(DRAFT) Tweed Urban Stormwater Quality Management Plan, 2016

AUSTRALIAN WETLANDS CONSULTING PTY LTD & DESIGNFLOW

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Project Control

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Executive Summary

Council prepared an Urban Stormwater Quality Management Plan for the Tweed in 2000. This document set out a rationale and objectives for stormwater quality management that were consistent with best practice at the time. In 2012 Council embarked on a process of reviewing the Tweed Urban Stormwater Quality Management Plan, to ensure that the specified approaches to water quality and stormwater asset design and management were consistent with contemporary industry best practice, and internal guidelines such as Development Design Specification – D7 (Stormwater Quality). This, the 2016 Tweed Urban Stormwater Quality Management Plan, has been developed consistent with the principles of Ecologically Sustainable Development and Water Sensitive Urban Design, and makes a strong case for implementation and maintenance of high quality stormwater management assets in the Tweed Shire.

The objectives of the review were to provide Council with a document that would:

- Confirm Council's stormwater management objectives
- Provide ambient water quality and stormwater quality treatment objectives
- Allow for flexibility and continual adoption of best practice improvements in stormwater management, and
- Provide specific guidance for monitoring and maintenance of stormwater quality improvement devices.

The Tweed Urban Stormwater Quality Management Plan 2016 provides a description of the environmental assets that stormwater management is designed to protect. A water quality data review has been undertaken to confirm ambient water quality objectives set for the Tweed waterways, which if attained, will protect aquatic ecosystem values. Stormwater treatment objectives have been set, consistent with recognised industry best practice, to guide the design of treatment facilities in proposed development. The plan highlights that while stormwater facilities must be well designed and constructed, it is also crucial that they are maintained in the long term in order for them to function effectively and protect waterways from the impact of stormwater pollution. Recommendations are included to guide Council's practice in this regard.

Tweed's waterways and water quality are affected by many impacts including catchment runoff, recreation and the impact of ongoing urban development. Implementing and maintaining a strong corporate and community focus on best practice stormwater management is an important and ongoing strategy in protecting the environmental and recreational values of the Tweed's waterways.

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1. Introduction

1.1 Background

The Tweed Urban Stormwater Quality Management Plan (Tweed USQMP) was originally adopted in 2000 in response the Notice issued to all NSW Councils by the Environment Protection Authority (now OEH) under Section 12 of the *Protection of the Environment Administration Act, 1991.* The Tweed USQMP was prepared by Tweed Shire Council (Council) for the urban areas, and Tweed Coast Villages.

The Local Government Authority boundary of Tweed Shire Council encompasses the whole catchment of the Tweed River and its tributaries. The catchments of the three coastal estuaries of Cudgen, Cudgera and Mooball Creeks are also contained within the boundary of the Tweed Shire Council. Stakeholders in the Tweed Urban Stormwater Quality Management Plan include Service Units within Council, Tweed River Committee, Tweed Coastal Committee, State Government Departments, Interest Groups, Industry Groups and the wider community.

The original purpose of the Tweed USQMP was to ensure urban stormwater management is addressed by Council and that related issues are incorporated into the planning, budgetary and ongoing works activities of the Council.Through ongoing capacity building relating to stormwater management, Council has come to understand the limitations of the existing Tweed USQMP (2000) and that it required updating. A key problem with the Tweed USQMP (2000) is that its scope is far too broad, making its application difficult. For example, it provides detail on elements such as vegetation communities and creek morphology which are not directly relevant to the management of stormwater. While written in the late 1990's, the Tweed USQMP (2000) was a good representation of best practice stormwater management at that time, however in the past ten years stormwater management as a practice has evolved and grown considerably both in understanding and expectation of what constitutes best practice. Additionally the ability to devise, quantify and build stormwater treatment strategies is now far more sophisticated.

In response, Council has reviewed the scope of the Tweed USQMP and determined that a revised Tweed USQMP should:

- Confirm Council's stormwater management objectives,
- Provide ambient and stormwater quality objectives,
- Insist on the use of best practice design guidance available to the industry, and
- Provide specific and measurable guidance for monitoring and maintenance of stormwater quality improvement devices (SQIDs).

This requires a document that is streamlined and focused upon Council's objectives for waterway health but not complicated by prescriptions that risk becoming dated as the practice of stormwater management evolves. In order to keep Council's stormwater management current, Tweed Shire Council's *Development Design Specification D7 – Stormwater Quality,* as the relevant policy document, refers to the latest versions of current best practice WSUD guidelines. The stormwater objectives provided in Tweed Shire Council's *Development Design Specification D7 – Stormwater Quality* apply to all new development in the Tweed region unless there is a catchment specific stormwater objective provided in, a catchment management plan, a Coastal Zone Management Plan or a Coastal Management Program.

1.2 This document

This USQMP communicates Council's stormwater quality management objectives and directs users to supporting guidelines and coastal zone management plans for specific technical information.

The plan is holistic in scope, promoting decision making for stormwater management from a catchment and ecological perspective. The plan seeks to expand on the traditional stormwater quality management focus of achieving compliance with water quality objectives, solely within the boundaries of a single development. The plan advocates consideration of practical and collaborative solutions that reduce construction and maintenance costs associated with managing stormwater devices, and encourages consideration and achievement of catchment wide water quality and ecosystem health objectives.

Council has a vision of collaborating with stakeholders to make holistic, catchment-wide, stormwater management decisions, via which the aquatic ecosystems of the Shires waterways are protected and enhanced, while the cost of stormwater management for all parties is kept to a minimum.

1.3 Stakeholder Consultation

This updated plan was prepared in consultation with the following stakeholder groups:

- Tweed Shire Council,
- Tweed River Committee,
- Tweed Coastal Committee,
- NSW Office of Environment and Heritage,
- General Tweed community.

The Tweed community were consulted through a series of newsletters and notices placed in local papers. Comments and contributions were invited during the development of the Tweed USQMP and the final document.

2. Context

2.1 Effects of Urbanisation on Waterways

There is a direct link between urban development and waterway health (Water by Design 2010). Urban development changes the natural hydrologic cycle in the following ways:

- Potable water – To supply water to households and businesses, large scale water storages are created starving natural river systems of flow. This water is treated to the highest standards, irrespective of the quality required, and supplied in unlimited quantities except in periods of drought.
- Wastewater – Wastewater is collected and transported to centralised treatment facilities and discharged to vulnerable receiving aquatic environments.
- Stormwater runoff - The impervious areas of developments, such as roads, roofs, driveways and footpaths, prevent water from infiltrating and evapotranspiring. Stormwater is conveyed via a system of pits and pipes to receiving waterways more frequently and in greater volumes than occurs naturally. This causes flooding, waterway erosion and significant disturbance of in-stream ecology. If untreated, stormwater carries large volumes of pollutants such as nutrients, sediment and litter that can seriously impact the health of aquatic ecosystems (known as urban diffuse stormwater pollution).

Many waterways in the Tweed are currently under stress as a result of urbanisation. This situation is expected to worsen given the expected population growth in the Tweed, which is driving urban development. The Tweed's waterways have significant economic, ecological and cultural importance making effective management of waterways a high priority.

2.2 Principles of Water Sensitive Urban Design and Stormwater Management

To manage the impact of urban design on the Tweed waters the principals of Ecologically Sustainable Development (ESD) and Water Sensitive Urban Design (WSUD) will be a fundamental part of stormwater planning for the Tweed. Figure 2-1. Role of WSUD in Achieving ESD (Hoban and Wong, 2006), Illustrates the central role of in the delivery of ESD and as the framework to bring together water management and urban planning. Figure 2-2 illustrates the role WSUD plays should there be changes in the natural water cycle as a result of traditional urbanisation.

Water sensitive urban design is an approach to the planning and design of urban environments that supports healthy waterway ecosystems (Source:http://waterbydesign.com.au/whatiswsud/website). The National Water Commission defines WSUD as ensuring "…that urban water management is sensitive to natural hydrological and ecological cycles. It integrates urban planning with the management, protection and conservation of the urban water cycle".

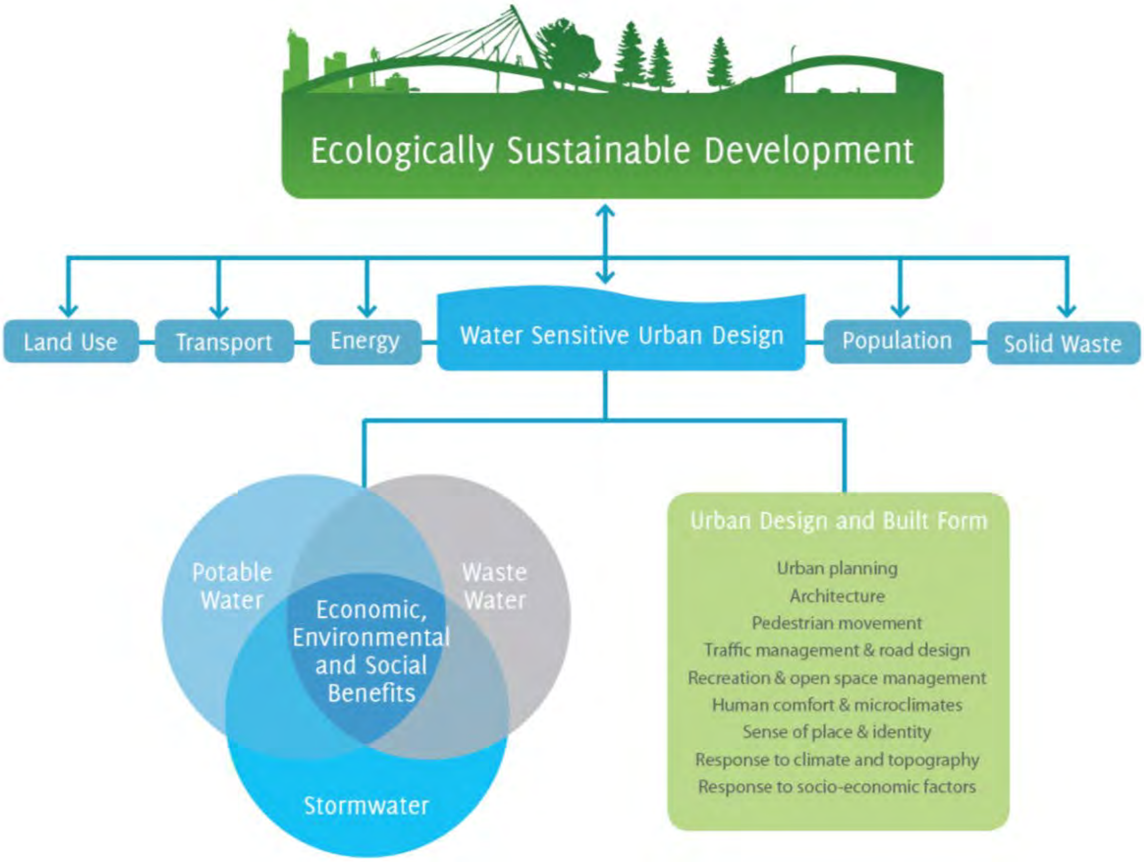

FIGURE 2-1. ROLE OF WSUD IN ACHIEVING ESD (HOBAN AND WONG, 2006)

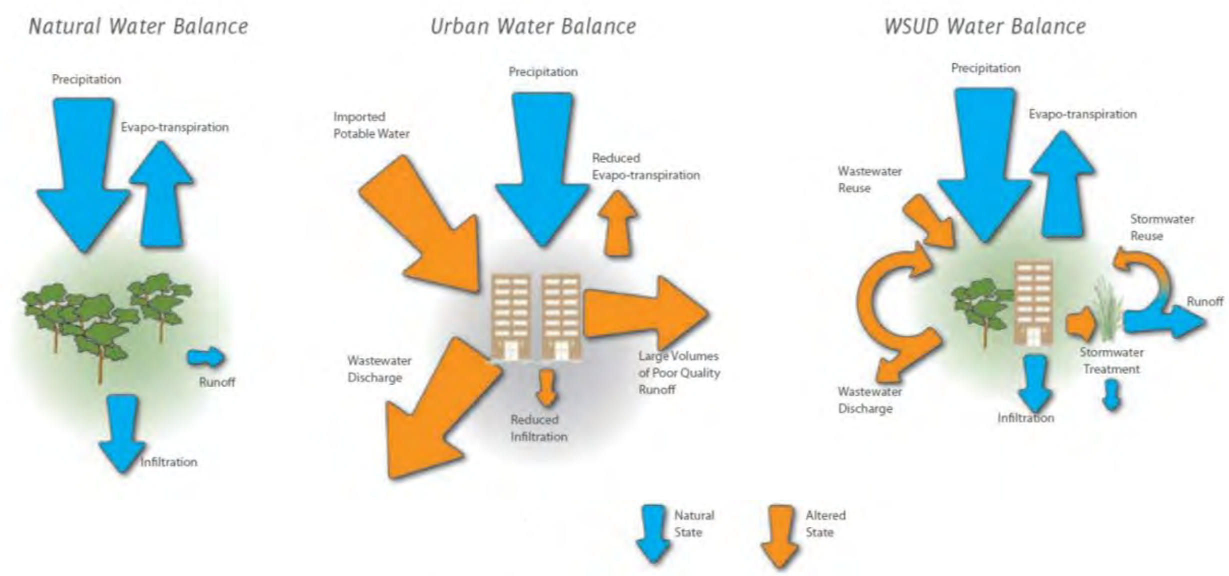

FIGURE 2-2. ILLUSTRATION OF THE CHANGES TO THE WATER CYCLE WITH URBANISATION AND WITH WSUD

Some specific WSUD principles are to (National Water Commission, 2009):

- **minimise impacts on existing natural features and ecological processes**
- **minimise impacts on natural hydrologic behaviour of catchments**
- **protect water quality of surface and ground waters**
- minimise demand on the reticulated water supply system
- **improve the quality of, and minimise polluted water discharges to the natural environment**
- **incorporate collection treatment and/or reuse of runoff, including roof water and other stormwater**
- **reduce run-off and peak flows from urban development**
- re-use treated effluent and minimise wastewater generation
- **increase social amenity in urban areas through multi-purpose green space, landscaping and integrating water into the landscape to enhance visual, social, cultural and ecological values**
- **add value while minimising development costs (e.g. drainage infrastructure costs)**
- account for the nexus between water use and wider social and resource issues
- **harmonise water cycle practices across and within the institutions responsible for waterway health, flood management, pollution prevention and protection of social amenity.**

As highlighted by the bold principles above, a key aspect of WSUD is stormwater management. In the context of stormwater management, the primary aim of WSUD is to treat stormwater to remove pollutants, and manage hydrology, and to protect downstream waterways. The implementation of WSUD has been found to have a net dollar benefit to our communities (refer to *A Business Case for Best Practice Urban Stormwater Management* (Water by Design, 2010)) provided it is implemented carefully.

2.3 Integrated Water Cycle Management – Vision for Tweed Shire

Tweed Shire Council is responsible for the urban water cycle (including drinking water, stormwater and wastewater) within the Tweed LGA. Central to the management of this water cycle is the impact of urban stormwater on natural waterways. In response to the combined challenge that managing drinking water, stormwater and wastewater creates, Council adopted an Integrated Water Cycle Management Plan (IWCMP) in 2006. As detailed within this plan, a key objective for the IWCM strategy was to:

- Develop guiding principles and objectives for urban water services that are consistent with the broader catchment and triple bottom line requirements.

and:

- Consider the urban water cycle issues in the context of the total catchment and total water cycle.

The IWCMP draws upon the existing Tweed USQMP (2000) for guiding principles on stormwater management and so the documents are strongly relevant to each other. On this basis the updated Tweed USQMP is written to be compatible with the objectives of the IWCMP.

3. Catchment Description

To ensure that urban water management is sensitive to natural hydrological and ecological cycles, it is important to have an understanding of the catchment. The following are some of the key catchment characteristics that require consideration in stormwater management: climate, rainfall, geology, topography and an understanding of catchment waterways.

3.1 Climate

The Tweed River catchment experiences a humid, subtropical climate with the regional climate predominantly controlled by the seasonal migration of the trade winds to the north and the anticyclone belt to the south. From approximately November to April the climate is generally warm and humid with south-easterly trade winds resulting from the anticyclone belt lying well to the south. The anticyclone belt migrates north during April and by July is generally covering the region, which results in a decrease in humidity and rainfall (Public Works Department, 1991).

3.1.1 Rainfall

Tweed Shire's subtropical climate is characterised by wet summers and predominantly dry winter months. The average annual rainfall is 1515 mm. Topographic features such as Mount Warning and the caldera means that a slightly higher rainfall is experienced in the upper catchment from orographic effects. However, being a small coastal catchment, rainfall is spread relatively evenly across the catchment.

Cyclonic disturbances are capable of producing very intense rainfalls. Twenty-four hour recordings of 250mm are not uncommon (Public Works Department, 1991).

Table 3.1 lists the average monthly rainfall and Figure 3-1 illustrates the average and highest monthly rainfall recorded over the period 1982 – 2011 (Bureau of Meteorology, Station 040717 Coolangatta).

