institution of Engineers - Queensland 1996);
- diversion banks created at the upstream boundary of construction activities to ensure upstream run-off is diverted around any areas to be exposed. Catch-drains created at the downstream boundary of construction activities to make maximum use of the permanent sedimentation basins. Where this is not possible, temporary sedimentation devices would be used;
- check dams in the form of rock dams, silt fences and sand bags to be placed along catch drains to slow flow, reduce scour and capture some sediment;
- construction of appropriately designed sedimentation basins at the downstream ends of catch drains to capture sediment from run-off generated at exposed areas. Sedimentation basins would be designed prior to construction commencing, consistent with the specifications of NSW Department of Housing (1998). Nominal locations for sedimentation basins are shown in Figure 4.1. These locations may be revised during detailed design. The number of basins required at each culvert crossing may be reduced during detailed design if it is possible to install drainage measures to pipe flows from the upstream side of the works to a downstream basin;
- native vegetation left undisturbed and topsoil stockpiled for final site rehabilitation and landscaping works, wherever possible;
- progressive revegetation of batters and other disturbed areas as quickly as possible, using vegetation relevant to the high intensity rainfall conditions of south-east Queensland/northern NSW. Native species would be used when practicable;
- discharge of waters from sedimentation basins as a diffuse sheet flow over vegetated buffer areas before entering waterways;
- water spraying of exposed areas to minimise dust generation;

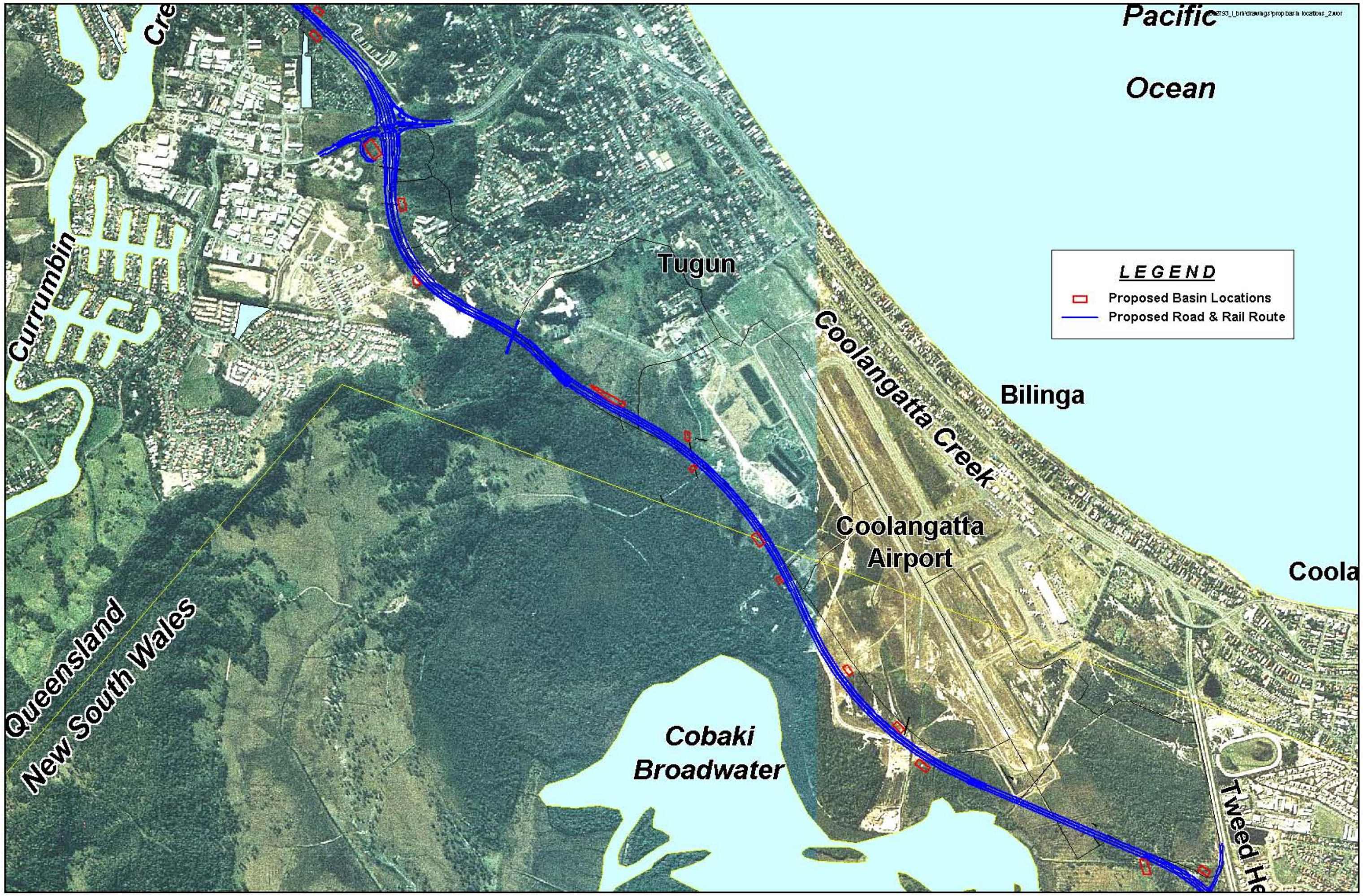


Figure 4.1: Proposed Locations of Sedimentation Basins (Construction Phase)

- regular inspection and maintenance of silt fences, sedimentation basins and other erosion control measures. Following rainfall events greater than 20 mm inspection of erosion control measures and removal of collected material should be undertaken. Replacement of any damaged equipment would be performed immediately;
- routine emptying of refuse containers and as required to maintain adequate capacity so that no refuse is left unsecured on the site; and
- regular monitoring of water quality impacts from construction activities in receiving waters and sediment basins prior to discharge (refer to Section 4.3).

4.1.3 Post-Construction Erosion and Sediment Control

Following the completion of construction works in a section of the proposal, the following activities would be performed:

- revegetation and landscaping of remaining exposed areas using the topsoil and mulched native vegetation retained from initial site clearing. Vegetation should be watered and maintained until vegetation is established;
- removal of structural drainage or sediment controls not required for the operational phase of the proposal;
- maintenance of mitigation measures retained during the operational phases (e.g. sedimentation basins retained to form constructed wetlands); and
- water quality monitoring, to monitor any ongoing impacts to water quality from the proposal (refer to Section 4.3).

4.2 Operational Phase

Stormwater discharges during the operational phase would be directed to three distinct receiving waters. The environmental risks associated with discharges to each of the receiving waters vary according to the proximity of the route, the contributing route catchment size, and the value of the receiving environment. The stormwater treatment measures required for each of the major subcatchments must therefore be considered individually, and are discussed in the following sections.

4.2.1 Cobaki Creek and Broadwater

The following points were considered in selecting treatment measures for flows to Cobaki Creek and Broadwater:

- key pollutants in terms of ecological impact (total suspended solids, heavy metals and hydrocarbons) must be reduced to acceptable concentrations in the run-off (setting acceptable water quality objectives is discussed in Section 4.3); and
- the proximity of *State Environmental Planning Policy Number 14* wetlands to the route justifies the incorporation of spill containment devices in the drainage network. Ideally, the selected stormwater treatment devices should also be able to perform a spill containment function.

Based on these considerations, a system of grassed swale drains directing flow to constructed wetlands fitted with gross pollution traps on the inlet was selected. Both grassed swales and constructed wetlands are effective at capturing both fine and coarse sediment (and the associated attached heavy metals).

It is also recognised that the incidental export of hydrocarbons may be treated effectively using grassed swales and wetlands, rather than oil and grease separators (Wong *et al.* 2000).

Grassed swales also provide moderate capture efficiency of litter, though maintenance activities to collect litter from the swale would have to be regularly undertaken (NSW Environment Protection Authority 1997). A trash rack or gross pollutant trap on the inlet to the wetlands would also be installed to help reduce the maintenance load on the wetland and minimise transport of litter to the receiving environment.

NSW Environment Protection Authority (1997) provides information regarding pollutant removal efficiencies of stormwater treatment devices. This information is reproduced in Table 4.1 for the treatment devices selected for this proposal.

Table 4.1: Pollutant Removal Ranges for Selected Treatment Techniques

Pollutant	Constructed Wetland	Grassed Swale	Gross Pollution Trap
Total Suspended Solids	75-100 %	75-100 %	10-50 %
Total Phosphorus	50-75 %	50-75 %	0-10 %
Total Nitrogen	10-50 %	50-75 %	0-10 %
Oil and Grease	10-50 %	75-100 %	0-10 %
Litter	10-50 %	50-75 %	50-75 %

For notes on parameters and acronyms included in tables please refer to the glossary.

Source: NSW Environment Protection Authority 1997

These removal efficiencies were applied to the typical road run-off pollutant concentrations given in Table 3.2 in order to estimate the likely discharge concentrations from the constructed wetlands to the receiving environment. The resulting predicted discharge concentrations are given in Table 4.2, where they are compared to ANZECC (2000) guidelines. For the purposes of these predictions the average values of the pollutant removal ranges were selected.

Table 4.2: Predicted Discharge Concentrations of Key Pollutants (μg/L)

Pollutant	Median Road Run-off Concentration Range (Drapper *et al.* 2000)	Predicted Discharge Concentration Range Following Treatment	ANZECC (2000) Guideline Value
Total Kjedahl Nitrogen	1,600-10,050	420-2,638	500 (total nitrogen)
Total Phosphorus	190-2,000	27-281	50
Total Petroleum Hydrocarbons	46-1,695	6-208	N/A
Total Suspended Solids	60,000-1,825,000	1,837-55,891	N/A

For notes on parameters and acronyms included in tables please refer to the glossary

From the predictions presented in Table 4.2 it can be seen that the ANZECC (2000) guidelines for total nitrogen and total phosphorus fall within the range of predicted median discharge concentrations. There are currently no ANZECC (2000) guideline values for total petroleum hydrocarbons and total suspended solids. However, the predicted total petroleum hydrocarbons values fall below the detection limit of 5,000 µg/L, indicating the likely levels are low. The predicted total suspended solids values are also low when compared to the objective of 50,000 µg/L (50 mg/L) that is used when sizing sedimentation basins (NSW Department of Housing 1998).

Although no pollutant removal efficiencies were available for heavy metals, it has been shown that the heavy metals likely in road run-off are strongly associated with suspended sediment, and measures which effectively remove fine sediment from run-off are also likely to effectively reduce heavy metal concentrations.

It should be noted that the ANZECC (2000) guidelines relate to receiving water quality rather than discharge quality. Comparing the concentrations predicted in Table 4.2 to ANZECC (2000) is therefore a conservative approach and it appears that the proposed treatment measures would be adequate to achieve acceptable discharge water quality.

4.2.2 Currumbin Creek

Currumbin Creek has the same environmental values as Cobaki Broadwater and would require the same stormwater treatment system of grassed swale drains discharging to a wetland fitted with a trash rack. Provision for spills containment would also be made for flows to Currumbin Creek due to the sensitive nature of the receiving waters and close proximity of the mouth of the creek and swimming beaches.