TABLE 3-1. AVERAGE MONTHLY RAINFALL IN PERIOD 1982 - 2011 (COOLANGATTA STATION, BOM)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
141.3	168.5	174.4	170.4	148.2	128.7	76.2	54.3	42.2	98.1	135.0	152.9	1515.3

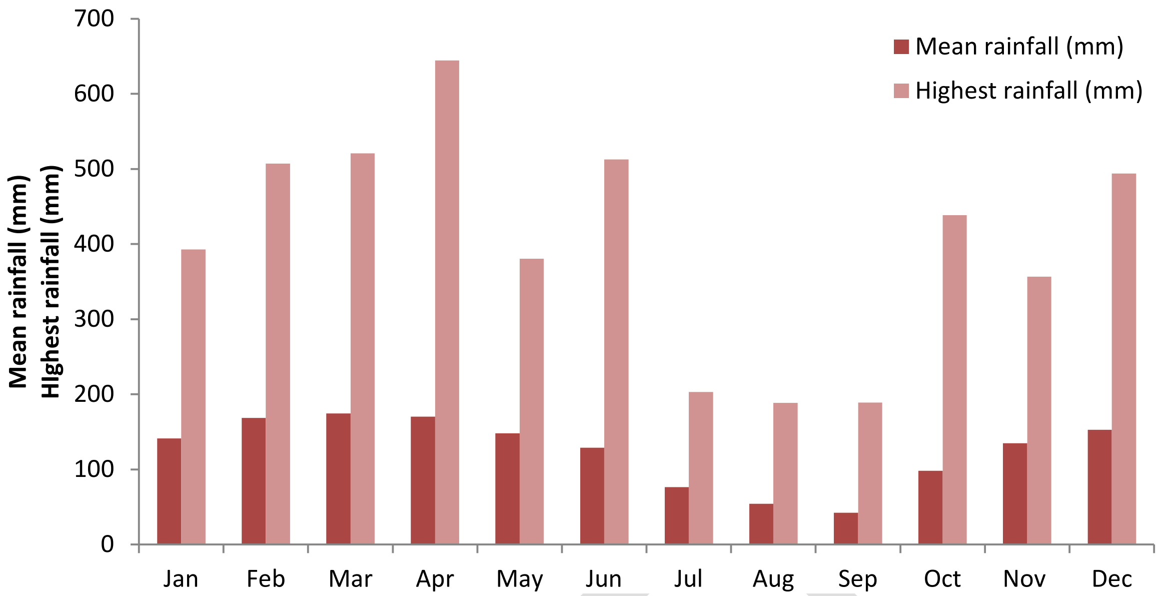

FIGURE 3-1. AVERAGE AND HIGHEST MONTHLY RAINFALL RECORDED AT COOLANGATTA, NSW

3.1.2 Temperature and Humidity

The mean temperature and relative humidity for each month as recorded at Coolangatta are listed in Table 3-2.

3.1.3 Evaporation

The Alstonville Agricultural Station is the closest weather recording station that also measures evaporation in the vicinity of Tweed Shire. It is to be expected that the evaporation in Tweed would be similar and that rainfall would exceed evaporation in the wet season from January to at least May. The Average Class A pan evaporation data for Alstonville is presented in Table 3-2..

TABLE 3-2. MEAN DAILY MINIMUM AND MAXIMUM TEMPERATURES AND RELATIVE HUMIDITY FOR COOLANGATTA. ALSTONVILLE EVAPORATION DATA. SOURCE: BUREAU OF METEOROLOGY, 2011

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Daily Maximum Temperature (C)	28.2	28.1	27.1	25.3	23.1	21.0	20.5	21.3	23.1	24.3	25.6	27.1	24.6
Mean Daily Minimum Temperature (C)	20.9	20.9	19.6	17.0	14.1	11.3	10.2	10.5	13.4	15.9	18.0	19.8	16.0
Relative Humidity (%) 3pm	69	69	67	64	62	60	56	56	61	66	68	68	64
Evaporation, mm (Class A, EPAN)	192	149	134	100	65	51	73	97	127	165	179	226	1558

3.2 Geology and Soils

The erosion of the different layers of the Mount Warning Complex has produced the diverse geomorphology and soil types that make up the complex Tweed Valley geology.

The complexities of geology in Tweed Shire have led to a diverse pattern of soils. Six soil groupings have been identified as existing in the Tweed Shire by McGarity in the Tweed Shire Strategic Plan (1973). These include coastal sands, krasnozems, alluvial soils, yellow earths, red podsolics and chocolate soils. A full description of soils is contained in Appendix 2 of the Tweed Shire State of the Environment Report 1996 – 1997 (Tweed Shire Council, 1997).

The coastal sands are fairly recent depositions along the coastline and older Pleistocene dunes. The krasnozems are found over the basalt rocks at Terranora, Cudgen and Duranbah. Alluvial soils are found within the floodplains of the main valleys (Graham, 1987).

Many of the soils found in the Tweed are highly susceptible to erosion, particularly in sloping areas. Due to their basaltic origin, many of the soils are also slightly acidic. Much of the floodplain areas have Potential and Actual Acid Sulfate Soils close to the surface.

3.3 Topography

The Water Resources Commission of NSW described the Tweed Valley as being hilly to mountainous over sixty percent of its area (Water Conservation and Irrigation Commission of NSW, 1968). Undulating to hilly land was considered to occupy a further twenty percent, with the remaining twenty percent flat land. These flat areas are confined mainly to the plain adjoining the lower reaches of the Tweed and Rous Rivers and limited areas along the lower section of the Oxley and Rous Rivers above Murwillumbah.

The Coastal Creeks catchments are twenty-five percent hilly to mountainous, forty percent undulating to hilly and thirty percent flat.

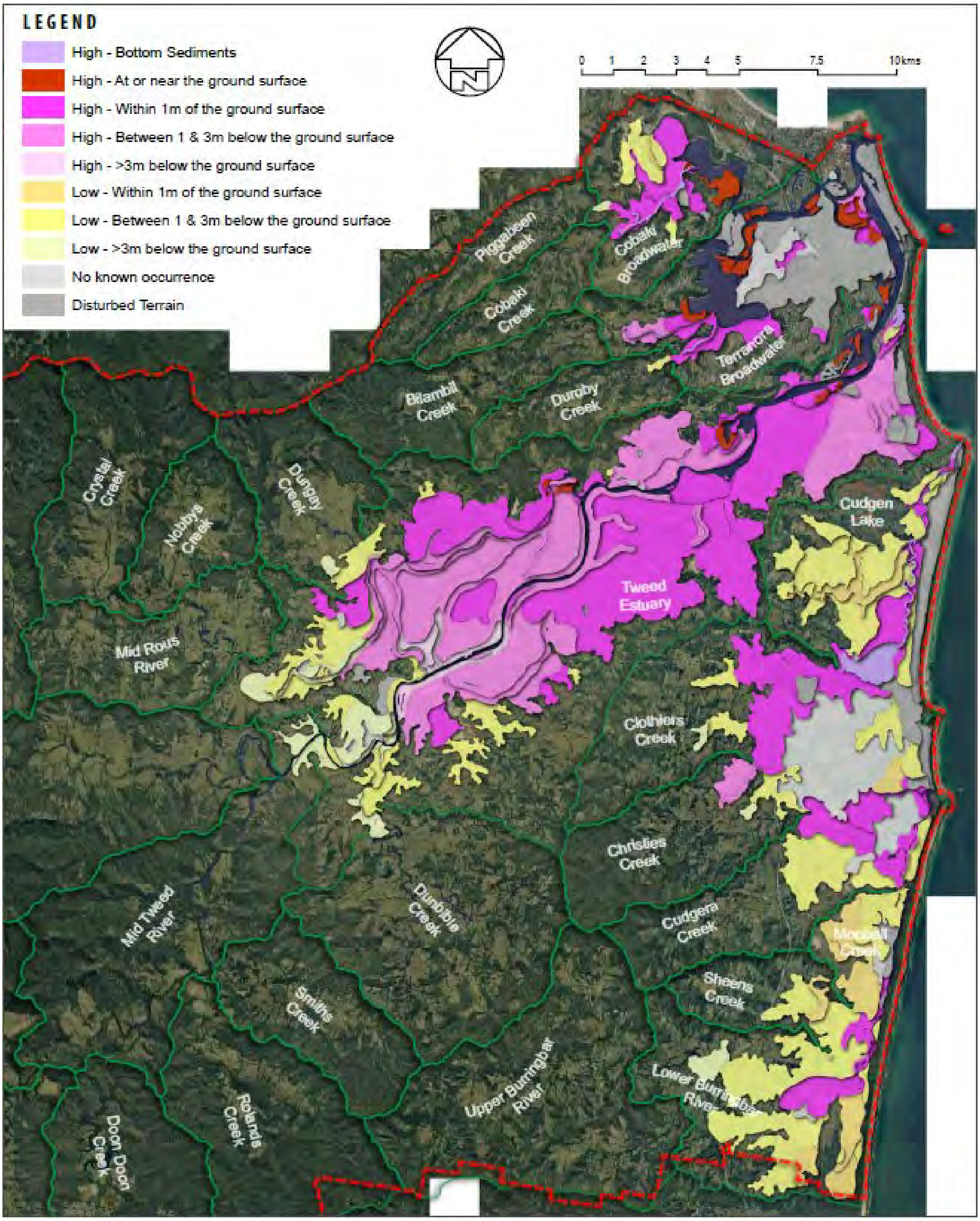

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FIGURE 3.2: ACID SULPHATE SOILS OF THE TWEED SHIRE

CLIENT: TWEED SHIRE COUNCIL

REF: AWC1-10077b

OCTOBER 2011

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3.4 Waterways

For the purposes of this plan, the Tweed Shire can be divided into five major sub-catchments: Four of which are estuarine and one freshwater (Table 3-3). The Tweed USQMP is applicable to all urban development throughout these sub-catchments (Table 3-3, Figure 3.3).

The five major sub-catchments relevant to the Tweed USQMP are:

- Tweed River - Freshwaters
- Tweed River – Upper estuary
- Tweed River – Lower estuary
- Cobaki and Terranora Broadwaters
- Tweed Coast Estuaries

TABLE 3-3. MAJOR SUB-CATCHMENTS OF THE TWEED SHIRE

Major Sub-catchments	Main Waterways	Description
Tweed River and Coastal Creeks – Freshwaters	Tweed River (fresh reach) Rous River (fresh reach) and tributaries Oxley River and tributaries Burringbar, Crabbes, Cudgera Reserve and Clothiers Creeks	Freshwaters of Tweed River and its tributaries; freshwaters of Tweed coastal creeks.
Tweed River – Upper Estuary	Tweed River (upper estuarine reach) Rous River (estuarine reach)	Murwillumbah to Pacific Highway bridge at Barney's Point
Tweed River – Lower Estuary	Tweed River (lower estuarine reach)	Barney's Point bridge to Tweed River mouth, including Terranora Inlet.
Cobaki and Terranora Broadwaters	Cobaki Broadwater Terranora Broadwater Terranora Creek Duroby Creek (estuarine reach) Bilambil Creek (estuarine reach) Cobaki Creek (estuarine reach) Piggabeen Creek (estuarine reach)	Tidal extent of Duroby, Bilambil, Cobaki and Piggabeen Creeks, the Broadwaters and Terranora Creek east to Boyd's Bay bridge.
Tweed Coast Estuaries	Cudgen Creek (estuarine reach) Cudgera Creek (estuarine reach) Mooball Creek (estuarine reach)	Estuarine reaches of all three coastal creeks.

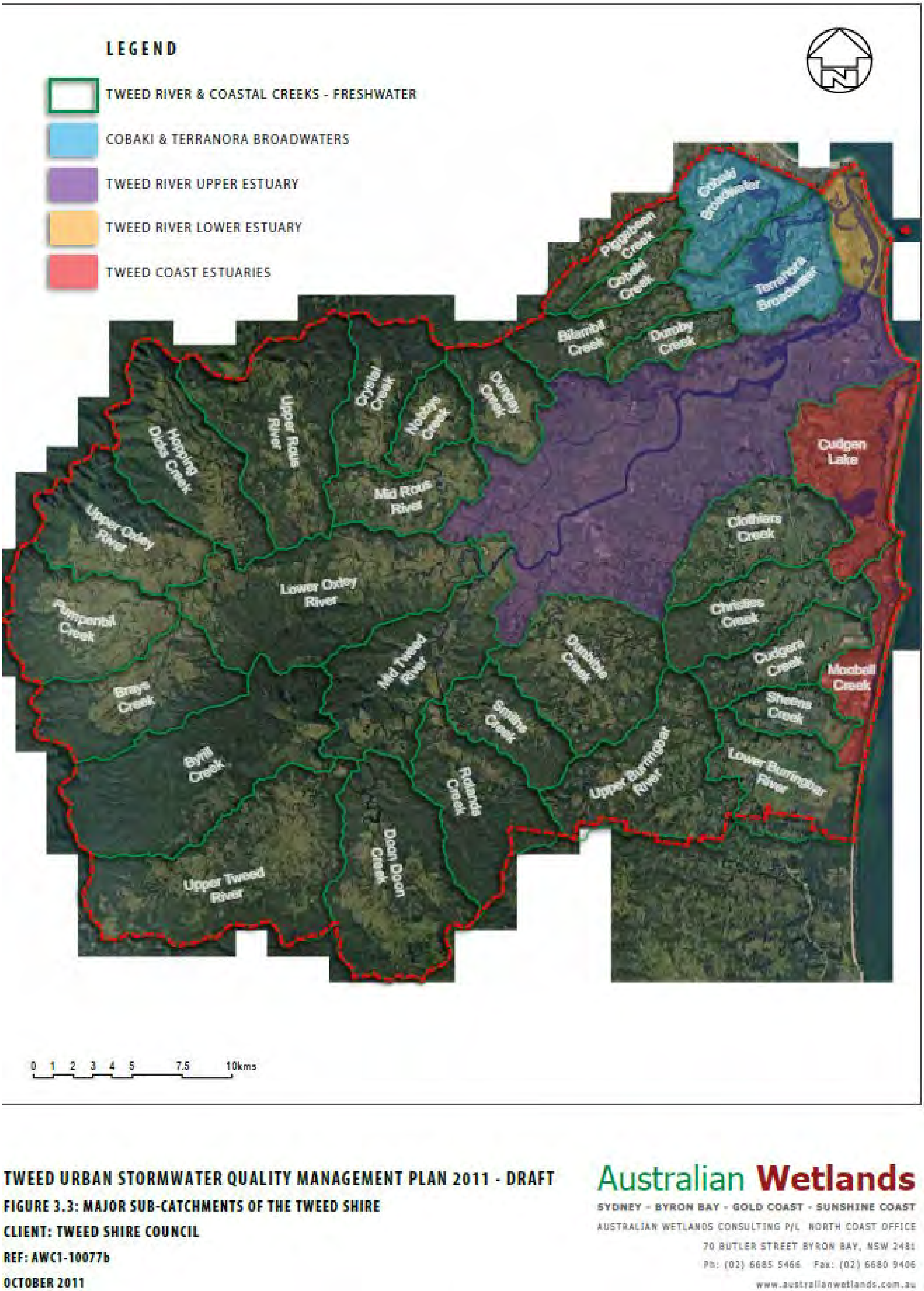

FIGURE 3-2. MAJOR SUB CATCHMENTS OF THE TWEED SHIRE.

3.2.1 Tweed River Upper Estuary

The Tweed River catchment is approximately 1100km^2 and a rugged and compact landscape. Upstream of Murwillumbah, in the freshwater reaches, the drainage pattern form of minor tributaries is fairly symmetrical due to the valley's volcanic origin. In contrast, the estuarine reaches of the Tweed River downstream of Murwillumbah weave a path across an extensive flood plain (Tweed Shire Council, 1998a).

The upper estuary extends toward the coast from Bray Park Weir west of Murwillumbah, through agricultural lands surrounding Condong and Tumbulgum, where the Rous River joins the Tweed River. The estuary continues flowing east around Stotts Island Nature Reserve and Tweed Broadwater. Further downstream the estuary passes through the more urbanised areas of Chinderah and Banora Point to Barney's Point Bridge, where the Pacific Highway crosses the Tweed River (Figure 3-3).

3.2.2 Tweed River Lower Estuary

The Tweed River lower estuary flows from the Pacific Highway, largely parallel with the coastline through the highly urbanised areas of Banora Point and Tweed Heads. The lower estuary is well flushed and extends into Shallow Bay around Tony's Island and around Ukerebagh Island into Terranora Inlet west to Minjungbal Drive. Prior to discharging through the rock walls at Point Danger, the estuary flows into Kerosene Inlet and Jack Evans Boat Harbour. The Tweed River Entrance Sand Bypassing Project collects sand from just south of the entrance to the Tweed River and pumps it to beaches to the north via a series of pipes, and supplemented by occasional dredging at the river entrance (Figure 3-3).

The lower estuary is highly valued for recreational use and a popular area for boating, recreational and commercial fishing and access to Nature Reserves. It is also an important area for local wildlife including migratory shorebirds.

3.2.3 Cobaki and Terranora Broadwaters

Cobaki and Terranora Broadwaters are both shallow water bodies (0.5m – 1.5m) and are fed by Bilambil, Duroby, Piggabeen and Cobaki Creeks. These creeks drain the rural catchment west of the broadwaters, becoming meandering floodplain estuaries. Piggabeen Creek flows into Cobaki Creek prior to discharge into Cobaki Broadwater. Bilambil and Duroby Creeks drain the rural catchment west of Terranora Broadwater (Figure 3-3).

Cobaki and Terranora Broadwater are highly valued for their aquatic ecosystem attributes as well as the recreation opportunities and visual amenity provided to the residents of surrounding urban areas. The habitat provided by the Broadwaters is important to the survival of local flora and fauna communities. Shallow-water vegetated habitat, notably saltmarsh, SEPP14 mangrove and seagrass communities and other instream habitat are critical for ecosystem health. The health of these systems is important as the Broadwaters are important feeding and roosting grounds for protected/threatened species of local and migratory shorebirds.

The Broadwaters are also an important recreational and commercial fishery, as well as supporting the local oyster industry. Such industries are all reliant upon good water quality.

The region also has a rich and continuing Aboriginal heritage. Historic records demonstrate a history of regular large gatherings along the Tugun sand plain, Lower Tweed Estuary and adjacent Broadwater shorelines supported by the significant number of middens and campsites (Fox, 2006).

The Broadwaters act as depositional basins for the surrounding catchment and therefore are susceptible to impact from activities undertaken throughout the catchment. There are several large urban subdivisions in the planning phases known as: Cobaki Lakes, Area E and Bilambil Heights. The scale of these developments means that best practice stormwater management will be crucial if the health of the Broadwaters and associated values such as aquatic ecosystem health, recreation and cultural heritage are to be protected.

Both Terranora and Cobaki Broadwater flow into Terranora Creek then into Terranora Inlet, the stretch of water that links Terranora Creek to the mouth of the Tweed River. This is a tidally well-flushed reach that flows through highly urbanised areas of Tweed Heads South and Tweed Heads, including several canal estates, and under the Pacific Highway. The major sewage treatment plant for the Tweed shire, Banora Point Wastewater Treatment Plant, currently discharges to Terranora Inlet on outgoing tides to promote tidal flushing of wastewater from the system.