4.2.3 Coolangatta Creek

During the operational phase, the bridge over Hidden Valley and grade of the road alignment would direct run-off from those sections of the route within the catchment of Coolangatta Creek to treatment devices located in the catchments of Currumbin Creek and Cobaki Broadwater. Conveyance would be by grassed swale drains where practicable. As no stormwater is planned for discharge into the catchment of Coolangatta Creek, no further stormwater treatment devices are proposed.

4.2.4 Additional Design Considerations

Where possible (within topographical constraints) the constructed wetlands should be designed to fulfil a secondary function as spill containment devices, with sufficient storage and an appropriate outlet device provided to contain a volume equal to 1.2 times a petrol tanker volume (35,000 - 40,000 L) under dry weather (base flow) conditions. It should be recognised that if a spill occurs the macrophytes in the wetland would be killed and would require replacement, but the spill should be largely contained.

Further design considerations which should be taken into account during the detailed design of the constructed wetlands include:

- appropriate outlets for the wetland in order to achieve the secondary function of spills containment include siphons or the incorporation of a baffled outlet;
- typical wetland areas may be estimated using the *Percentage Catchment Area Method* (NSW Department of Land and Water Conservation 1998), which states that wetland areas may be estimated as two percent of the catchment area for preliminary determination of wetland feasibility. Constructed wetlands have been sized on a two percent water area to which the widths for freeboard and banks (approximately 14 m) and specific access for maintenance ramps have been added. Experience has shown WBM Oceanics that a more realistic value for south-east Queensland may be three to four percent of catchment area. However, further testing undertaken by PB on the

dispersive nature of soils has shown that a catchment area of two percent is adequate for this site. A practical margin/envelope has also been allowed around all works resulting in an area of approximately five percent as a worst-case estimate for the area of land that would be impacted by the sedimentation basins;

- the wetlands may become occasionally inundated due to flooding from the Cobaki Broadwater. Wetland vegetation should therefore be selected to be tolerant of occasional exposure to saline water; and
- the wetlands should be designed to treat run-off from a specific storm event, with higher flows bypassed to avoid damage to the macrophyte zone and mobilization of sediments. Research has shown that a volumetric treatment efficiency in excess of 95 percent may be achieved by adopting a design storm event of one year ARI (Wong *et al*. 2000).

The key features of a typical constructed wetland are shown in Figure 4.2. The locations of the wetlands will be determined during detailed design of the route drainage system, and will replace some of the sedimentation basins shown in Figure 4.1. The wetlands are not expected to be placed in areas that have not previously been the location of sedimentation basins.

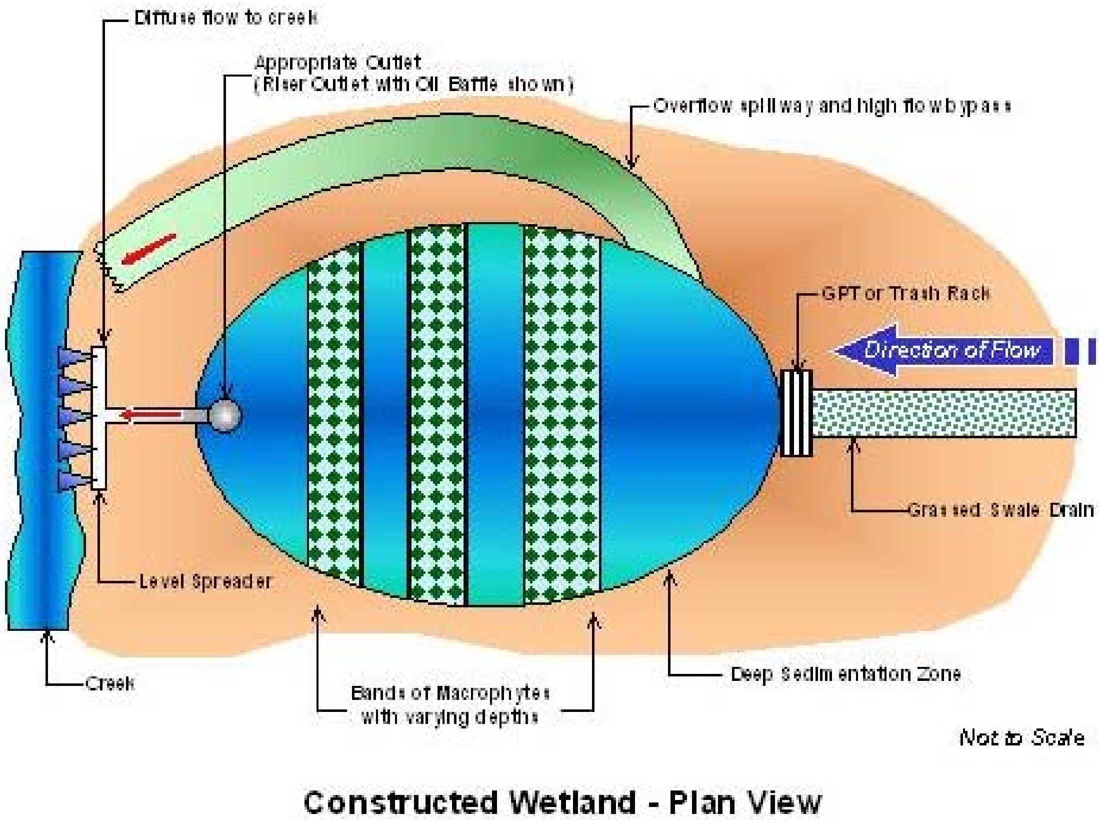
A large section of the road in the southern section would be below 0.0 m AHD due to the use of a tunnel. Run-off from this section would require pumping to treatment devices. It is proposed that pumped run-off would be discharged into a grassed swale drain that would flow to a wetland. For run-off from other sections, flows would be conveyed parallel to the highway in grassed swales which would discharge to wetlands at low points (likely to correspond to culvert crossings).