3.2.4 Tweed Coast Estuaries

Cudgen, Cudgera and Mooball Creeks are relatively small coastal estuaries located between Kingscliff and Wooyung and are typical of small coastal creeks along the northern NSW coast. They flow northwards behind the coast sand barrier and have dynamic, congested sandy entrances that largely control their tidal and morphological characteristics (Tweed Shire Council, 1997a).

Cudgen Creek has its mouth near the township of Kingscliff and follows a meandering course over 9.4km to Cudgen Lake at Bogangar. Cudgen Lake covers an area of 1.65km^2 and is generally less than two metres deep. Cudgen Lake has been subject to several major fish kills due to impacts from the presence of actual Acid Sulfate Soils within the catchment. Cudgen Creek and Lake have a catchment of approximately 66km^2. There has been substantial urban development within this catchment, with the potential to adversely impact on Cudgen Creek (Figure 3-3).

Cudgera Creek meets the sea at Hastings Point, has a reasonably straight channel and follows a 3.5km course south to Pottsville. It has three major branches, Christies Creek opposite the mouth, Palmvale Creek which branches off at North Pottsville, and Cudgera Creek continues to the south (Figure 3-3).

Cudgera Creek has a relatively small catchment of approximately 50km^2. The majority of drainage enters the creek via Palmvale Creek. The southern arm of Cudgera Creek has practically no catchment area, a relic feature of when Cudgera and Mooball Creek were joined. It became isolated when Mooball Creek broke through to the ocean at Potts Point (Tweed Shire Council, 1997a).

Urban development has increased within the Cudgera Creek catchment since the Tweed USQMP was first written (2000), notably within the Koala Beach, Black Rocks and Seabreeze Estates at Pottsville.

Mooball Creek is the largest and most southern of the three creeks. The waterway runs parallel to the coastal dune, extending approximately 9km from its mouth at Potts Point. Mooball Creek has a catchment of approximately 117km^2 which is dominated at its southern end by cane farming activities. Mooball Creek is joined by Crabbes Creek which is the major drainage system in the area as well as a number of other tributaries (Figure 3-3). An extended horseshoe-shaped canal system with two openings to Mooball Creek is located approximately 1.8km from the mouth (Tweed Shire Council, 1997a).

FIGURE 3-3. DESCRIPTION OF ESTUARINE SUB-CATCHMENTS

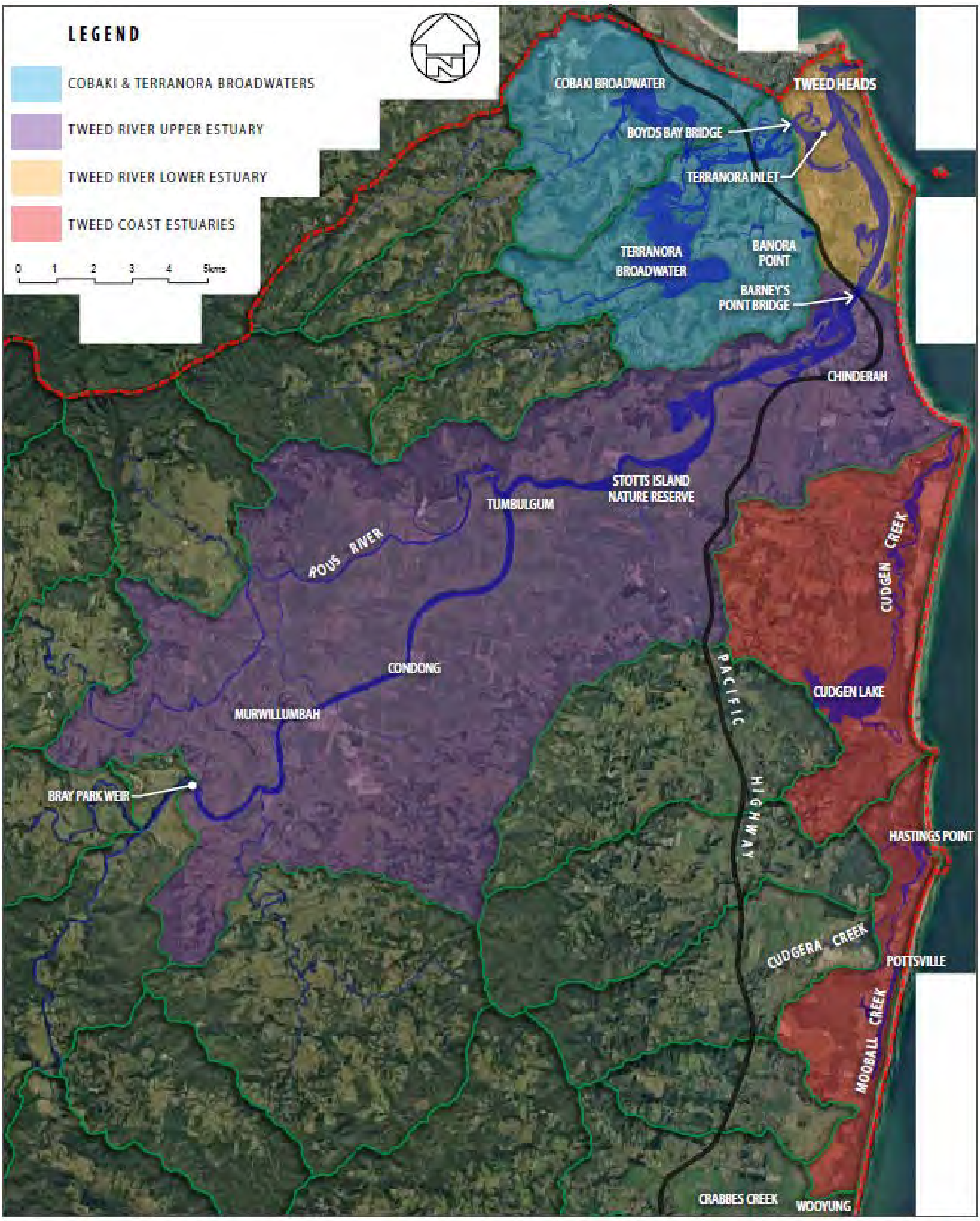

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FIGURE 3.4: DESCRIPTION OF ESTUARINE SUB-CATCHMENTS
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4. Catchment Condition – Water Quality

Tweed Shire Council undertakes a number of water quality monitoring programs within its catchments. Surveys can broadly be categorised into those which occur within upper catchments and estuaries. Water quality monitoring has been undertaken by Council since the early 1990's on a quarterly basis for most programs.

A summary of data has been undertaken with the aim of describing the water quality within receiving environments, and how this is affected by rainfall and landuse. Figures 4.1 – 4.3 show the location of Council's estuarine water quality monitoring sites.

4.1 Tweed River Upper Estuary

Water quality within the Tweed and Rous Rivers is currently being monitored at 11 sites, as shown in Figure 4-1,. Sites TWE3 – TWE10 are sampled in the Tweed River Estuary, Sites TWE11 – TWE13 are sampled in the Rous River Estuary. Boxplots have been prepared for each of these sites, displayed in Figure 4-4, which outlines the mean, median, and range of the data gather by TSC between May 2009 and May 2011. As shown in this graph, water quality at the sampling sites closest to the estuary mouth achieve the best water quality results: showing lower TN, TP, and TSS concentration and a more stable pH and Chlorophyll *a* range compared to sites further upstream.

A statistical analysis of the data recorded in the Tweed Upper Estuary at Sites 3-13 between May 2009 and 2011 indicates rainfall significantly increases the concentration of TN, TP and TSS within the Tweed River and a number of key sampling sites. The extent and strength of this relationship varies with site location and the amount of rainfall preceding each sampling date, however it can be conclusively stated that the water quality at each of the sampling sites site within the Tweed and Rous Rivers deteriorates in response to rainfall (Person correlation between given parameter and rainfall, $p=<0.05$).

This relationship is demonstrated further in Figure 4-8, which graphs TN concentrations at Sites TWE 4-8 against seven day rainfall data. As can be seen from this figure, the concentration of TN within the Tweed River increases significantly (Person Correlation $p=<0.05$) as a result of rainfall within the catchment. Median values for TN and TP in the Upper Tweed River Estuary indicate that water quality does not typically meet NSW water quality objectives for nutrients. The most recent comprehensive analysis of water quality in the Tweed River Estuary (ABER, 2012) can be accessed from Councils website. TSC continually collects water quality data and can provide data beyond the date of this document.

4.2 Tweed River Lower Estuary

Water quality in the Tweed River Lower Estuary is currently monitored at seven sites, as shown in Figure 4-1. For the purposes of this analysis, the Tweed River Lower Estuary includes sites downstream of Boyd's Bay Bridge (Terranora Inlet) and downstream of Barney's Point Bridge (Tweed

River). Sites TES8 – TES12 are sampled in Terranora Inlet, sites TWE1 and TWE2 are sampled within Tweed River Estuary.

Boxplots have been prepared for each of these sites, displayed in Figure 4-5 which outlines the mean, median, and range of the data gathered by TSC between May 2009 and May 2011. As shown in this graph, water quality does not vary greatly between lower estuarine sites, likely due to the well-flushed nature of the lower estuary. Median values for all sites were compliant with NSW water quality guidelines for TN. The data set for TP has not been sampled with a detection limit low enough to judge compliance with the water quality objective of <30µg/L. There were some low DO results in Terranora Inlet (TES8-10) (refer to Appendix A for water quality data summary table). The most recent comprehensive analysis of water quality in the Tweed River Estuary (ABER, 2012) can be accessed from Councils website. TSC continually collects water quality data and can provide data beyond the date of this document.

A statistical analysis of the data recorded in the Tweed Lower Estuary between May 2009 and 2011 indicates rainfall significantly increases the concentration of TN, TP and TSS within the Tweed Lower Estuary and a number of key sampling sites. The extent and strength of this relationship varies with site location and the amount of rainfall preceding each sampling date, however it can be conclusively stated that the water quality at each of the sampling sites site within the Tweed Lower Estuary deteriorates in response to rainfall (Person correlation between given parameter and rainfall, $p=<0.05$).

This relationship is demonstrated further in figure 4.9 which graphs TN concentrations at Sites TWE1, TES 9 and TES 11 against seven day rainfall data. As can be seen from this figure, the concentration of TN within the Tweed Lower Estuary increases significantly (Person Correlation $p=<0.05$) as a result of rainfall within the catchment.

4.3 Cobaki and Terranora Broadwaters

Water quality within the Cobaki and Terranora Broadwaters has been monitored at 11 sites, as shown in Figure 4-2,. Boxplots have been prepared for each of these sites and outline the mean, median and range of the data gather by TSC between May 2009 and May 2011 (see Figure 4-6). As shown in this graph, water quality across the Cobaki and Terranora Broadwaters varies in terms of compliance with the relevant NSW water quality objectives (TN, TP, TSS, DO and pH). Sites TES 13-16 which exceed the TP, TSS and DO water quality objectives are all located within creeks or channels surrounded by urban development or agricultural land which flow into the main Cobaki and Terranora Broadwaters. Upon entering the Broadwaters, water quality improves and is largely compliant with water quality objectives (refer to Appendix A for water quality data summary table).

Water quality within the Cobaki and Terranora Broadwaters was found, like sampling sites within the Tweed and Rous Rivers, to decrease in response to rainfall within the catchment. As noted in a report entitled *Water Quality in the Lower Tweed Estuary System* (KEC Science, 1998), the water quality of this region decreases in response to rainfall. Water quality parameters TN, TP and TSS were found to increase in response to rainfall (Person Correlation, $p=<0.05$) at most sampling sites, with the strongest relationships at sampling sites with little hydraulic buffering potential (i.e. not at the estuary mouth or in the middle of the Broadwaters where there is greater mixing and flushing of waters). Figure 4.10 displays two graphs investigating the relationship between TN concentration and rainfall at TES sampling sites 13-16, showing increasing TN concentration following rainfall.

A statistical analysis of the data recorded in the Cobaki and Terranora Broadwater sub catchment between May 2009 and 2011 indicates rainfall significantly increases the concentration of TN, TP and TSS within this sub catchment at a number of key sampling sites. The extent and strength of this relationship varies with site location and the amount of rainfall preceding each sampling date, however it can be conclusively stated that the water quality at each of the sampling sites site within the Cobaki and Terranora Broadwater sub catchment deteriorates in response to rainfall (Person correlation between given parameter and rainfall, $p=<0.05$).

This relationship is demonstrated further in Figure 4-10 which graphs TN concentrations at Sites TES 1, TES 4-6, TES 13 AND TES 16 against seven day rainfall data. As can be seen from this figure, the concentration of TN within the Cobaki and Terranora Broadwater sub catchment increases significantly (Person Correlation $p=<0.05$) as a result of rainfall within the catchment.

4.4 Tweed Coast Estuaries

Water quality has been monitored at three sites in Cudgen Creek, five sites in Cudgera Creek and four sites in Mooball Creek (Figure 4-3).

TWEED URBAN STORMWATER QUALITY MANAGEMENT PLAN 2011 - DRAFT
FIGURE 4.3: WATER QUALITY MONITORING SITES- TWEED COAST ESTUARIES
CLIENT: TWEED SHIRE COUNCIL
REF: AWC1-10077b
OCTOBER 2011

Australian Wetlands
SYDNEY - BYRON BAY - GOLD COAST - SUNSHINE COAST
AUSTRALIAN WETLANDS CONSULTING P/L NORTH COAST OFFICE
70 BUTLER STREET BYRON BAY, NSW 2481
Ph: (02) 6685 5466 Fax: (02) 6680 9406
www.australianwetlands.com.au

Figure 4-3).

Figure 4-3).

Data analysed for this report encompasses the monitoring period June 2008 – April 2011. Boxplots have been prepared for each of these sites, displayed in Figure 4-7, and outline the mean, median, and range of the data. As shown in this graph, water quality across the Tweed Coast Estuaries is largely compliant with most of the assessed water quality objectives (TN, TP, TSS, DO and pH), with the exception of Sites CGR 2-6 which exceed at least one, if not all, of the TN, TSS, pH and DO water quality objectives. The most notable trend was in Cudgera Creek; where there was a progressive increase in TN and decrease in DO from downstream to upstream. While TN increased progressively upstream in all three coast estuaries, median TN increased from Cudgera Creek estuary mouth (CGR 1, TN = 230ug/L) to the upper estuary sites (CGR 4 and CGR 6, TN = 690ug/L) by a factor of three. The majority of TP data for both Cudgen and Mooball Creeks was at or below the detection limit of 0.05mg/L, whereas TP data for Cudgera Creek exceeded the water quality guideline (refer to Appendix A for water quality data summary table).

A statistical analysis of the data recorded in the Tweed Coast Estuaries sub catchment between May 2009 and 2011 indicates rainfall significantly increases the concentration of TN, TP and TSS within this sub catchment at a number of key sampling sites. The extent and strength of this relationship varies with site location and the amount of rainfall preceding each sampling date, however it can be conclusively stated that the water quality at each of the sampling sites site within the Cudgera and Cudgen Creek sub catchments deteriorates in response to rainfall (Person correlation between given parameter and rainfall, p=<0.05).

This relationship is demonstrated further in Figure 4-11, which graphs TN concentrations at Sites CGN 2, CGR 3 and MBL 3 against seven day rainfall data. As can be seen from this figure, the concentration of TN within the Cobaki and Terranora Broadwater sub catchment increases significantly (Person Correlation p=<0.05) as a result of rainfall within the catchment.

The relationship between rainfall and water quality would also be influenced by the tidal cycle. A lesser correlation between rainfall and water quality may be explained by the influence of an incoming tide. For example, a sample from a site sampled on the outgoing tide would reflect catchment rainfall runoff, whereas a sample taken from a site sampled on the incoming tide would be influenced by the flushing generated by incoming seawater.