The final numbers and locations of wetlands would depend on the detailed design of the road drainage system, which would be determined during subsequent design phases of the proposal.

4.3 Monitoring Programs

Water quality monitoring of the drainage lines and creeks located down-slope of the proposed road route are essential if the performance of the control measures is to be assessed. While monitoring in the creeks and watercourses traversing the proposed routes is recommended, monitoring in the Cobaki Broadwater is not. This is due to the large dilution that would occur once flows reach this waterbody and the difficulty in differentiating between impacts associated with the proposal and external influences on water quality in the Cobaki Broadwater.

As the routes do not cross any permanently wet (or flowing) watercourses, monitoring would have to occur on an event basis, with a particular rainfall intensity triggering a monitoring event. The rainfall trigger would be the amount required to generate run-off in the waterways crossing the routes. An indication of appropriate rainfall triggers may be gained from *Australian Rainfall and Run-off- Volume 1* (Institution of Engineers Australia 1987), which states initial rainfall losses for NSW and Queensland east of the Great Dividing Range of 10-35 mm and 15-35 mm respectively. The value of 25 mm is approximately the mid-point for these ranges and has been used successfully in other projects undertaken for the NSW Roads and Traffic Authority (WBM 1999).



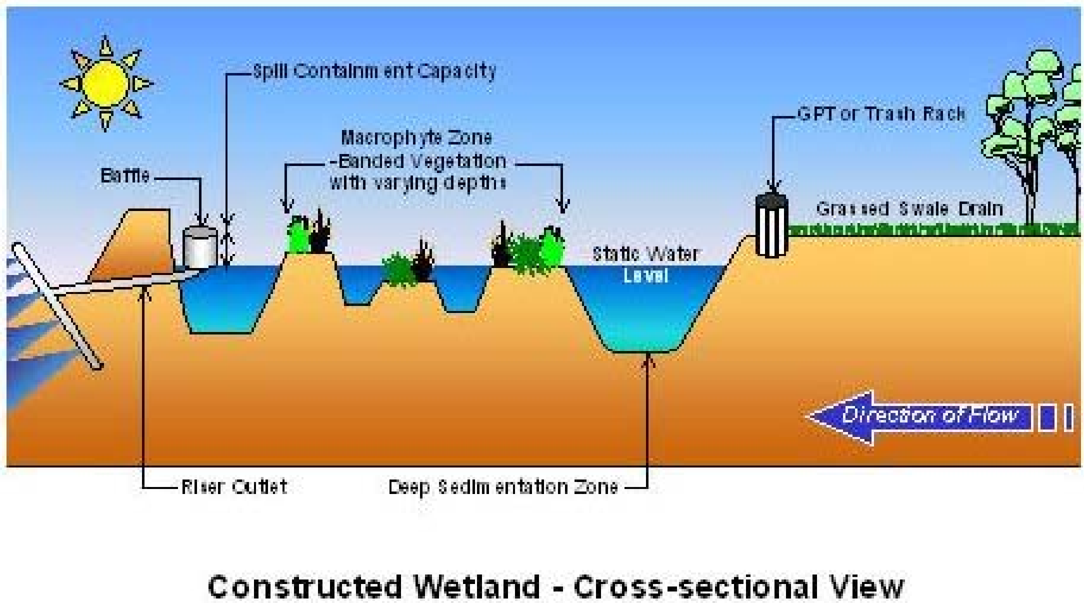


Figure 4.2: Typical Constructed Wetland Features

The monitoring requirements for the proposal may be divided into three distinct phases, as:

- pre-construction;
- during construction; and
- post-construction.

Details of the essential elements and timing of these monitoring programs are provided below.

4.3.1 Pre-construction Monitoring

Pre-construction monitoring would be used to establish the baseline water quality at locations where the proposed route crosses waterways (it should be noted that as stated before these waterways are not permanently wet (or flowing) watercourses). Monitoring sites upstream and downstream of the route in all major crossings would be established, with monitoring taking place at these sites following rainfall events of greater than 25 mm in 24 hours. This criterion may have to be refined once monitoring commences to account for the response time of the catchment.

Baseline monitoring should occur throughout the year in order to characterise the range of water quality conditions that may occur in the waterways. The water quality parameters included in the baseline monitoring program should include those materials generated by the proposal that have been identified previously as having the potential to impact on water quality during either the construction or operational phases if left unmitigated. These parameters would include as a minimum:

- total suspended solids;
- oil and grease (to be sampled when visible slicks are observed);
- metals (copper, zinc, lead, nickel, cadmium and chromium);
- temperature;
- pH;
- dissolved oxygen;
- salinity/conductivity;
- turbidity;
- total phosphorus and total nitrogen; and
- total petroleum hydrocarbons.

Prior to pre-construction monitoring commencing all staff involved in the water sampling collection and monitoring tasks will be trained in the use of use, maintenance and calibration of the water quality monitoring instruments.

4.3.2 During Construction Monitoring

Water quality monitoring during highway construction would be conducted at the same sites as those established during baseline monitoring for the duration of construction with monitoring taking place at these sites following rainfall events of greater than 25 mm in 24 hours.

A set of water quality guidelines would be derived for each monitoring location, using the values obtained from baseline monitoring, ANZECC (2000) water quality guidelines and criteria specified in the Airports (Environment Protection) Regulations 1997. The exact form of the water quality guidelines would be determined prior to construction commencing through negotiations with the relevant government departments. One approach is to select the higher of either the average baseline concentration or the ANZECC (2000) guideline as the water quality objective for a certain parameter at a certain site. This approach for setting water quality objectives is consistent with the requirements of the Queensland *Environmental Protection (Water) Policy 1997*.