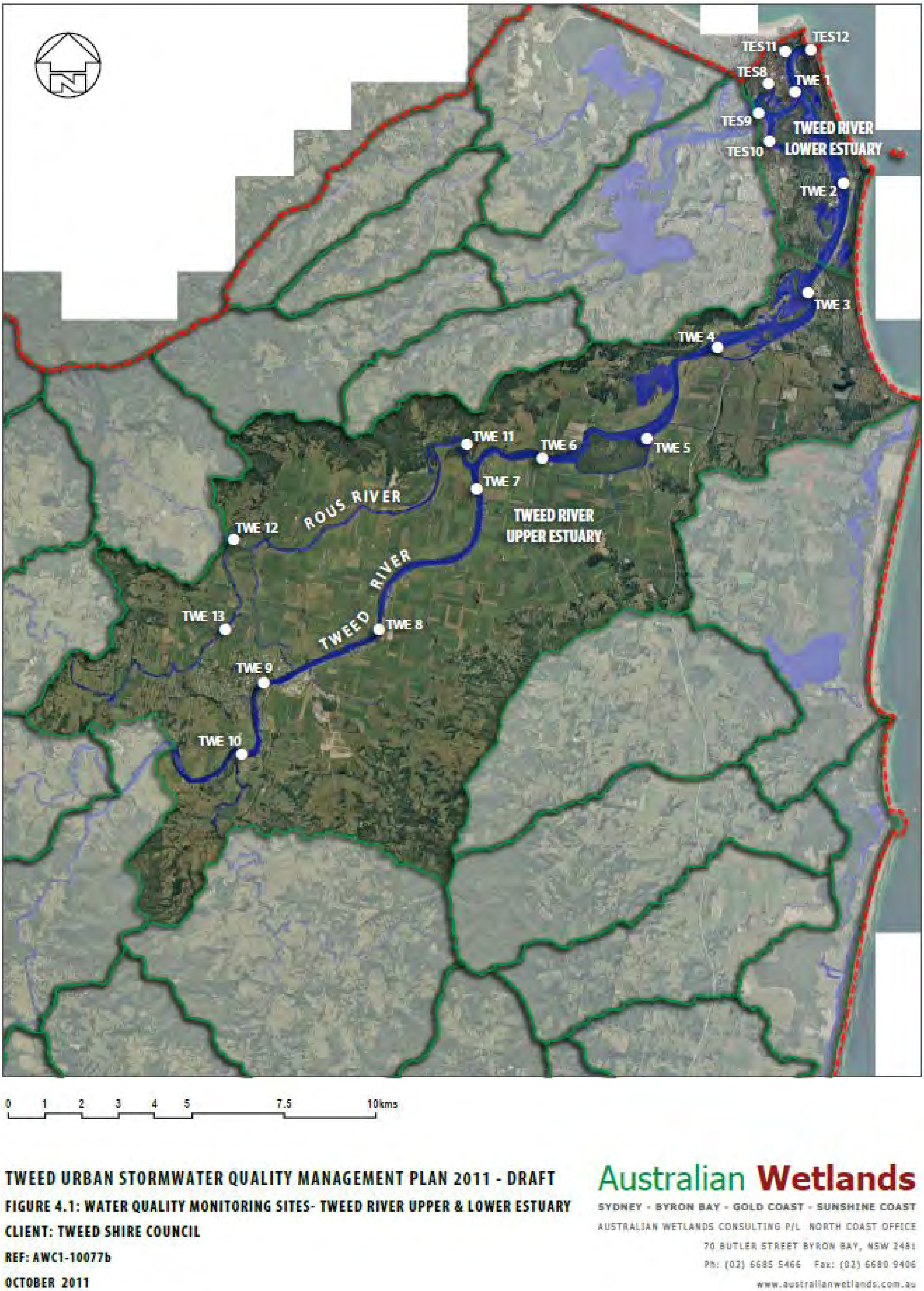

FIGURE 4-1. LOCATION OF WATER QUALITY SAMPLING IN THE TWEED RIVER UPPER AND LOWER ESTUARY

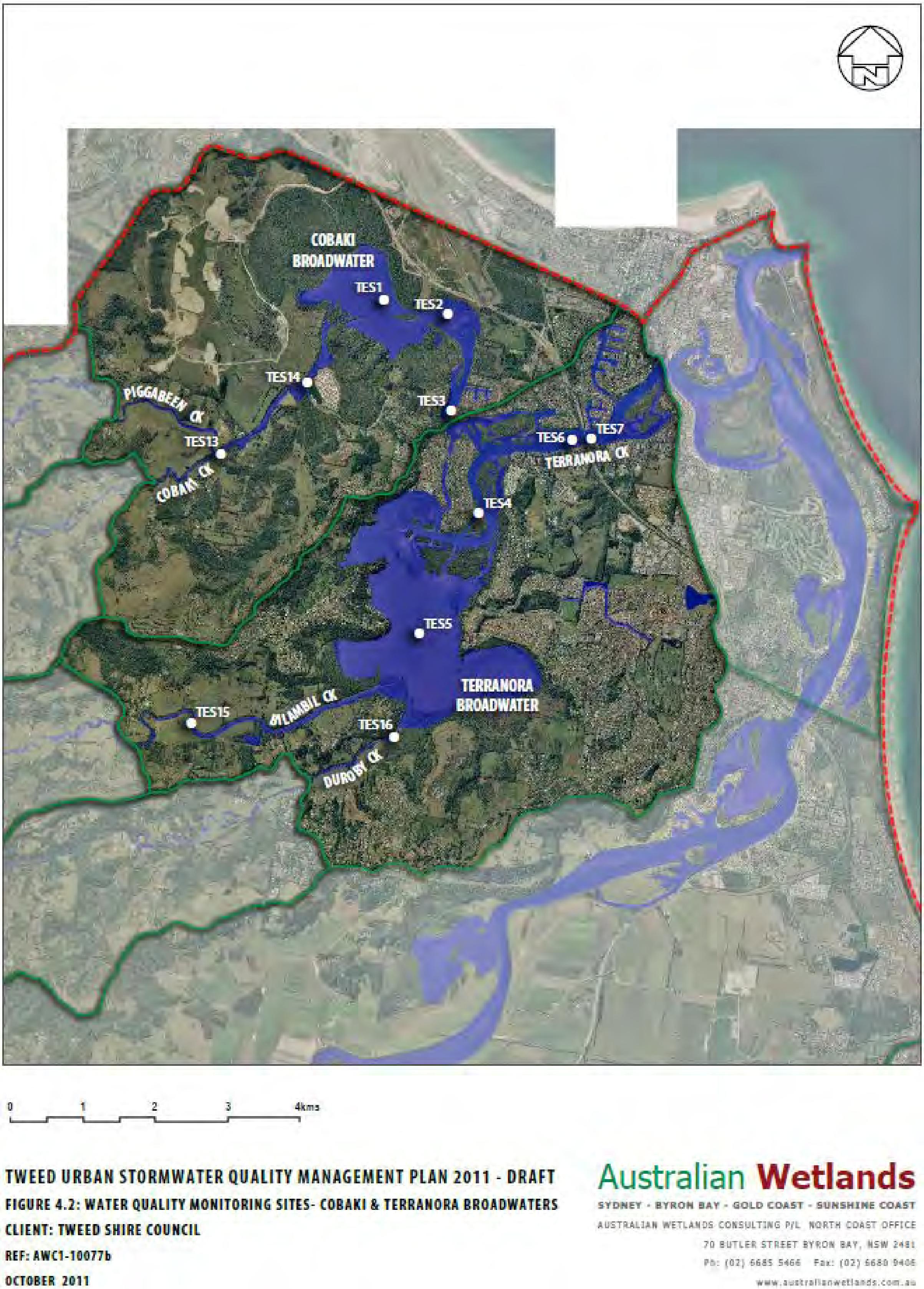

FIGURE 4-2. LOCATION OF WATER QUALITY SAMPLING IN COBAKI AND TERRANORA BROADWATERS

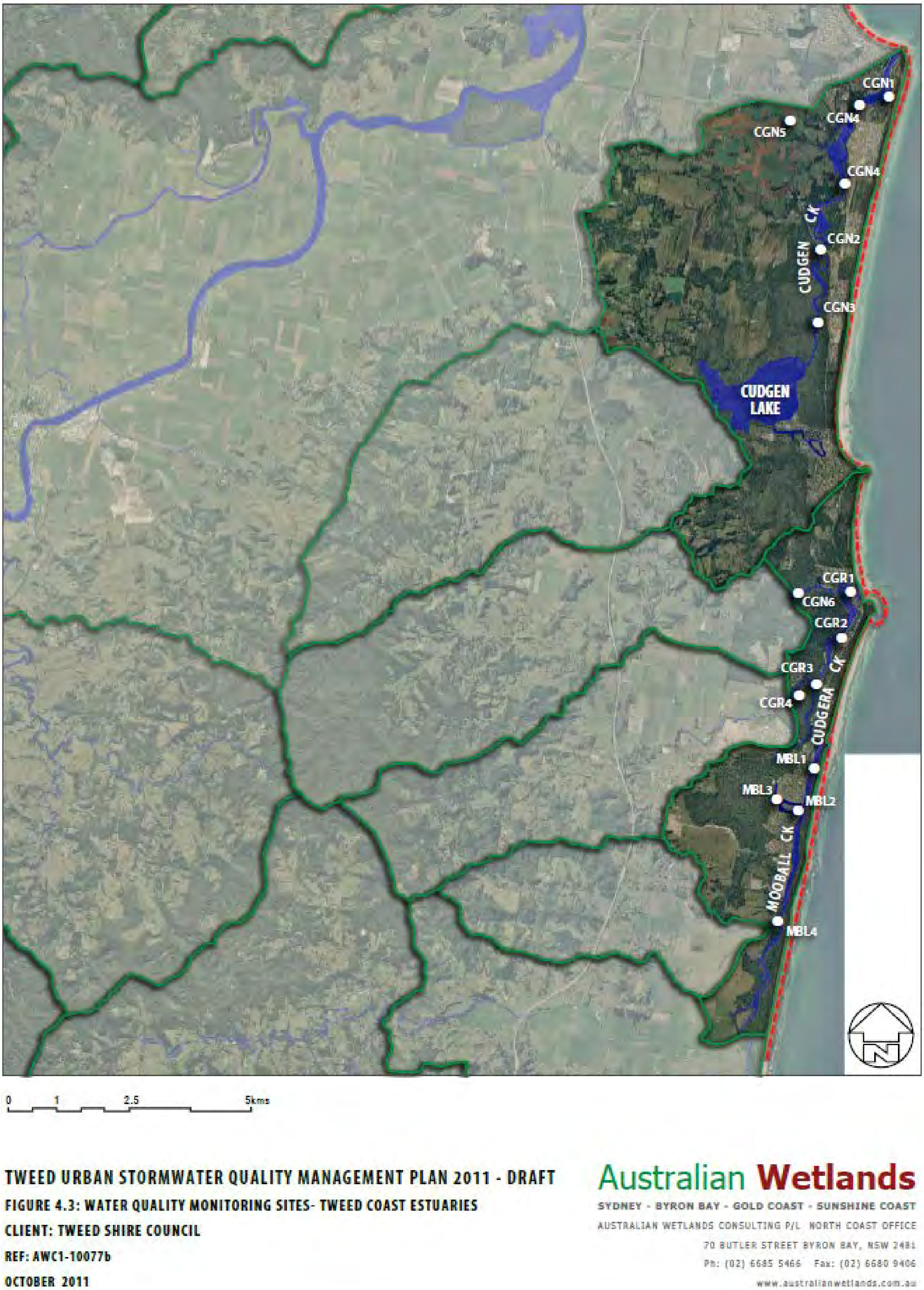

FIGURE 4-3. LOCATION OF WATER QUALITY SAMPLING IN THE TWEED COAST ESTUARIES

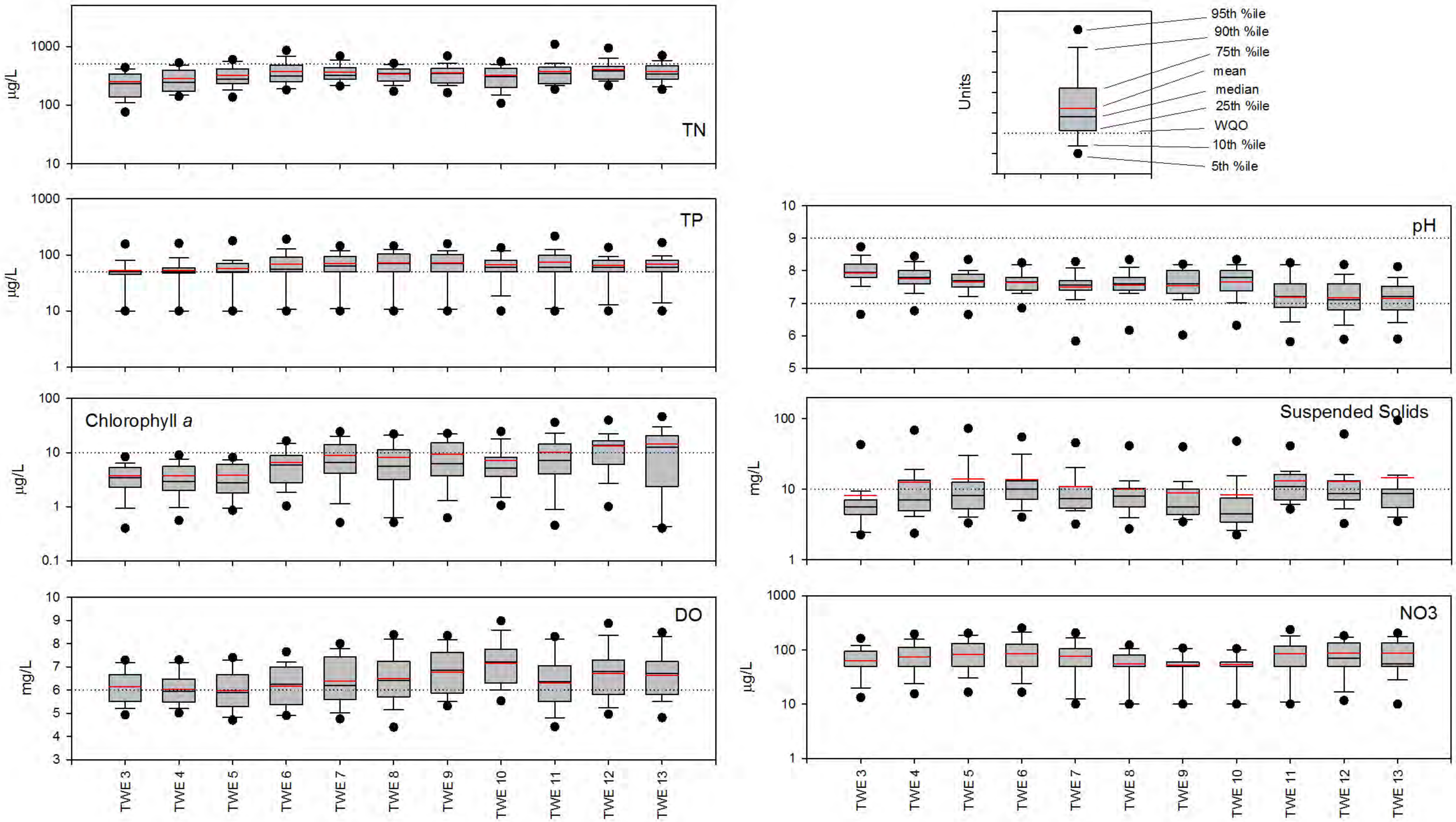

FIGURE 4-4. BOXPLOT INDICATING WATER QUALITY FOR SITES WITHIN THE TWEED RIVER UPPER ESTUARY

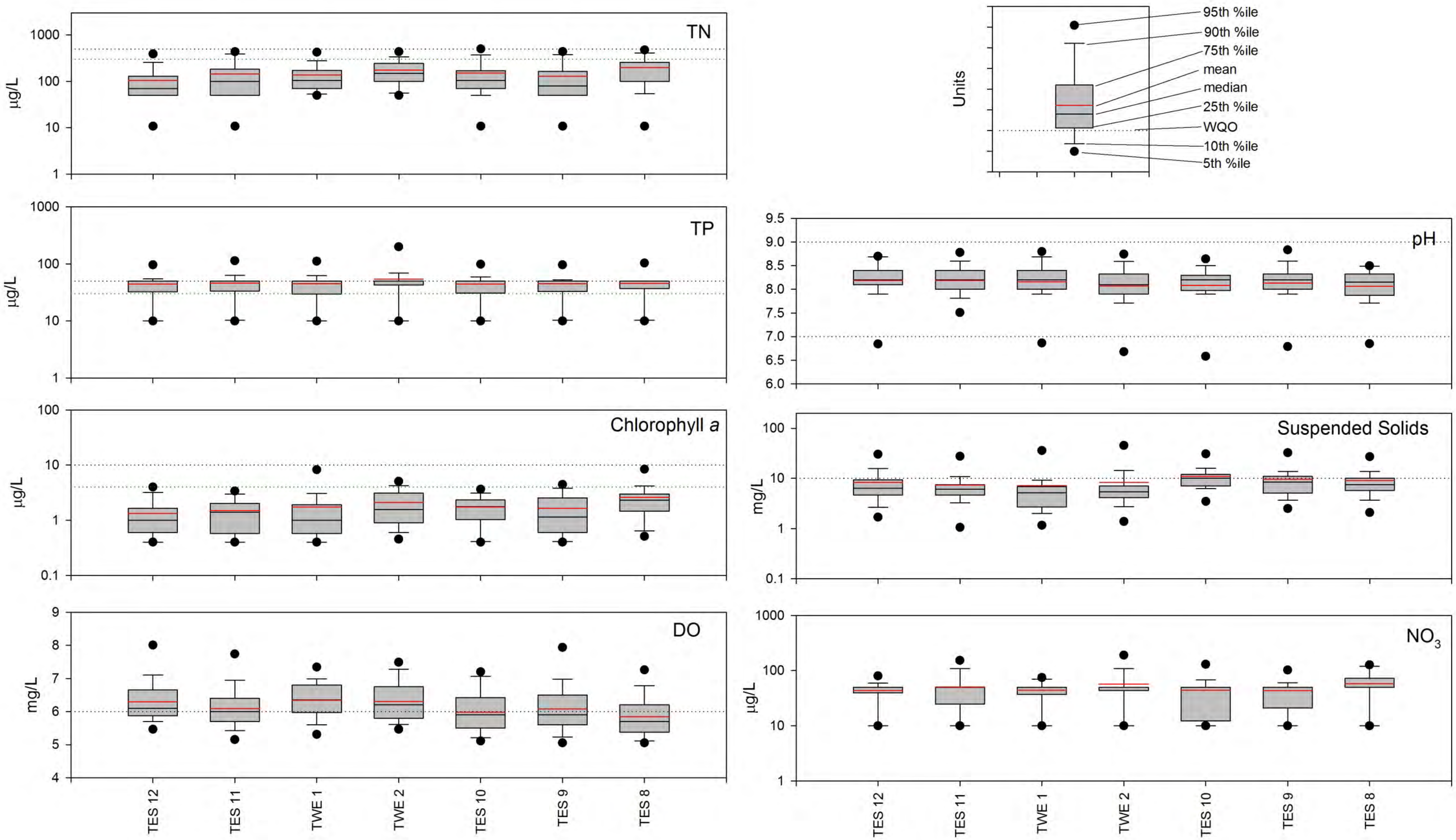

FIGURE 4-5. BOXPLOT INDICATING WATER QUALITY FOR SITES WITHIN THE TWEED RIVER LOWER ESTUARY

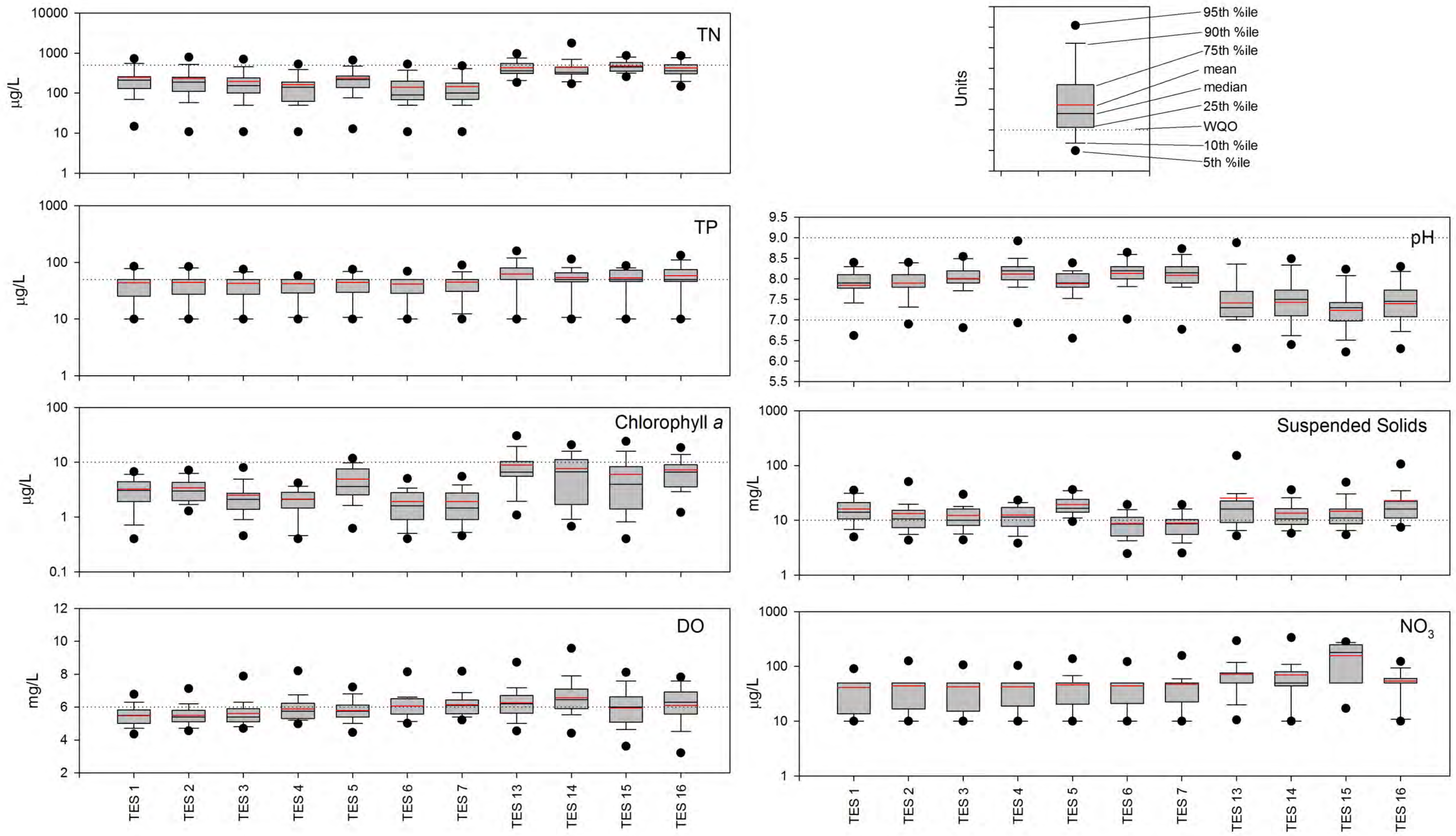

FIGURE 4-6. BOXPLOT INDICATING WATER QUALITY FOR SITES WITHIN COBAKI AND TERRANORA BROADWATER

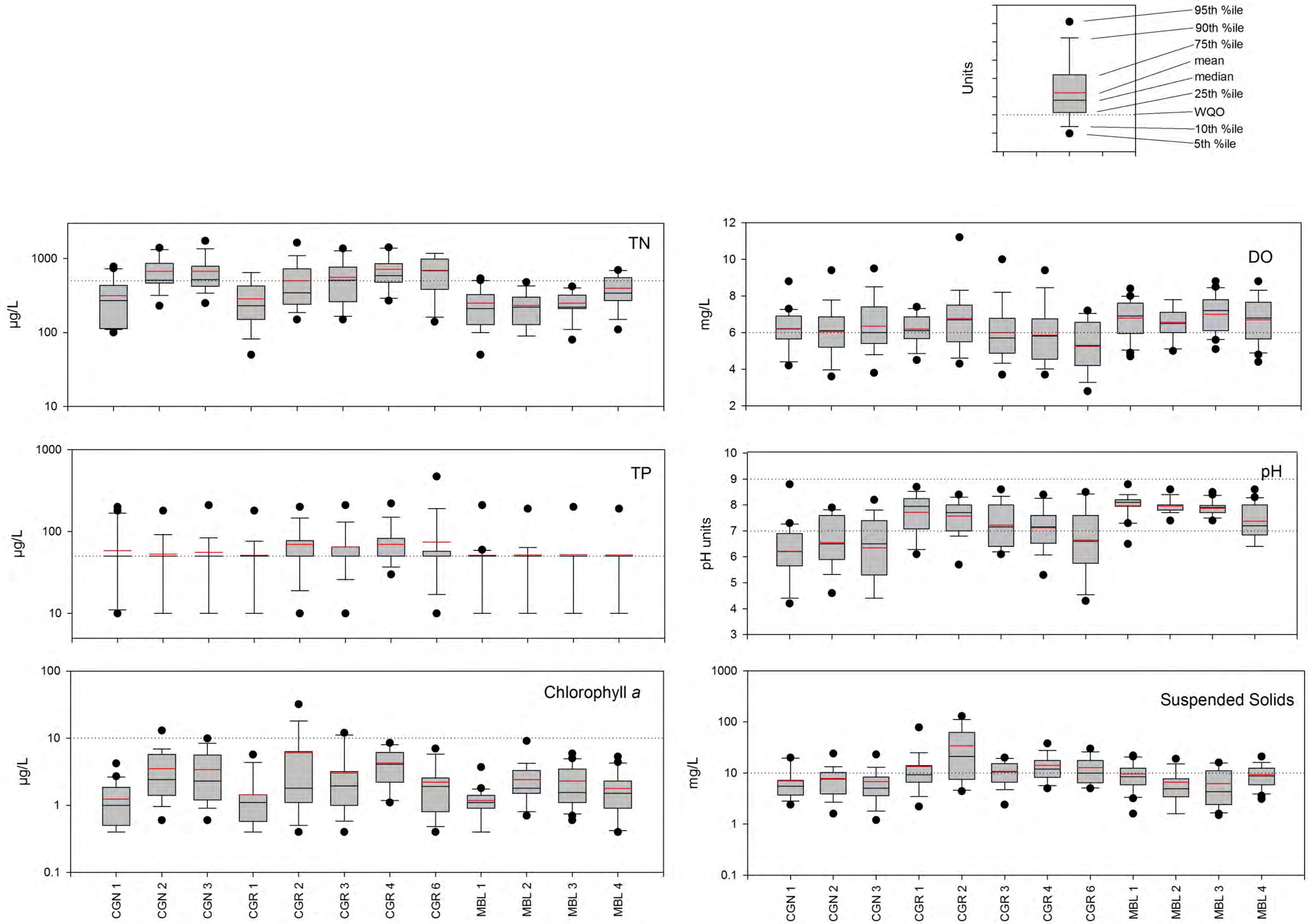

FIGURE 4-7. BOXPLOT INDICATING WATER QUALITY FOR SITES WITHIN TWEED COAST ESTUARIES

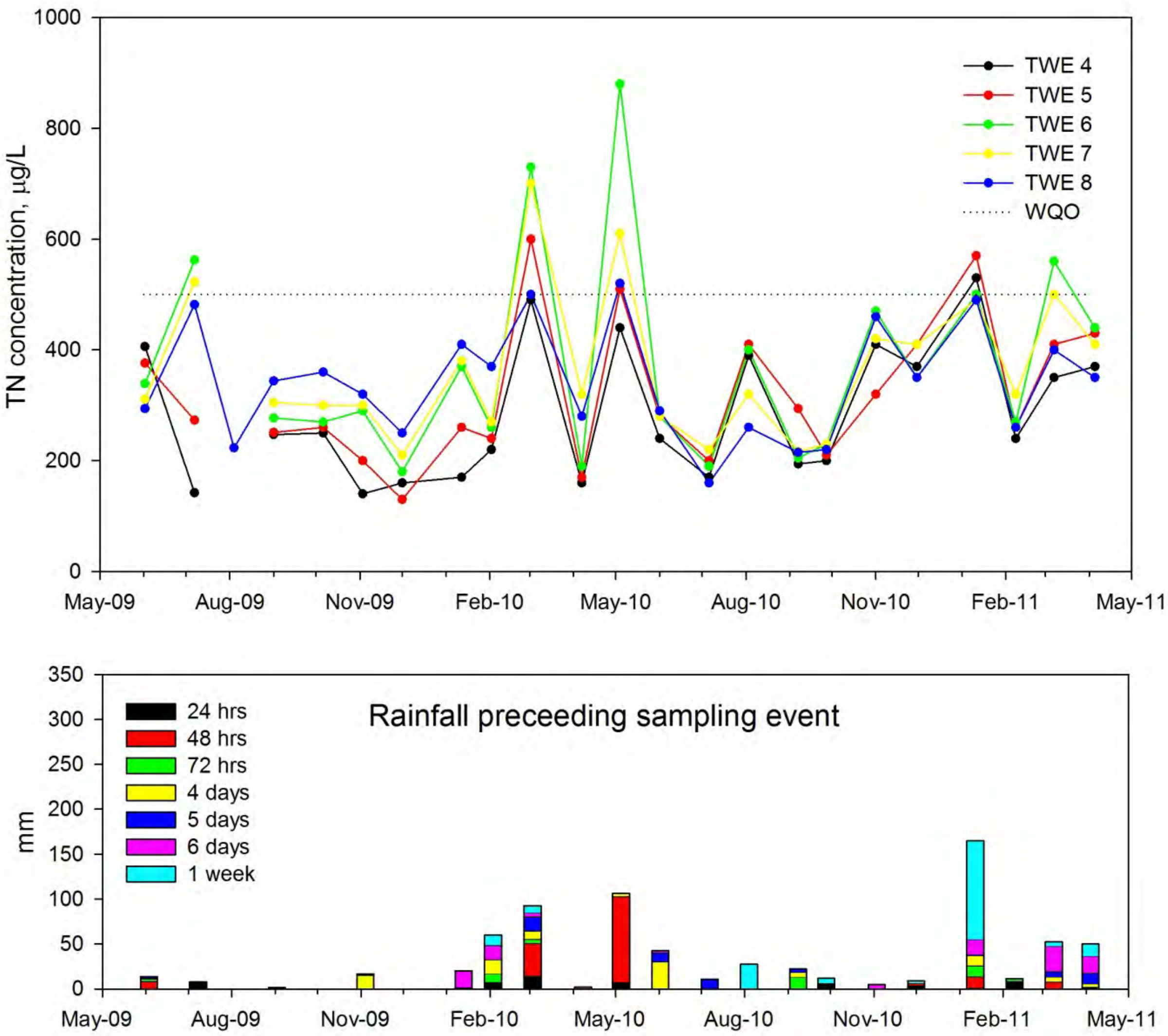

FIGURE 4-8. RELATIONSHIP BETWEEN RAINFALL AND TN AT INDICATIVE SITES WITHIN TWEED RIVER UPPER ESTUARY SUB-CATCHMENT

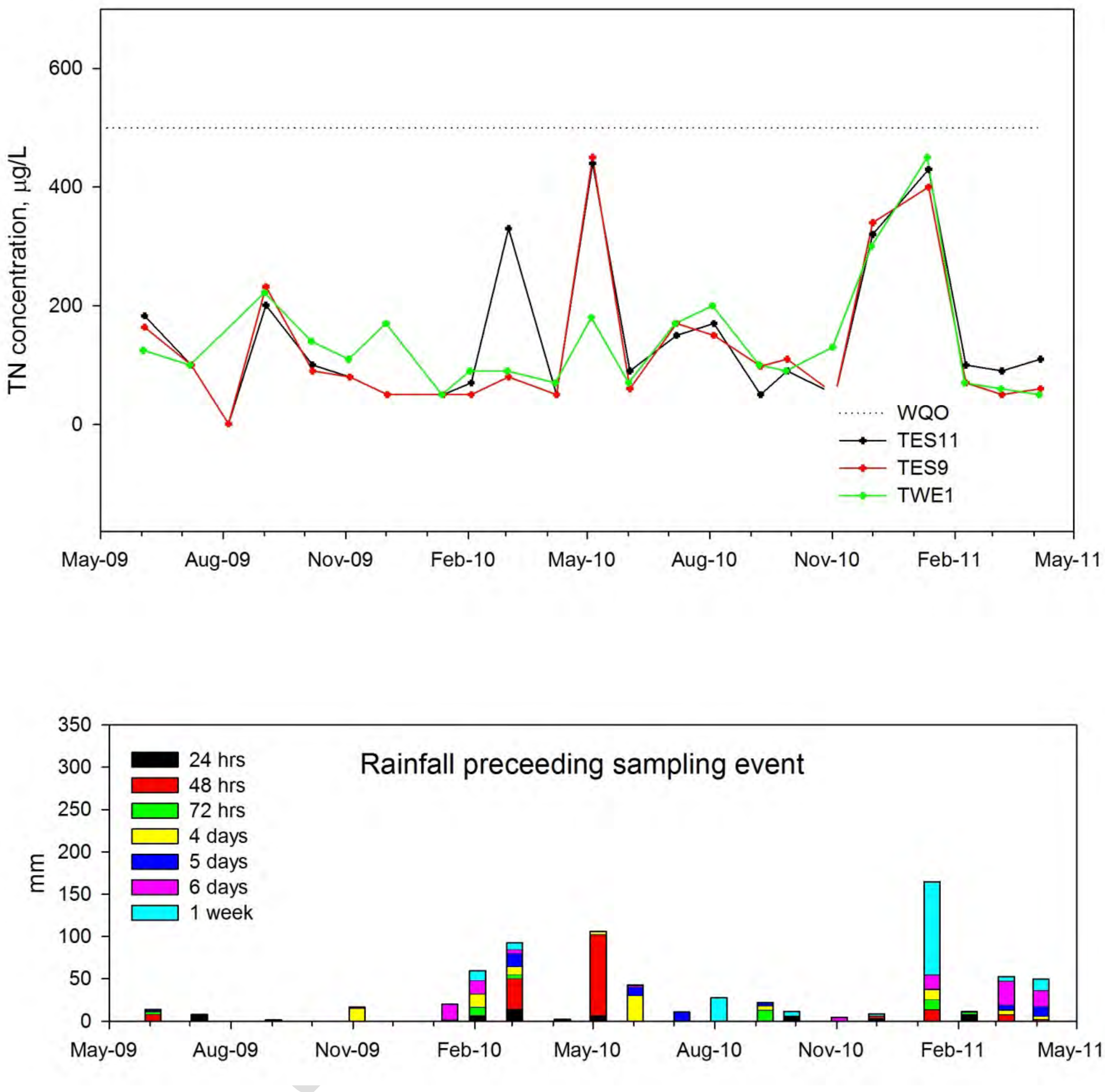

FIGURE 4-9. RELATIONSHIP BETWEEN RAINFALL AND TN AT INDICATIVE SITES WITHIN TWEED LOWER ESTUARY SUB-CATCHMENT

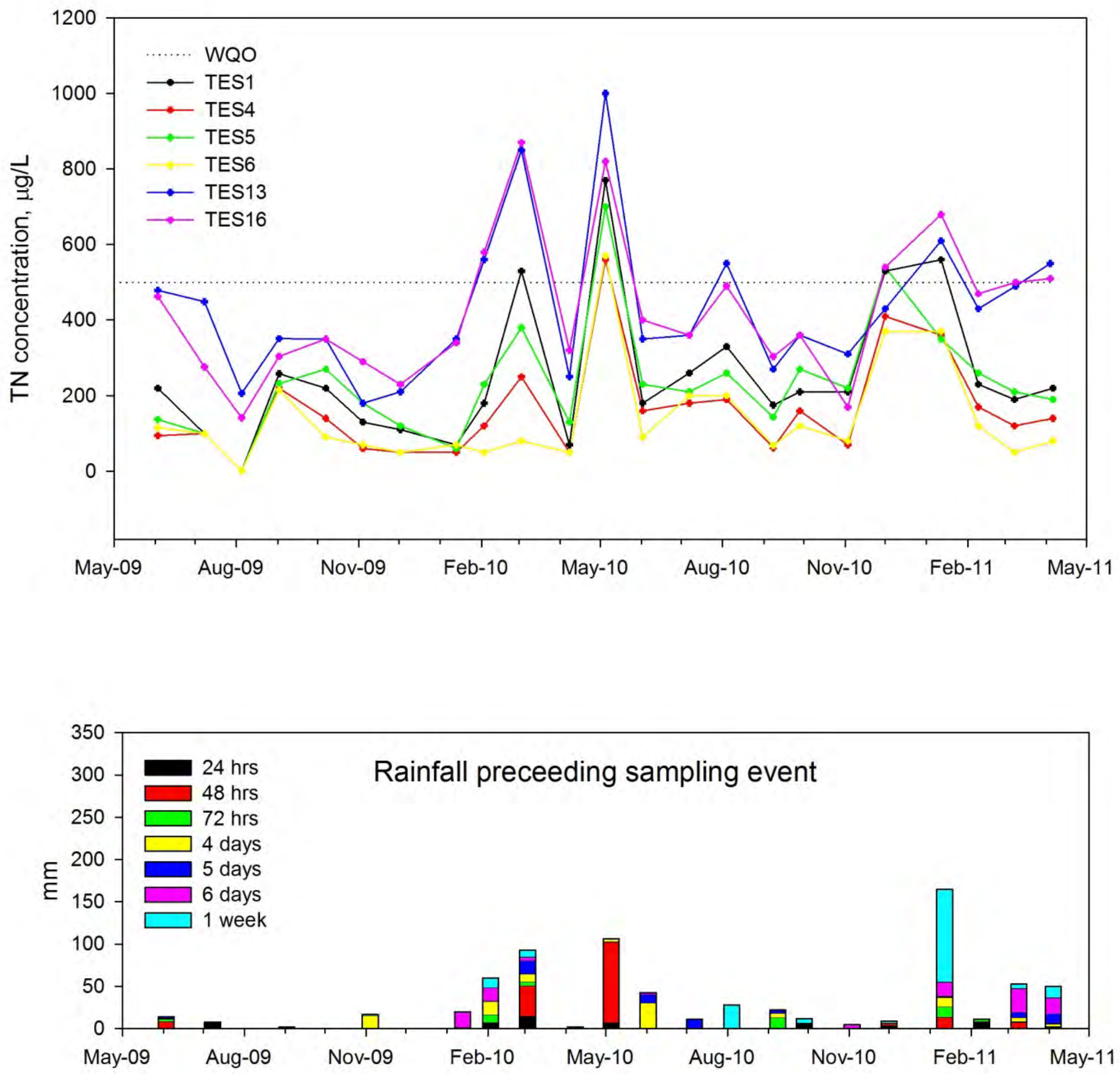

FIGURE 4-10. RELATIONSHIP BETWEEN RAINFALL AND TN AT INDICATIVE SITES WITHIN COBAKI AND TERRANORA BROADWATER SUB-CATCHMENT