These guideline values would be used in conjunction with a comparison of values at upstream and downstream monitoring sites to indicate when the highway is having an unacceptable impact on water quality. Results showing unacceptable impacts would trigger an investigation into the cause of the problem and subsequent mitigating actions. A possible investigation process is outlined as a flowchart in Figure 4.3.

The parameters monitored as part of construction monitoring would include material generated during construction phase activities that has been previously identified as having the potential to impact on receiving water quality if left unmitigated. These parameters would include as a minimum:

- total suspended solids;
- oil and grease;
- temperature;
- pH;
- dissolved oxygen;
- salinity/conductivity;
- turbidity; and
- total phosphorus and total nitrogen.

Photographs and general comments should be noted to assist with the speedy modification to site water quality management measures. These include:

- physical observations associated with water appearance (e.g.: colour, clarity, odour), flow rate and levels;
- recent rainfall and weather;
- summary of current site activities that have the potential to impact receiving waters;
- the name of the relevant site foreman / engineer responsible for the works; and
- the name of the person(s) collecting the samples/data.

A system would be established for rapid reporting of the preliminary physical results (in particular turbidity) so mitigating actions may be rapidly undertaken if the construction activities are found to be affecting the waterways.

As well as monitoring receiving water quality, discharges from the sedimentation basins should be monitored for turbidity and suspended solid levels. The NSW Department of Housing (1998) uses a discharge objective of 50 mg/L when specifying design requirements for sedimentation basins. This objective could be adopted for monitoring of basin discharges. A site-specific relationship between suspended solids and turbidity could also be developed from monitoring data in order to set a corresponding turbidity objective.

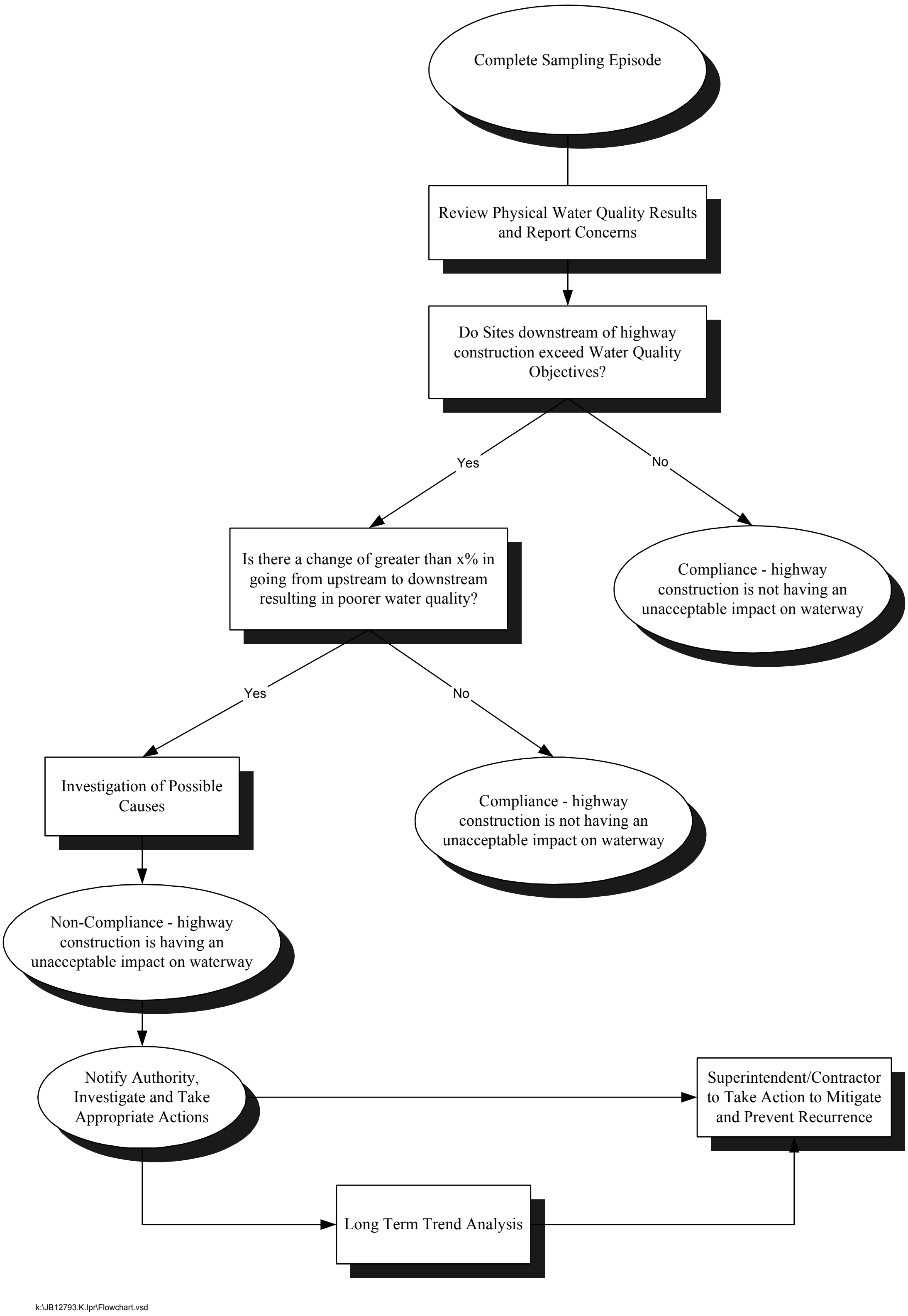


Figure 4.3: Water Quality Monitoring Investigation Procedure

Throughout the construction period all staff involved in the water sampling collection and monitoring tasks will be trained in the use of, maintenance and calibration of the water quality monitoring instruments. Copies of all monitoring results associated with airport land would be provided to Gold Coast Airport Limited.