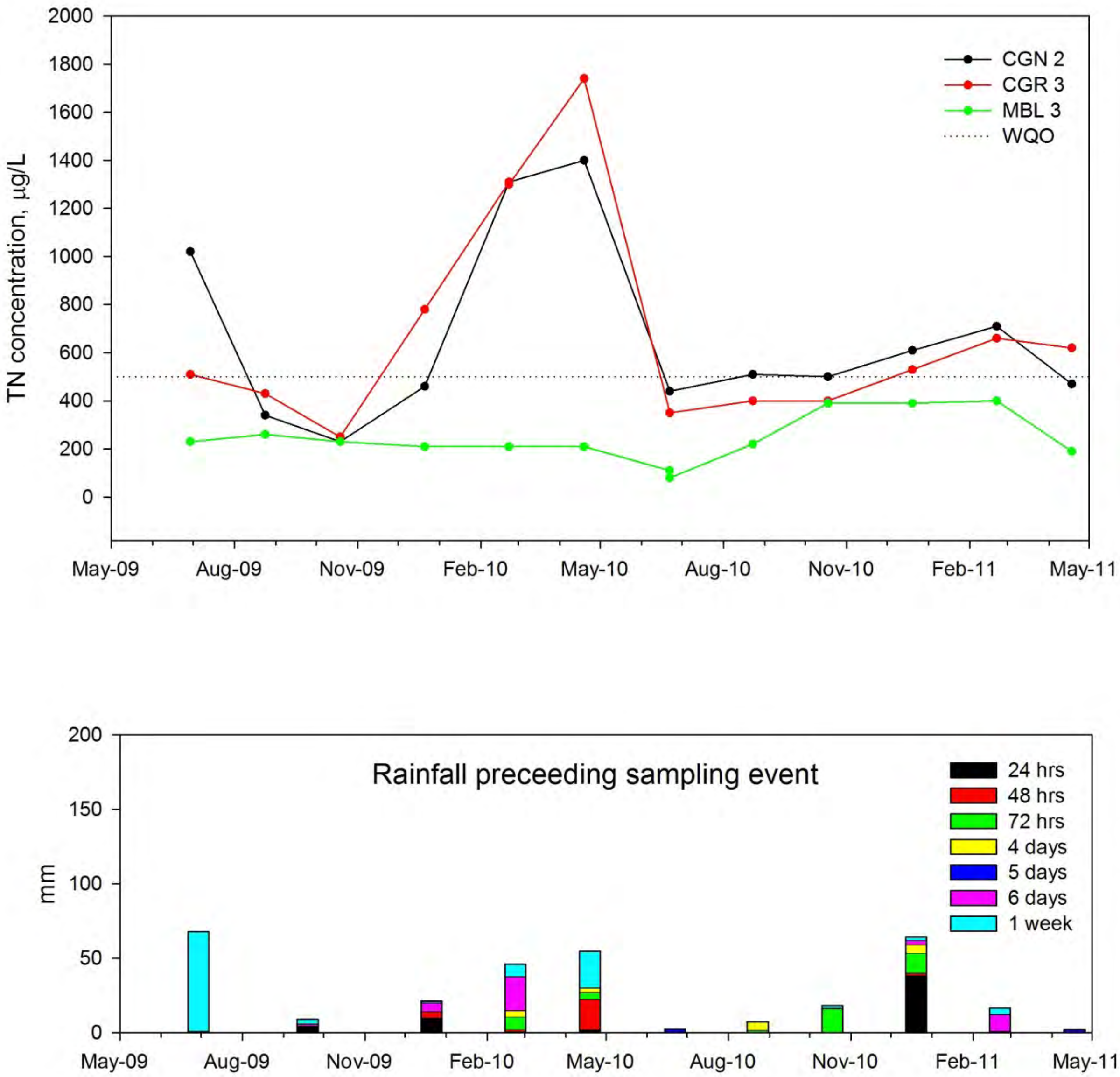

FIGURE 4-11.RELATIONSHIP BETWEEN RAINFALL AND TN AT INDICATIVE SITES WITHIN TWEED COAST ESTUARIES SUB-CATCHMENT

5. Receiving Water Environmental Values and Water Quality Objectives

5.1 Background

The water quality standard most commonly adopted is the Australian and New Zealand Environment Conservation Council (ANZECC) *Water Quality Guidelines for Marine and Freshwaters*, 2000. This document provides quantitative and qualitative guidelines for minimum water quality standards for various uses of marine and fresh water. The ANZECC (2000) document emphasises that it is a guideline rather an absolute standard and recommends moving toward tailoring guidelines for local conditions (Section 2.2.1.4) as local water quality varies naturally due to a variety of factors such as the type of land the waters are draining, rainfall and runoff patterns and different landuse and land management practices.

In 1999 the NSW Government adopted the NSW Water Quality and River Flow Objectives. These WQOs use the ANZECC framework to establish and recognise the community's environmental values for each catchment in NSW. Using this approach, WQOs were defined for the Tweed River catchment, which are the same as those outlined by ANZECC (2000) for slightly-moderately disturbed estuaries in South-east Australia (Table 5-2).

In a further attempt to create local objectives, the Tweed River and Catchment Interim Water Quality Management Plan outlined a set of 'Interim' WQOs in 2000. Consistent with the process outlined in ANZECC (2000), an assessment of 'background' water quality levels from relatively undisturbed catchments, with similar characteristics to that of the Tweed River, was made. This included particular consideration of water quality data from selected waterways within the Burrum, Burnett, and Maroochy River catchments in South East Queensland. These river systems were considered to have the most similarity to the Tweed River system, and are largely undeveloped and can be considered to be quasi-undisturbed catchments. From this data, and through the process of community consultation, a set of local Environmental Values (EVs) (Table 5-1) and Interim Water Quality Objectives (WQOs) (Table 5-1) was derived. Appendix B contains a summary of the historical derivation of EVs and Interim WQOs.

5.2 Environmental Values

Tweed Shire Council and the NSW State Government have undertaken several community consultation workshops to define the EVs for the Tweed River and Tweed Coast Estuaries.

For the purpose of this Plan, EVs are defined as:

Particular values or uses of the aquatic environment that society determines should be maintained and/or enhanced. The set EVs for fresh and estuarine waters of the Tweed Shire include those outlined in Table 5.1.

TABLE 5-1. ENVIRONMENTAL VALUES FOR FRESH AND ESTUARINE WATERS OF THE TWEED RIVER

Environmental Value	Water Type	Description
Aquatic Ecosystem Protection	E / F	This EV relates to the protection of water quality to ensure that all elements of aquatic ecosystem are protected. It is not designed to protect a particular species, or for commercial farming of fish/shellfish, but is intended to ensure that all essential ecological processes can be performed, and the ecological integrity of the system is maintained.
Commercially produced shellfish for human consumption	E	Commercially produced shellfish are grown under an industry guideline, with careful supervision of conditions, specific water quality criteria, treatment of the shellfish and testing requirements before sale. The Tweed Shellfish Quality Assurance Program requires that water quality and oyster meat testing is undertaken regularly, especially in response to rainfall.
Primary Contact Recreation*	E/F	This EV is to protect the waterbody for use in primary human contact activities, such as swimming, bathing or other activities in which the user comes in frequent direct contact with the waterbody and is likely to ingest significant quantities of water.
Secondary Contact Recreation*	E/F	This EV is to protect the waterbody for use in secondary human contact activities, such as boating, fishing or other activities where there is less frequent (or unintentional) direct contact with the waterbody.
Potable Water	F	This EV relates to the water being of sufficiently high quality to drink when taken directly from the waterbody, without any sterilisation or treatment. It does not relate to the supply of potable water for treatment nor the ability to drink treated water from the reticulated water mains.
Agricultural Irrigation Water	F	This EV relates to the ability to use water for irrigation of crops. Irrigation waters need to be of a particular quality to ensure adequate crop growth, and that neither alternation of the soil structure nor environmental harm is caused. Numerous farms in the Shire require irrigation waters for their crops to be viable.
Livestock Drinking Water	F	This EV ensures water can be safely used as a drinking water supply for a variety of animals (cattle, pigs, sheep etc). Water of lower quality may be able to be drunk by livestock for short durations without ill effect, however long term sources of drinking water should meet EV to maintain healthy and successful livestock production.
Farmstead Supply (non-potable)	F	This EV aims to ensure water can be used for washing, cooking and other domestic purposes safely, however water many need to be sterilised before it is suitable to be used for drinking. This EV does not aim to provide potable water which is covered by the potable water supply EV.

E – Estuarine waters
F – Fresh waters
* Note: For protection of human health from threats posed by the recreational use of estuarine water, Council may consider the recommendations found within *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008) as appropriate.

5.3 Water Quality Objectives

The water quality objectives for fresh and estuarine waters, as specified by the NSW Office of Environment and Heritage, are summarised in Table 5-2 below.

For the comparison of a sample site monitoring data against WQOs, the median concentration of n independent samples at a particular monitoring site should be compared against the WQO of the same indicator as listed in Table 5-2. Exceedance of the WQOs is an 'early warning' mechanism to alert managers of a potential problem and may trigger further investigation.

TABLE 5-2. AMBIENT FRESH AND ESTUARINE WATER QUALITY OBJECTIVES FOR KEY WATER QUALITY PARAMETERS APPLICABLE FOR THE TWEED RIVER

Parameter	Units	Freshwater (low land rivers*)	Estuarine
pH	pH units	67.0 – 8.5	7.0 – 8.5
Dissolved Oxygen	% saturation	85 – 100	80 - 110
Turbidity	NTU	6 – 50	0.5 – 10
Total Phosphorus	**µg/L**	< 25	<30
Total Nitrogen	**µg/L**	< 350	<300
Chlorophyll *a*	µg/L	< 5	< 4
* Lowland Rivers - ANZECC (2000) and OEH (1999)			

6. Stormwater Management Objectives

The water quality objectives provided in Section 5 are ambient concentration criteria for the waterways of the Tweed. If these objectives are achieved then protection of the waterway's environmental values should be achieved, subject to the maintenance of other essential characteristics such as water flow and the presence of riparian vegetation and instream habitat.

Given the nature of water quality objectives (ambient receiving water concentrations), they cannot be readily applied to assess the stormwater runoff. Even under natural conditions stormwater runoff exhibits quite different water quality than the receiving waterways that the stormwater enters. As outlined in ANZECC (2000), stormwater management objectives need to be established which properly consider the episodic and variable nature of stormwater runoff. The following sections outline specific stormwater management objectives for existing urban areas and new development in the Tweed. These objectives are based on extensive research and technical assessment which has occurred in South-east Queensland over the last 10 years.

6.1 Relationship to Tweed Shire Council *Development Design Specification D7 – Stormwater Quality*

Tweed Shire Council Development Design Specification D7 – Stormwater Quality is the policy specification that prescribes stormwater quality measures to be adopted for development requiring consent under the Environmental Planning and Assessment Act 1979.

Tweed Shire Council Development Design Specification D7 – Stormwater Quality refers to this USQMP, which may be updated over time with catchment-specific (local) stormwater objectives. The stormwater objectives provided in Development Design Specification D7 apply to all new development in the Tweed Shire, unless there is a catchment specific stormwater objective provided in revised editions of this USQMP, or a Coastal Management Program (an instrument of the Coastal Management Act and Coastal Management SEPP), prepared for specific catchments.

6.2 Existing Urban Areas

The USQMP (2000) provided specific stormwater management actions to be implemented throughout existing urban areas of the Tweed. During the update of this plan, an audit was undertaken on the implementation status of these existing stormwater management actions. Many of those actions have been implemented by TSC over the past 10 years (Appendix C).

The approach to urban stormwater management is now moving toward a catchment-based or coastal zone-based approach. Rather than providing specific stormwater management actions, the revised Tweed USQMP will act as the regional stormwater management document. The development of local Coastal Management Plans will collate or undertake additional investigations to make specific locality based stormwater management recommendations which will be detailed within Coastal Management Plan action tables.

Long and short-term stormwater objectives for existing urban areas are listed in Table 6-1. Short-term objectives are defined as those that are expected to be met within five years of adoption of this Plan. Long-term objectives are aspirational and provide a "vision" for management of stormwater in Tweed Shire for up to twenty-five years. These objectives and vision were developed as part of the USQMP (2000).

TABLE 6-1. STORMWATER MANAGEMENT OBJECTIVES FOR EXISTING URBAN AREAS

Value	Long Term Objectives	Short-term Objectives
Aquatic ecosystems (AQ)	o Water quality in all waterways meets WQOs o Aquatic habitat is present, with spatial extent maintained or increased, and is in good condition. This long term objective is particularly important for seagrass in the lower Tweed River estuary and coastal creeks.	1. Physico-chemical water quality of estuaries to meet TSC WQOs 2. Physico-chemical pollutant loading from rural sub-catchments is reduced. 3. Physico-chemical pollutant loading from developing sub-catchments not to exceed pre-development levels. 4. Nitrogen and phosphorus concentrations reduced in all waterways impacted by urban land use. 5. Suspended solids load in all waterways is to meet TSC WQOs.
Commercial shellfish production (CS)	o Retention of a viable commercial oyster industry maintained in the Tweed River estuary.	6. Reduce incidence of sewer pump station overflows. 7. Minimise runoff to stormwater systems from on-site sewage disposal
Primary contact recreation (PC)	o Water quality in the Tweed River and Coastal Creeks to meet ANZECC guidelines for primary contact recreation.	o No's 4, 9 and 10 above 8. Physico-chemical water quality of estuaries to meet ANZECC criteria for primary contact recreation.
Secondary contact recreation (SC)	o Water quality in the Tweed River and Coastal Creeks to meet ANZECC guidelines for primary contact recreation.	o Covered by objective 11

6.3 Regional Stormwater Objectives for New Urban Development

Regional stormwater objectives for new urban development requiring consent in the Tweed are outlined in Tweed Shire Council's *Development Design Specification D7 – Stormwater Quality*. This specification details the information relating to stormwater quality required to accompany development applications and construction certificate applications. This specification complements the Tweed USQMP by detailing stormwater objectives/standards and prescribed stormwater management measures that comply with the Tweed USQMP and contemporary best practice. The stormwater objectives provided in this specification apply to new development in the Tweed Region unless there is a catchment specific stormwater objective provided in the Tweed USQMP (as discussed in Section 6.3). These objectives are repeated below for clarity.

6.3.1 Construction Phase Stormwater Quality

Stormwater quality objectives in the construction phase are focused on erosion and sediment control. The objectives of erosion and sediment control are:

- Minimise soil erosion and exposure
- Minimise transportation of eroded soil by air and water
- Limit suspended solids concentration in stormwater to not more than 50mg/l
- Limit/minimise the amount of site disturbance
- Isolate the site by diverting clean upstream "run on" water around the development
- Control runoff and sediment at its point source rather than at final point
- Stage ground disturbance/earthworks and progressively revegetate the site where possible to reduce the area contributing sediment
- Retain topsoil for revegetation works
- Locate sediment control structures where they are most effective and efficient

Construction phase stormwater quality is specifically addressed in Council's *Development Design Specification (D7) Stormwater Quality, Version 1.3*. This specification is currently being updated.

6.3.2 Operation Phase Stormwater Quality

Stormwater Quality Objectives for the Tweed adopt a 'best practice' pollutant load reduction approach, whereby the mean annual pollutant loads generated from an un-mitigated development are to be reduced by at least the percentage reduction rates prescribed in the design objectives. This form of design objective for stormwater quality management is consistent with the current load-based design objectives adopted in Queensland, Victoria and NSW and with the recommendations of Australian Runoff Quality (2005, p1-7) and ANZECC (2000, p.3.3-2). Appendix D contains the process of the derivation of operation phase stormwater quality objectives.

Operation phase stormwater quality objectives for new urban development in the Tweed are outlined in Tweed Shire Council's Development Design Specification D7 – Stormwater Quality and provided below.

Intent - Reduce pollutant loads discharged in the operational phase of the development. Ensure that the impacts of urban development do not degrade water quality in the receiving environment.

Objective - Achieve the following minimum reductions in total pollutant load, compared with that in untreated stormwater runoff, from the developed part of the site:

- 80% reduction in total suspended solids*
- 60% reduction in total phosphorus
- 45% reduction in total nitrogen*
- 90% reduction in gross pollutants.

* When adopting constructed wetlands only, the TSS and TN objectives may be relaxed to 75% and 40%, respectively (given that the exponential increase in wetland size does not justify the small pollutant removal gains, refer to Appendix D).

Compliance – Compliance with the objective is to be demonstrated through the submission of a stormwater management plan incorporating MUSIC modelling, and consideration of the impact of resultant discharge on the water quality objectives (WQO's) of the receiving environment., The adoption of a 'Deemed to Comply Solution' does not exempt the proponent from considering the residual impact of runoff from the development on the receiving environment.

6.3.3 Residual and cumulative impacts of stormwater discharge into waterways

In sensitive areas, pollutant reduction loads proposed in Specification D7 may not be sufficient to avoid a worsening of ambient water quality post development. In these instances stormwater harvesting and/or water quality buffers would be required to achieve the pollutant load reduction objectives, or offsite compensatory works planned and implemented as highlighted in.

There may be instances where the application of best practice stormwater management measures (achieving minimum load reductions) still results in the discharge of significant loads of N, P, and SS to the receiving environment. As such, the proposed stormwater treatment system may be insufficient to maintain WQO's within the receiving environment and ensure protection of sensitive ecological values. CZMP's or Coastal Management Programs for specific catchments will provide information relating to the sensitivity of receiving environments and highlight areas where the capacity of the ecosystem to assimilate additional loads, particularly nutrients, is critically constrained. In such instances further investigation into the cumulative impact of residual loads of contaminants on the receiving environment will be required, and should be considered through the development assessment process, consistent with the objectives of the Environmental Planning and Assessment Act 1979.

Where it is determined that the residual or cumulative discharge from a development will have a detrimental impact on water quality objectives in the receiving environment, Council and development proponents should consider a Voluntary Planning Agreement (VPA) under section 93F of the EP&A Act 1979 through which stormwater impacts on the waterway can be offset by rehabilitation, retrofit or compensation measures at another location – within the same catchment. The basis of this concept is that the overall ecological health and resilience of a waterway could be improved as a result of the development, despite the potential worsening of water quality due to development discharge. A VPA can also be a mechanism through which resources are strategically contributed to catchment wide water quality initiatives, achieving ecological and economic benefits of scale, rather than smaller, localised stormwater devices. This concept does not negate the need for avoidance of stormwater pollution as the most important measure in catchment management.

6.3.4 Impacts on Streams

Urban development can have significant negative impacts upon waterways beyond simple changes in water quality. Increases in the frequency, duration, volume and velocity of stormwater discharge can damage the hydrological and geomorphic character of a stream and consequently degrade in-stream habitat and ecosystem health. Consideration of waterway stability and flow regimes as part of a stormwater strategy are therefore an important requirement and are described in the following sections.

6.3.5.1 Operation Phase Hydraulic and Geomorphic Impacts

Intent - Ensure urban development does not increase channel-bed and bank erosion. Limit changes in flow rate and flow duration within the receiving environment.

Objective - Limit the post-development peak 1-year Average Recurrence Interval (ARI) event discharge within the receiving waterway to the pre-development peak 1-year ARI event discharge.

Application – This objective applies where run-off from or within the site passes through or drains to unlined channels, waterways or wetlands. This consideration may be waived where it is clear that the channel size, flow rate and volume within the receiving waterway significantly exceeds the potential of discharge to affect the receiving environment, e.g. discharge to the main channel of the Tweed River.

Note this provision does not negate an individual's or companies responsibilities under the Water Management Act 2000, whereby approval is required to carry out any activity that affects the quantity or flow of water in a water source, undertake instream works, install outlet structures or lay pipes and cables.

Compliance - The Design Objectives for Water Sensitive Developments in SEQ, Appendix C (SEQ Healthy Waterways Partnership) outlines two methods for defining the detention storage requirements. These should be read in addition to Guidelines for controlled activities outlined by NSW Department of Primary Industries.

6.4 Local Stormwater Management Objectives

Over time Council will complete a range of catchment investigations and prepare or review Coastal Management Programs across the Tweed. In some situations, these investigations may establish more detailed stormwater management objectives. These may be in the form of stormwater quality, erosion potential, design storm event, stream velocities or actual stream stabilisation works.

The regional stormwater objectives provided in Tweed Shire Council *Development Design Specification D7 – Stormwater Quality* apply to new development requiring consent in the Tweed Shire. If Council adopts a certified Coastal Management Program (as defined under the Coastal Management Act) with more stringent or catchment-specific (local) stormwater objectives, these will over-ride the regional objectives listed in Tweed Shire Council's *Development Design Specification D7 – Stormwater Quality*.

7. Riparian Zones and Vegetated Buffers

Riparian zones (or buffers) are known to play a substantial role in buffering waterways from overland stormwater run-off, as well as providing ecological benefits such as aquatic habitat, fauna corridors and maintaining wetland resilience to climate change (DECCW, 2010). Riparian corridors assist in stabilising waterways and protecting the significant ecological features of the Tweed including fishery resources, migratory bird habitat, significant vegetation communities and important riparian corridors. Defining riparian corridors is an important step towards the protection and/or enhancement of waterway health in Tweed Shire. This applies to both existing areas (for protection or rehabilitation of riparian zones) and areas under pressure from development (to exclude development within riparian corridors and contribute to their rehabilitation).

Riparian buffer width, measured from the top of bank, should be applied to both sides of a waterway such that the overall riparian corridor is twice the defined buffer width plus the width of the waterway (top of bank to top of bank).

7.1 Planning Context

The importance of riparian zones is reflected in the Regional Stormwater Design Objectives (Tweed Shire Council *Development Design Specification D7 – Stormwater Quality)* which include:

> *Existing natural watercourses and riparian vegetation (with appropriate buffer strips) are to be retained and restored. (D7.04a)*

The definition of a 'buffer area' in Tweed Shire Council's Development Control Plan, Section A5.E.2 of the Subdivision Manual is:

> *..an area of prescribed width and treatment created between two or more landuses for the purpose of mitigating the impacts of one or more of those landuses*.

Subdivisions in the Tweed Shire should be consistent with Tweed Shire Development Control Plan: Section A5 – Subdivision Manual. Section A5.4.7 Stormwater Runoff, Drainage, Waterways and Flooding states the following:

> *Development in or adjacent to waterways, water bodies, wetlands or within their catchments must provide a riparian buffer of 50m along major streams (Tweed River, Rous River, Oxley River, Cudgen Creek, Cudgera Creek, Mooball Creek and major tributaries) and a width along other streams in accordance with Table A5-5.*

Section 5.4.5 Environmental Constraints states the following:

> *Development sites must be assessed to determine if there are areas of significant vegetation.* The definition of significant vegetation includes riparian vegetation. *Areas of significant vegetation are to be preserved.* Proposals for sites that contain significant vegetation must be consistent with the requirements of Section A5.4.5.

The following guidelines and planning documents make additional recommendations on appropriate buffer widths in the Tweed Shire.

- Tweed Coast Estuaries Management Plan 2004-2008 for Cudgen, Cudgera and Mooball Creeks (Australian Wetlands, 2004) – Recommended minimum buffer width of 50m to creeks.

- Coastal Zone Management Plan for Cobaki Broadwater and Terranora Broadwater (Australian Wetlands, 2010) - *In areas where development is proposed, anywhere adjacent to the broadwater foreshores, Terranora Creek or Bilambil, Duroby, Cobaki and Piggabeen Creeks, a minimum 50m buffer is recommended. The recommended buffer distance to rural landuse in non-tidal sections of Bilambil, Duroby, Cobaki and Piggabeen Creeks is 30m. Generally, buffers should be fully revegetated with appropriate local native riparian species.*

- Policy and Guidelines Aquatic Habitat Management and Fish Conservation (NSW Department of Industry and Investment, Primary Industries, 2005) – *The width of buffer zones may need to be increased from 50m to 100m or more where they are adjacent to ecologically sensitive areas. Setbacks of 50-100m for key fish habitat are recommended to ensure that water quality and habitat are adequately protected from adjoining developments. Council are required to recognise the value of riparian and aquatic habitat and ensure new developments have appropriate setbacks.*

- Coastal Design Guidelines for NSW (Coastal Council of NSW, 2003) – *Setbacks should where possible be increased to 100m or more where they are adjacent to ecologically sensitive areas*.

- The NSW Office of Environment and Heritage (2010) - *Maintaining adequate vegetated buffers will be an important factor in maintaining wetland resilience to climate change, particularly intertidal wetlands that will need to migrate upslope with sea-level rise. It is critical to recognise the important role wetlands can play in adapting to the impacts and implications of likely climate change in NSW. For example, mangrove forests may reduce storm surge associated with more severe weather, saltmarshes provide essential habitat for migratory shorebirds. Protecting wetlands of NSW is the principal way of protecting these functions, and many others, which provide benefits beyond the wetland boundary*.

7.2 Riparian Buffer Zone Recommendations

In order to ensure consistent and effective implementation/protection of riparian corridors, the following actions would provide an important basis for defining priority waterway categories and assigning appropriate management responses:

1. Waterway category mapping (based on stream orders)

2. Riparian condition assessment (high value, moderate, poor)

3. Riparian corridor width allocation (according to waterway category/stream order)

4. Prioritisation of riparian management opportunities (based on riparian condition and future pressures)

For the purpose of this plan, it is recommended that a minimum riparian buffer of 50m is adopted for all major waterways (rivers and creeks) and wetlands in which development is excluded. In addition, buffers to minor waterways (25m) and ephemeral drainage lines (10m) should be adopted. However, this would not negate the recommendation of a wider buffer prescribed within a specific locality or Coastal Management Plan.

8. Design and management of stormwater assets

In relation to the design and management of Stormwater Quality Improvement Devices (SQIDs), the updated Tweed USQMP aims to ensure the following:

- stormwater design and maintenance is always consistent with current best practices, and
- all stages of SQID implementation, including the planning, design, construction, performance monitoring and asset handover phases, are conducted with consultation between the applicant and Council.

8.1 Stormwater Management Guidelines and Tools Relevant to the Tweed

Since the authoring of the first Tweed USQMP (2000), a significant amount of guidance material has been developed to assist with the implementation of WSUD and best practice stormwater management. Fortunately most of the guidance material, including stormwater design objectives, has been developed by the Water by Design program of the South East Queensland Healthy Waterways Partnership and is directly relevant to the Tweed (i.e. similar climate, waterway uses and ecosystem characteristics).

Table 8-1 lists the information available to assist with implementation of the Tweed USQMP and best practice stormwater management. The information is split into two parts with primary information being objectives, guidance and tools that are considered directly relevant to the Tweed. The guidelines in Table 8-1 are updated periodically to ensure they are current with best practices. Therefore the onus is on the applicant to ensure they are using the latest version of each relevant guideline and to confirm with Council the guidelines they intend to use at project commencement.

TABLE 8-1. RESOURCES, GUIDANCE AND TOOLS THAT SHOULD BE USED TO IMPLEMENT BEST PRACTICE STORMWATER MANAGEMETN AND THE TWEED USQMP

Primary Resources, Guidance and Tools Considered to be directly relevant to the Tweed and to be used in preference to Secondary Resources		
Activity/Issue	**Resource**	**Where to access**
Stormwater design objectives	Water sensitive urban design: Developing design objectives for urban development in South East Queensland (Water by Design) SEQ Regional Plan Implementation Guideline No. 7: Design Objectives for Stormwater Management State Planning Policy for Healthy Waters - Queensland	www.waterbydesign.com.au www.dlgp.qld.gov.au www.derm.qld.gov.au
Benefit and Cost of Stormwater Management	A Business Case for Best Practice Urban Stormwater Management (Water by Design)	www.waterbydesign.com.au
Conceptual design for development planning and application	Concept Design Guidelines for WSUD (Water by Design) MUSIC Modelling Guidelines for SEQ *Water by Design) WSUD Deemed to Comply Solutions for SEQ (Water by Design) Stormwater Harvesting Guidelines (Water by Design) Example Site Based Stormwater Management Plan (Mackay Regional Council)	www.waterbydesign.com.au www.mackay.qld.gov.au
Design development and detailed design	WSUD Technical Design Guidelines (Water by Design) Institute of Public Works Engineers Australia – Queensland Standard drawings WSUD 001-012	www.waterbydesign.com.au www.ipwea.org.au
Erosion and Sediment Control	Best Practice Erosion and Sediment Control (IECA) preferred The Blue Book - Managing Urban Stormwater (MUS): Soils and Construction	www.ieca.org www.landcom.com.au
Construction and Establishment	Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands Guidelines for Filter Media Biofiltration Systems (FAWB)	www.waterbydesign.com.au www.monash.edu.au/fawb/
Asset compliance and handover	Handing Over WSUD Assets (Water by Design, likely released in mid-2011) As Design As Constructed	www.waterbydesign.com.au www.adac.com.au
Asset management	Maintaining WSUD Assets (Water by Design, likely released in mid-2011) Rectifying WSUD Assets (Water by Design, likely released in mid-2011)	www.waterbydesign.com.au
Secondary Resources, Guidance and Tools		
WSUD in public open space	Multiple use of Public Open Space: Discussion paper	www.waterbydesign.com.au
Technical documents	Australia Runoff Quality (Engineers Australia) Stormwater Biofiltration: Adoption Guidelines (FAWB)	www.eabooks.com.au www.monash.edu.au/fawb
Stormwater harvesting	Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes (Bligh Tanner and DesignFlow for the Queensland Water Commission) Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2): Stormwater Harvesting and Reuse	www.qwc.qld.gov.au

8.2 Summary of Stormwater Quality Improvement Device Design and Management Process

The following provides a summary of the SQID design and management process (as part of a new urban development) incorporating planning approval, design, construction and maintenance for new urban stormwater devices. Further detail is provided in Sections 8.3 – 8.7.

Submit DA - SQID Concept Design	• SQID Concept Design
DA Approval	• Council reviews and approves SQID Concept Design
SQID Detailed Design	• SQID Detailed Design • Stormwater Management Plan • Operation and Maintenance Plan
Construction	• Regular inspections at designated 'hold points' during construction and establishment
Practical Completion	• Applicant provides Council with a package of documents and completed checklists • Coundil assesses design and construction conformance and approves construction
On-Maintenance	• On-Maintenance period specified by Councll • Applicant undertakes periodic performance-based monitoring of the SQID/s • Applicant submits reports containing the results of monitoring throughout the maintenance period
Off Maintenance	• At end of On-Maintenance period, applicant provides a package of documents to Council including performance-based monitoring reports demonstrating compliance with the relevant guidelines and detailed design.
Asset Handover	• Council is satisfied SQID is performing in accordance with detailed design and asoociated checklists received. • Asset is transferred to Council.
On-going Council Maintenance	• Asset is recorded in SQID Asset Database • Maintenance Schedule recorded • On-going maintenance conduc ted by Council • Asset included into Council SQID Monitoring Program

8.3 SQID Design

Stormwater Quality Improvement Device concept and detailed designs are to be consistent with current best practice as outlined in Tweed Shire Council's *Development Design Specification D7 – Stormwater Quality* and resources referred to in Table 8.1 of the Tweed USQMP. Designs and Stormwater Management Plan must be accompanied by enough information concerning long-term asset operation and maintenance requirements to enable an informed decision to be made regarding Council's ability to commit to such maintenance.

8.4 Construction and Establishment Phase

Swales, bioretention systems and constructed wetlands will be constructed and established in accordance with the most recent version of *The Guidelines: Swales, Bioretention Systems and Wetlands* (Water by Design). This Guideline includes details relating to construction methods, specifications, and certification and compliance methodologies.

Inspections at designated 'Hold Points' during construction will be undertaken and attended by a Council representative, in accordance with relevant guidelines outlined in Tweed Shire Council *Development Design Specification D7 – Stormwater Quality* and Table 8.1 of the Tweed USQMP. The applicant will provide Council with the relevant checklist at each inspection hold points.

Following construction and certification, the applicant may wish to hand the asset over to Council. In which case, the developer will need to demonstrate to Council that the asset will not present a liability to Council in the future.

The applicant seeks 'Practical Completion' and to enter an on- maintenance phase. A package of documents will be provided to Council that includes the construction checklists and other documents outlined in the relevant guidelines (refer to *The Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands* (Water by Design)). Council will assess construction and design conformance with relevant guidelines. If approved, the applicant will commence an on- maintenance period, the length of which is specified by Council.

8.5 Monitoring

There are two types of monitoring to be undertaken during the On-Maintenance Phase.

1. Performance-based Monitoring of SQID Physical Characteristics

The applicant is to conduct monthly performance-based monitoring of the SQID/s and submit reports containing the results of monitoring. This involves conducting monthly inspections of the physical aspects of each SQID and completing the relevant checklist to record results. Any non-conformance can be quickly identified and the appropriate rectification implemented in accordance with the relevant guideline. Refer to checklists in *The Construction and Establishment Guidelines: Swales, Bioretention Systems and Wetlands* (Water by Design)

2. Sampling of water quality discharging from SQIDs

Meaningful sampling of water quality discharged from SQIDs can be onerous and expensive – on this basis an applicant can choose to carry out their own water quality monitoring, or make a contribution to Council's SQID Monitoring Program.

If the applicant chooses to undertake their own water quality sampling, a sampling design must capture:

- Key parameters such as flow, TSS, TN and TP to enable quantification of event mean concentrations (EMC's)
- Continuous data for not less than six months via continuous automatic sampling once the stormwater device is established.

This information will then enable calculation of pollutant load reductions identified within the Stormwater Management Plan approved for the development. Event- based grab sampling without the support of flow data will not enable the production of EMC's and will not be accepted. Results should be presented in a short report to Council.

Where there are multiple devices within a development, the applicant should sample one device for every five of that device type within an estate. Where only one device of any SQID type exists, that one device is to be sampled. For remaining devices, Council will work from the premise that if a device is demonstrated to be compliant with Tweed Shire Council *Development Design Specification D7 – Stormwater Quality*, then monitoring can be limited to physical aspects of the device including: vegetation cover, weeds, condition of media, scour and structural stability.

Frequency of monitoring

Prior to a device being accepted off maintenance, proof of the following monitoring regime having been completed must be provided to Council:

- Practical Completion inspection
- Monthly maintenance inspections
- Off-maintenance inspection

8.6 Asset Handover to Council

At the completion of the specified maintenance period, the applicant will apply to have a device accepted 'Off Maintenance'. A package of documents will be provided to Council that includes the performance-based monitoring reports demonstrating compliance with the relevant guidelines (refer to *Handing Over WSUD Assets* (Water by Design)).

Once Council is satisfied that the device is performing as per the design and all documentation has been provided, the process of transferring ownership of the asset to Council can commence. This process will take place in accordance with the most recent version of *Handing over WSUD Assets* (Water by Design).

Council will ensure that a commitment to ongoing asset maintenance requirements is in place to ensure the implementation of the Operation and Maintenance Manual.

8.7 Ongoing maintenance and monitoring of Council-owned SQIDs

Upon transferral of the stormwater asset to Council, the asset will be added by Council to their SQID Asset Database, and maintenance requirements handed over/communicated to the relevant Council Unit.

Council will undertake routine SQID maintenance in accordance with the Operation and Maintenance Manual prepared by the applicant. Council will also conduct a SQID Monitoring Program.

For further details and relevant monitoring and maintenance checklists, refer to the most recent version of *Maintaining WSUD Assets* (Water by Design) and *Rectifying WSUD Assets* (Water by Design).