4.3.3 Post-Construction Monitoring

Following the completion of highway construction, monitoring during the operational phase would be conducted for a minimum of a further 12 months to determine if the completed route has any impact on downstream water quality. Water quality monitoring during highway operation would be conducted at the same sites as those established during baseline monitoring for the duration of the construction phase, with monitoring taking place at these sites following rainfall events of greater than 25 mm in 24 hours.

A set of water quality guidelines would be derived for each monitoring location, using the values obtained from baseline monitoring, ANZECC (2000) water quality guidelines and criteria specified in the Airports (Environment Protection) Regulations 1997. These guideline values would be used in conjunction with a comparison of values at upstream and downstream monitoring sites to indicate when the highway is having an unacceptable impact on water quality. Results showing unacceptable impacts would trigger an investigation into the cause of the problem and subsequent mitigating actions. The exact form of the water quality guidelines would be determined prior to construction commencing through negotiations with the relevant government departments and Gold Coast Airport Limited.

Run-off draining into the tunnel section would be pumped to treatment devices before release to the receiving environment. Discharges from these treatment devices would be monitored during the operational phase and should meet the Airports (Environment Protection) Regulations 1997 criteria and ANZECC (2000) guidelines for the south-east Queensland default trigger values for physical and chemical stressors for slightly disturbed ecosystems and toxicant trigger values for 95 percent level of species protection, in the absence of baseline or upstream monitoring data.

The parameters initially included in post-construction monitoring would include those identified previously as potentially impacting on receiving water quality during the operational phase of the proposal if left unmitigated. Flexibility should be incorporated into the monitoring program to reduce or even stop monitoring for a particular parameter if monitoring indicates that the parameter is having minimal impact. Flexibility should also be incorporated into the monitoring program to allow monitoring to continue at a particular site/s for a particular parameter/s if they fail to meet the guideline levels previously determined. Further flexibility should also be incorporated into the monitoring program to ensure adequate albeit reduced, inspection and maintenance of the proposed wetland continues until stable functioning of the wetland has been achieved. Such decisions would involve agreement between the relevant authorities and Gold Coast Airport Limited.

Parameters initially monitored during post-construction monitoring should include:

- total suspended solids;
- oil and grease;
- metals (copper, zinc, lead, nickel, cadmium, chromium);
- temperature;

- pH;
- dissolved oxygen;
- salinity/conductivity;
- turbidity; and
- total phosphorus and total nitrogen.

Throughout the post-construction period all staff involved in the water sampling collection and monitoring tasks will be trained in the use of, maintenance and calibration of the water quality monitoring instruments.

5. Recommendations

The key recommendations of this study, required for implementation in order to effectively mitigate and monitor the potential water quality impacts of the proposal are:

- **Prior to Construction Commencement**
  - Undertake baseline water quality monitoring for 12 months (or as long as practicable) prior to construction commencement in all the waterway crossings of the proposed route, according to the details specified in Section 4.3.1.
- **Construction Phase**
  - Design and implement an effective Erosion and Sediment Control Plan during construction of the proposed route, in accordance with the detail provided in Section 4.1.
  - Undertake water quality monitoring at all waterway crossings of the proposed route, according to the details specified in Section 4.3.2.
- **Operational Phase**
  - Implement a stormwater quality treatment train to treat all run-off from the proposed route prior to discharge to the receiving environment. The treatment trains should consist of a grassed swale drain, gross pollution trap and constructed wetland. The treatment train should incorporate the additional design considerations outlined in Section 4.2.4.
  - Undertake water quality monitoring in all waterway crossings of the proposed route for 12 months following construction completion, according to the details specified in Section 4.3.

6. Conclusions

If the mitigation measures proposed in this report are implemented, the potential water quality impacts from the proposal may be expected to be reduced to acceptable levels. By implementing the recommended monitoring regime during construction and operation of the proposal, impacts from the proposal would be accurately identified and further mitigation measures would be employed, if required.

Further, the requirements of the Queensland *Environmental Protection Act 1994* have been met by this document recommending an appropriate means of setting water quality guidelines consistent with ANZEC (2000), The *Environmental Protection (Water) Policy 1997* and the NSW *Environment Protection Authority Interim Water Quality Objectives (2000)*. Consideration of the NSW *Environment Protection Authority Interim Water Quality Objectives (2000)* is consistent with the intent of the *NSW Water Management Act 2000*. Additionally the requirements of the *Environmental Protection (Water) Policy 1997* has been met by the specification of a stormwater treatment drain to ensure these water quality objectives will be met by the proposed project.

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Legislation

Queensland

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Environmental Protection (Water) Policy 1997.

NSW

Environmental Protection Authority Interim Water Quality Objectives 2000

Appendix A

Historical Water Quality Information

State Pollution Control Commission Data

Various water quality data were collected and analysed by the State Pollution Control Commission during 1983 and 1984 (State Pollution Control Commission 1985). These data were collected primarily to review effluent disposal strategies in the region.

Those data pertaining to the Cobaki Broadwater are illustrated in Tables A1 and A2.

Table A1: SPCC Water Quality Data - Off PWD Tide Recorder Cobaki Broadwater

Date	Salinity (g/L)	Temp (°C)	D.O. (% Sat.)	TSS (mg/L)	Chl-*a* (µg/L)	TN (mg/L)	TP (mg/L)	pH
27/10/83	30.4	25.4	100.	29.	7.2	0.74	0.09	7.9
31/10/83	30.4	27.4	99.	47.	13.0	0.37	0.06	7.9
19/01/84	18.0	26.1	89.	30.	9.0	0.73	0.12	7.5

For notes on parameters and acronyms included in tables please refer to the glossary

Table A2: SPCC Water Quality Data - Off Cobaki Creek Mouth - Western Side of Cobaki Broadwater

Date	Salinity (g/L)	Temp (°C)	D.O. (% Sat.)	TSS (mg/L)	Chl a (µg/L)	TN (mg/L)	TP (mg/L)	pH
27/10/83	28.6	24.1	80.	49.0	0.4	0.76	0.12	7.7
31/10/83	29.5	28.6	105.	75.0	19.0	0.71	0.15	7.9
19/01/84	17.4	26.1	88.	19.0	9.1	0.21	0.11	7.5

For notes on parameters and acronyms included in tables please refer to the glossary

Tweed Shire Council Data

The Tweed Shire Council has been monitoring the water quality of the Cobaki Broadwater since 1989. An average and range of the available data between September 1989 to July 1995 for Cobaki Broadwater is presented in Table A3.

Table A3: Tweed Shire Council - Water Quality Data in Cobaki Broadwater

Location	Temp (°C)	Turbidity (NTU)	Cond. (mS/cm)	DO (mg/L)	DO (% saturation)	Secchi (m)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
Average	23.02	13.9	28	6.83	83.64	0.95	33.7	0.96	0.07
Maximum	30.78	31.0	35	8.88	92.53	1.28	77.4	2.40	0.16
Minimum	16.55	6.3	13	4.43	66.25	0.25	8.8	0.25	0.03

For notes on parameters and acronyms included in tables please refer to the glossary

This data set indicates that the water quality in Cobaki Creek and Broadwater is variable.

WBM Oceanics Data

Several water quality surveys of Cobaki Creek have been performed as part of the WBM Oceanics study performed in 1991, associated with a proposed residential development. These surveys established baseline water quality levels in the receiving water at that time. The results of these surveys for those sites shown in Figure 2.2 are given in Tables A4 and A5.

Table A4: WBM Oceanics Australia In Situ Water Quality Data - Cobaki Creek and Broadwater (1991)

Site	Date	TEMP (oC)	SAL. (g/L)	D.O. (mg/L)	D.O. (% Sat)	pH	TURB. (NTU)	SECCHI (m)
1	12/09/91	18.9	34.1	7.37	97.0	8.1	1.0	>5
	24/10/91	20.3	34.1	7.05	95.0	8.1	2.0	3.3
	6/11/91	21.4	34.1	–	–	8.2	3.0	2.6
	10/12/91	24.2	32.8	7.10	101.0	8.1	2.0	4.5
	13/12/91	23.0	9.5	6.30	77.3	7.3	42.0	0.3
2	12/09/91	19.5	33.9	7.58	101.0	8.0	7.7	1.5
	24/10/91	20.8	33.5	6.89	93.0	8.1	9.0	1.5
	6/11/91	23.7	34.0	–	–	8.1	8.0	1.3
	10/12/91	25.2	32.4	6.80	99.0	8.1	6.5	1.5
	13/12/91	23.8	12.9	5.70	72.5	7.3	30.2	-
3	12/09/91	19.6	34.1	7.45	99.0	7.9	12.0	1.5
	24/10/91	21.4	32.7	6.64	91.0	7.9	14.0	1.0
	6/11/91	25.4	33.7	–	–	8.0	18.0	0.6
	10/12/91	26.5	31.7	6.80	100.0	7.9	16.0	0.8
	13/12/91	23.9	6.3	6.10	74.5	6.9	59.0	0.2
4	12/09/91	20.5	34.3	7.59	103.0	7.9	35.0	0.5
	24/10/91	21.3	32.1	6.68	91.0	7.9	21.0	0.6
	6/11/91	26.4	34.2	–	–	8.0	34.0	0.5
	10/12/91	28.0	31.6	7.40	112.0	7.9	47.0	0.3
	13/12/91	26.6	1.5	6.30	78.9	6.7	74.0	0.2
5	12/09/91	20.6	34.1	7.66	104.0	7.9	28.0	0.6
	24/10/91	21.4	32.2	6.34	86.0	7.9	25.0	0.6
	6/11/91	26.1	34.1	–	–	7.9	29.0	0.6
	10/12/91	27.8	31.4	7.10	106.0	7.9	34.0	0.4
	13/12/91	24.0	1.4	5.60	66.6	6.5	71.0	0.2
6	12/09/91	20.4	33.8	7.61	103.0	7.9	34.0	0.6
	24/10/91	21.4	32.1	6.07	83.0	7.9	57.0	0.7
	6/11/91	25.8	34.0	–	–	7.9	27.0	0.5
	10/12/91	27.8	31.1	7.00	105.5	7.8	35.0	0.5
	13/12/91	23.6	0.5	5.90	69.3	6.2	67.0	0.2
7	12/09/91	20.0	33.2	7.44	99.0	7.9	27.0	0.8
	24/10/91	21.4	31.1	6.58	89.0	7.8	25.0	0.6
	6/11/91	25.3	33.7	–	–	7.9	33.0	0.5
	10/12/91	26.5	29.9	6.30	92.4	7.8	39.0	0.5
	13/12/91	23.0	0.5	6.20	72.7	6.2	68.0	0.2

Site	Date	TEMP (oC)	SAL. (g/L)	D.O. (mg/L)	D.O. (% Sat)	pH	TURB. (NTU)	SECCHI (m)
8	12/09/91	19.7	32.5	7.39	98.0	7.8	25.0	0.6
	24/10/91	21.8	30.0	6.49	88.0	7.7	22.0	0.7
	6/11/91	24.9	32.9	–	–	7.8	34.0	0.5
	10/12/91	26.6	28.6	6.40	92.2	7.7	40.0	0.5
	13/12/91	22.9	<0.5	6.40	75.0	6.2	72.0	0.2
9	12/09/91	20.0	32.1	6.89	91.0	7.7	23.0	0.8
	24/10/91	22.4	29.0	4.67	63.0	7.6	22.0	0.8
	6/11/91	25.4	32.1	–	–	7.8	34.0	0.6
	10/12/91	26.6	27.3	6.50	94.4	7.7	33.0	0.5
	13/12/91	24.0	<0.5	6.30	75.1	6.1	52.0	0.2
10	12/09/91	20.0	31.0	5.65	74.0	7.5	17.0	1.0
	24/10/91	22.7	28.8	4.06	55.0	7.5	18.0	1.0
	6/11/91	25.7	31.0	–	–	7.7	23.0	0.7
	10/12/91	26.3	26.9	6.30	90.5	7.7	34.0	0.5
	13/12/91	23.2	<0.5	6.50	76.1	6.3	70.0	0.2
11	12/09/91	21.3	31.9	5.94	80.0	7.5	22.0	1.0
	24/10/91	23.1	27.7	3.28	45.0	7.5	15.0	1.0
	6/11/91	26.5	30.4	–	–	7.7	26.0	0.7
	10/12/91	27.3	25.7	7.40	107.2	7.7	31.0	0.6
	13/12/91	25.4	<0.5	7.20	87.6	6.3	45.0	0.3

For notes on parameters and acronyms included in tables please refer to the glossary

Table A5: WBM-Oceanics Laboratory Water Quality Data - Cobaki Creek and Broadwater (1991)

Site	Date	Apparent Colour (PCU)	True Colour (PCU)	TSS (mg/L)	TKN (mg/L)	NO_x-N (mg/L)	TN (mg/L)	Ortho-P (mg/L)	TP (mg/L)
3	12/09/91	15.	3.	7.	0.06	0.01	0.07	0.04	0.06
	24/10/91	26.	12.	9.	0.05	0.02	0.07	0.04	0.06
	06/11/91	19.	5.	5.	<0.01	0.14	0.14	0.02	0.06
	10/12/91	20	4		<0.01	<0.01	<0.01	0.01	0.14
	13/12/91	229	44	48	0.67	0.44	1.11		0.34
4	12/09/91	37.	2.	20.	0.03	0.01	0.04	0.04	0.08
	24/10/91	29.	13.	11.	0.06	0.03	0.09	0.01	0.06
	06/11/91	33.	5.	16.	0.29	0.11	0.40	0.02	0.07
	10/12/91	40	6		<0.01	<0.01	<0.01	0.02	0.09
	13/12/91	236	29	47	0.05	0.38	0.43		0.34
6	12/09/91	36.	2.	13.	0.02	<0.01	0.02	0.04	0.07
	24/10/91	33.	16.	13.	0.05	0.03	0.08	0.01	0.06
	06/11/91	38.	6.	10.	0.21	0.09	0.30	0.02	0.06
	10/12/91	35	7		0.44	0.03	0.47	0.03	0.05
	13/12/91	213	52	34	0.35	0.48	0.83		0.33
8	12/09/91	32.	5.	6.	0.05	<0.01	0.05	0.03	0.07
	24/10/91	32.	17.	9.	0.06	0.02	0.08	0.07	0.08
	06/11/91	61.	10.	11.	0.28	0.07	0.35	0.03	0.11
	10/12/91	35	9		0.53	<0.01	0.53	0.02	0.07
	13/12/91	221	68	34	0.24	0.63	0.87		0.36

For notes on parameters and acronyms included in tables please refer to the glossary

NSW Environment Protection Authority Data

The NSW Environment Protection Authority performed a review of water quality in the Tweed River, Brunswick River, Richmond River and Clarence River catchments in 1994/1995 (NSW Environment Protection Authority 1996). This water quality review involved the collection of water quality data at 35 locations within the Tweed Catchment, two of which were located within the Cobaki Creek and Cobaki Broadwater area. Seven surveys were performed between May 1994 and May 1995, six of which were under low flow conditions (i.e. no recent rainfall had been recorded before the survey) and one high flow survey. The Environment Protection Authority water quality assessment was performed at a time when the Tweed catchment was suffering a drought, and the high flow survey represented the break of this lengthy drought. Therefore, the water quality during this high flow event was poor, however recent studies by WBM Oceanics Australia for the Tweed Shire Council have indicated that this data is not unrepresentative of other high flow events which are not preceded by such a drought.

Data from this water quality assessment for Cobaki Creek and Cobaki Broadwater area has been averaged, and a summary is presented in Table A6.

Table A6: NSW Environment Protection Authority - Average Water Quality Data in Cobaki Creek and Broadwater (1994/1995)

Location	Temp (ºC)	Turbidity (NTU)	Cond. (mS/cm)	DO (mg/L)	DO (%sat)	Secchi (m)	pH	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Chl*a* (μg/L)
Average	20.9	19.38	43.72	7.66	85.0	1.12	7.77	0.36	0.05	8.15	2.4
Maximum	24.0	250.0	55.2	9.00	99.5	2.10	8.15	1.07	0.24	40.0	8.2
Minimum	17.2	1.00	0.12	4.98	58.7	0.1	6.62	0.14	0.02	2.60	0.4

For notes on parameters and acronyms included in tables please refer to the glossary