8.7.1 Database of Existing SQIDs and Maintenance Schedules

The aim of managing stormwater in existing urban areas/Council-owned SQIDs is to confirm that all SQIDs are in good condition and operating optimally as per the design. The regional management intent for existing urban areas is to undertake an assessment of existing SQIDs to assess the current condition and effective functioning of each SQID. Recommendations can then be made as to whether the SQID requires repair, upgrade, updated maintenance regime, retrofit or decommission. Council will maintain a database of all existing SQIDs containing a historical record of such investigations, current status, and recommendations for each SQID.

This database will act as a starting point for Council's Maintenance Schedule, providing a summary of the ongoing maintenance requirements of each Council-owned SQID. SQIDs are to be maintained in accordance with device-specific Operation and Maintenance Manual which should be consistent with the most recent version of *Maintaining WSUD Assets* (Water by Design). Ideally the database would be online and accessible remotely by field staff and the data is self-organising and in a format that allows generation and interpretation of statistical data which can inform future management actions.

Each SQID will be located in Council's GIS mapping with a unique asset identification number.

8.7.2 Monitoring SQID Performance

Monitoring SQIDs to see if they are improving water quality can be complex and costly (Maintaining WSUD Assets, Water by Design, in press). The nature of stormwater is dynamic. The quality and the variation in concentrations of pollutants during, and between storms make monitoring stormwater treatment systems a highly specialised field and costly undertaking. Timing between inflows and outflows also means the temporal variation in sampling is critical, and needs continuous or event-based monitoring of flow and quality into and out of the system.

Rather than monitoring all SQID assets in the Tweed, a discrete number of representative assets should be monitored. The results of this monitoring could be extrapolated across the whole region if other SQIDs of the same type are designed and maintained using the same approach as the system being monitored.

1. *General Performance Indicators*

There are a number of visual 'cues' which can indicate the health and performance of a SQID asset. For example, observations of oil and grease or other petrochemicals, odours, plant or animal die-off and evidence of dumping, are evidence of problems requiring investigation. A checklist of general performance indicators for each SQID type should be utilised as part of the monitoring program for Council-managed SQIDs. This should be undertaken in accordance with *Maintaining WSUD Assets* (Water by Design, in print).

An obvious water quality problem should be followed up with testing or seeking further advice.

9. Recommendations and Council Actions

In order for Council to establish the programs described in the Tweed USQMP, the following set of initial actions is recommended:

1. Implement training and build skills of staff involved in the design, assessment and maintenance of SQIDs.
2. Investigate a bonding processes to achieve better SQID asset handover and establishment.
3. Confirm the preferred construction and asset handover process.
4. Identify stormwater assets (map and condition assessment) to generate a SQID Asset Database.
5. Undertake mapping of waterway categories and riparian corridor width requirements
6. Confirm funding required to monitor and maintain existing SQID assets at desired condition, and work towards allocating sufficient resources to assets managers to achieve optimal asset management.
7. Commit to SQID maintenance requirements and programs.

10.Conclusions

Stormwater pollution has economic, social and environmental implications on receiving environments. Management of stormwater pollution is therefore a significant challenge to Council particularly as the population of Tweed grows placing housing and employment demands on the region into the future. In response Tweed Shire Council has determined that the principals of ESD WSUD are a fundamental part of urban design and Council is committed to the implementation of current best practice in stormwater management.

The revised Tweed USQMP:

- Confirms Council's stormwater management objectives,
- Provides ambient and stormwater quality objectives,
- Insists on the use of best practice design guidance available to the industry,
- Provides specific and measurable guidance for monitoring and maintenance of stormwater quality improvement devices (SQIDs),
- Ensures stormwater design and maintenance is always consistent with current best practices, and
- Promotes consultation between the applicant and Council at all stages of SQID design and construction, including the planning, design, construction, performance monitoring and asset handover phases.

Tweed Shire Council's *Development Design Specification D7 – Stormwater* complements the Tweed USQMP by detailing stormwater objectives/standards and prescribed stormwater management measures that comply with the Tweed USQMP and contemporary best practice. The stormwater objectives provided in this specification apply to new development in the Tweed Region unless there is a catchment specific stormwater objective provided in the Tweed USQMP.

The approach to urban stormwater management is now moving toward a catchment-based or coastal zone-based approach. Rather than providing specific stormwater management actions, the revised Tweed USQMP will act as the regional stormwater management document. The development of local Coastal Management Plans will collate or undertake additional investigations to make specific stormwater management recommendations for existing areas which will be detailed within Coastal Zone Management Plan action tables.

The Tweed USQMP includes provisions to be easily updated to remain consistent with current best practice. Relevant best practice guidelines are updated regularly, keeping the Tweed USQMP and Tweed Shire Council's *Development Design Specification D7 – Stormwater Quality* current. The Tweed USQMP can also be updated with localised ambient and stormwater quality objectives, by incorporating the recommendations of studies as they become available.

11. References

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Appendix A. Water Quality Data Summary Tables

TABLE A.1. WATER QUALITY DATA SUMMARY FOR TWEED RIVER UPPER ESTUARY

Tweed River Upper Estuary		Water Quality Parameter					
		TN	TP	DO	pH	Chlor a	SS
Sampling Site	Statistical Parameter	µg/L	µg/L	mg/L	pH	µg/L	mg/L
	NSW WQO	< 300	< 30	> 6	7 - 9	4	< 10
TWE3	Mean	247.3636	52.2667	6.1267	7.9233	3.7333	8.0833
	Median	232.0000	50.0000	6.1500	7.9500	3.4500	5.6000
	Std Dev	110.5728	34.4042	0.7002	0.4591	2.1427	10.8648
TWE4	Mean	285.8636	53.4100	6.0400	7.7567	3.7400	12.5200
	Median	243.5000	50.0000	5.9500	7.8000	2.9500	7.1000
	Std Dev	121.8212	36.9905	0.6936	0.3945	2.4664	19.4343
TWE5	Mean	321.0909	56.8200	5.9833	7.6633	3.8800	13.9433
	Median	276.5000	50.0000	5.9000	7.7000	2.8000	8.1000
	Std Dev	127.7005	39.8353	0.8167	0.4081	2.3882	20.8868
TWE6	Mean	374.6818	69.0467	6.1700	7.6433	6.5100	13.6600
	Median	314.5000	55.0000	6.2500	7.6500	5.9000	10.0000
	Std Dev	182.4720	46.7328	0.8655	0.3645	4.4122	14.1673
TWE7	Mean	365.7273	70.2900	6.3967	7.4900	8.9267	10.8033
	Median	320.0000	62.8500	6.2000	7.5500	6.6000	7.3000
	Std Dev	131.0802	36.4403	0.9978	0.5492	6.7228	12.8130
TWE8	Mean	339.4783	72.6033	6.5033	7.5533	8.0600	10.0300
	Median	344.0000	70.0000	6.4000	7.6000	5.6000	7.9000
	Std Dev	102.4038	37.3293	1.0918	0.5865	6.6145	11.3502
TWE9	Mean	353.8696	71.6233	6.7800	7.5400	9.2367	8.8667
	Median	345.0000	70.0000	6.8500	7.6000	6.3000	5.6000
	Std Dev	123.4012	37.8759	0.9521	0.6393	7.3283	11.7956
TWE10	Mean	317.2609	67.4000	7.1600	7.6533	7.1033	8.3133
	Median	308.0000	60.0000	7.2000	7.8000	5.1500	4.4500
	Std Dev	129.1575	32.3937	0.9640	0.5457	6.2418	13.0643
TWE11	Mean	374.4783	74.0300	6.3067	7.1900	10.2567	13.0767
	Median	350.0000	60.0000	6.3500	7.2000	7.1500	11.0000
	Std Dev	213.6703	56.4414	1.1310	0.6326	9.5467	10.4963
TWE12	Mean	406.1304	64.5967	6.7100	7.1567	13.3733	12.9400
	Median	385.0000	60.0000	6.8000	7.1000	13.5000	8.6500
	Std Dev	172.2180	31.9433	1.0643	0.5888	10.3654	19.0932
TWE13	Mean	370.1304	67.6100	6.6333	7.1500	14.3300	14.5733
	Median	340.0000	60.0000	6.7000	7.2000	12.4500	8.6500
	Std Dev	137.6515	38.9079	1.0196	0.5764	13.2206	32.4347

TABLE A-2. WATER QUALITY DATA SUMMARY FOR TWEED RIVER LOWER ESTUARY

Tweed River Lower Estuary		Water Quality Parameter					
		TN	TP	DO	pH	Chlor a	SS
Sampling Site	Statistical Parameter	µg/L	µg/L	mg/L	pH	µg/L	mg/L
	TSC WQO	< 500	< 50	> 6	7 - 9		< 10
TES12	Mean	103.956	44.466	6.296	8.190	1.3367	8.3533
	Median	70.0000	50.000	6.100	8.200	1.0000	6.3500
	Std Dev	93.2784	22.911	0.712	0.510	1.0666	8.2938
TES11	Mean	143.695	46.230	6.086	8.190	1.4900	7.4233
	Median	100.000	50.000	6.000	8.200	1.4000	6.1000
	Std Dev	122.544	24.414	0.642	0.318	0.9386	7.8580
TWE1	Mean	138.045	44.916	6.340	8.160	1.7367	7.1600
	Median	105.000	50.000	6.350	8.200	1.0000	5.2000
	Std Dev	93.7486	26.832	0.551	0.548	2.3329	11.724
TWE2	Mean	175.772	53.573	6.306	8.073	2.1000	8.2600
	Median	150.000	50.000	6.200	8.100	1.5500	5.4500
	Std Dev	101.569	47.042	0.599	0.527	1.3906	11.426
TES10	Mean	150.521	44.466	5.980	8.083	1.7333	11.013
	Median	104.000	50.000	5.900	8.200	1.7500	10.000
	Std Dev	125.989	22.076	0.608	0.605	0.9510	7.7077
TES9	Mean	128.478	44.956	6.076	8.133	1.6567	9.6233
	Median	80.0000	50.000	5.900	8.200	1.1500	8.4000
	Std Dev	118.757	22.074	0.731	0.519	1.2378	8.1400
TES8	Mean	198.652	45.360	5.840	8.063	2.6000	9.0300
	Median	200.000	50.000	5.700	8.150	2.3000	7.5500
	Std Dev	126.061	21.622	0.627	0.435	1.9815	6.8588

TABLE A-3. WATER QUALITY DATA SUMMARY FOR COBAKI AND TERRANORA BROADWATER

Cobaki and Terranora Broadwater		Water Quality Parameter					
		TN	TP	DO	pH	Chlor a	SS
Sampling Site	Statistical Parameter	µg/L	µg/L	mg/L	pH	µg/L	mg/L
	TSC WQO	< 500	< 50	> 6	7 - 9		< 10
TES1	Mean	250.1739	43.5633	5.4667	7.8467	3.2400	16.0867
	Median	210.0000	50.0000	5.5000	7.9000	3.0500	14.0000
	Std Dev	183.2149	21.7905	0.6244	0.4224	1.8511	8.1413
TES2	Mean	231.3043	44.5000	5.5000	7.8967	3.4333	13.3033
	Median	190.0000	50.0000	5.4000	7.9000	3.0000	10.5000
	Std Dev	192.2017	22.0966	0.6275	0.3690	1.6283	14.2904
TES3	Mean	197.1304	42.6600	5.6067	8.0033	2.5100	12.1800
	Median	153.0000	50.0000	5.4000	8.0000	2.1000	10.0000
	Std Dev	167.2805	18.4250	0.8485	0.3917	1.8764	7.2876
TES4	Mean	161.6087	41.8000	5.8767	8.1200	2.1200	12.4733
	Median	140.0000	50.0000	5.7500	8.2000	2.1000	11.5000
	Std Dev	130.8680	15.2528	0.8447	0.4390	1.0456	5.8733
TES5	Mean	235.7826	44.1800	5.7900	7.8800	4.9233	19.4967
	Median	220.0000	50.0000	5.7500	7.9000	3.6000	16.5000
	Std Dev	150.7095	18.5396	0.7004	0.4156	3.3298	7.9516
TES6	Mean	139.5217	41.6833	6.0500	8.1300	1.9133	8.7567
	Median	90.0000	50.0000	6.0500	8.2000	1.6000	8.5000
	Std Dev	132.9815	16.8689	0.8161	0.3780	1.2481	4.4006
TES7	Mean	146.5652	44.7333	6.1333	8.0867	1.9113	8.8633
	Median	100.0000	50.0000	6.1000	8.1500	1.4500	8.6000
	Std Dev	128.5980	20.5308	0.8040	0.4890	1.3895	4.4001
TES13	Mean	432.3913	62.4133	6.2467	7.4133	8.9033	25.4967
	Median	360.0000	50.0000	6.2000	7.3000	6.6500	16.0000
	Std Dev	197.0634	39.6630	1.0663	0.5993	7.3066	45.8248
TES14	Mean	445.0435	53.5900	6.5733	7.4267	7.6600	13.5267
	Median	330.0000	50.0000	6.4500	7.5000	6.7000	10.5000
	Std Dev	375.6996	27.1565	1.1858	0.5349	6.0664	8.2412
TES15	Mean	477.9565	53.2800	5.9300	7.2367	6.0500	14.5067
	Median	450.0000	50.0000	6.0000	7.3000	3.9500	11.0000
	Std Dev	166.6317	23.6563	1.1627	0.5149	6.6139	10.9493
TES16	Mean	424.6522	58.3367	6.0900	7.4000	7.2233	22.9467
	Median	360.0000	50.0000	6.3000	7.4500	6.6000	16.0000
	Std Dev	186.2883	33.1556	1.1845	0.5153	4.5840	25.6783

TABLE A-4. WATER QUALITY DATA SUMMARY FOR TWEED COAST ESTUARIES

Tweed Coast Estuaries		Water Quality Parameter					
		TN	TP	DO	pH	Chlor a	SS
Sampling Site	Statistical Parameter	µg/L	µg/L	mg/L	pH	µg/L	mg/L
	TSC WQO	< 500	< 50	> 6	7 - 9		< 10
CGN1	Mean	314.5000	58.5000	6.2095	6.2095	1.2286	7.2143
	Median	270.0000	50.0000	6.2000	6.2000	1.0000	5.5000
	Std Dev	218.7639	47.0470	1.0421	1.0421	0.9706	5.5266
CGN2	Mean	672.3529	52.9412	6.0500	6.5500	3.5056	7.8167
	Median	510.0000	50.0000	6.1000	6.5000	2.4000	7.6500
	Std Dev	339.0525	36.5316	1.3866	0.9432	3.0587	5.1630
CGN3	Mean	671.6667	55.5556	6.3368	6.3526	3.4000	6.7632
	Median	520.0000	50.0000	6.0000	6.5000	2.3000	5.0000
	Std Dev	393.8236	41.0484	1.4878	1.1602	2.7303	5.2040
CGR1	Mean	286.4706	51.1765	6.1778	7.7222	1.4278	13.4556
	Median	230.0000	50.0000	6.1000	7.9500	1.1000	9.2000
	Std Dev	184.0496	36.2081	0.8207	0.7612	1.3650	16.7646
CGR2	Mean	501.6667	69.4444	6.7684	7.5737	6.0421	34.0684
	Median	345.0000	50.0000	6.7000	7.7000	1.8000	21.0000
	Std Dev	384.3138	46.9633	1.5560	0.6781	8.7162	38.1713
CGR3	Mean	555.2941	64.7059	5.9944	7.2167	3.0111	10.8056
	Median	510.0000	50.0000	5.7000	7.1500	1.9500	10.5000
	Std Dev	355.2836	44.7378	1.5330	0.7808	3.2581	5.0346
CGR4	Mean	713.7500	69.3750	5.8588	7.1188	4.2529	14.0706
	Median	585.0000	50.0000	5.8000	7.1500	4.1000	12.0000
	Std Dev	350.2356	45.9665	1.5835	0.7748	2.3351	8.5501
CGR6	Mean	683.1250	74.3750	5.2412	6.6471	2.2000	12.7765
	Median	690.0000	50.0000	5.3000	6.6000	1.9000	10.0000
	Std Dev	346.6933	106.4562	1.3370	1.2461	1.7219	7.2229
MBL1	Mean	250.0000	0.0515	6.7857	7.9714	1.1810	9.6476
	Median	210.0000	0.0500	6.9000	8.1000	1.1000	8.4000
	Std Dev	140.7499	0.0403	1.0268	0.4961	0.7033	5.5439
MBL2	Mean	233.3333	51.6667	6.5526	7.9632	2.4158	6.6000
	Median	220.0000	50.0000	6.5000	8.0000	1.8000	4.9000
	Std Dev	120.1470	37.2985	0.8255	0.2587	1.8913	4.8056
MBL3	Mean	250.5263	52.1053	7.0015	7.8700	2.3000	6.2100
	Median	220.0000	50.0000	7.2000	7.9000	1.5500	4.3000
	Std Dev	95.6541	38.3810	1.0211	0.2755	1.5553	4.8299
MBL4	Mean	396.3158	51.5789	6.6952	7.3762	1.7762	9.3238
	Median	340.0000	50.0000	6.8000	7.2000	1.5000	8.8000
	Std Dev	180.9607	36.2496	1.2213	0.6730	1.3274	4.5813

Appendix B. Historical Derivation of Environmental Values and Interim Water Quality Objectives

Environmental Values

Eight environmental values (EV's) were considered possibly appropriate for the various segments within the study area. These EV's were generally based on values outlined in the ANZECC Guidelines (2000) and were:

- Aquatic ecosystem protection
- Commercially produced shellfish for human consumption
- Potable water
- Primary body contact recreation (swimming and action sports)
- Secondary body contact recreation (boating)
- Agricultural irrigation water supply
- Livestock drinking water
- Homestead water supply (non potable)

Aquatic Ecosystem Protection

This environmental value relates to the protection of water quality to ensure that all elements of the freshwater, estuarine and marine aquatic ecosystem are protected. It is not designed to protect a particular species, or for commercial farming of fish/shellfish, but is intended to ensure that all essential ecological processes can be performed, and the ecological integrity of the system is maintained.

Commercially Produced Shellfish for Human Consumption

This environmental value should not be confused with the production of edible raw shellfish. Commercially produced shellfish are grown under an industry guideline, with careful supervision of conditions, specific water quality criteria, treatment of the shellfish and testing requirements before sale. It was determined that this guideline would be more suitable for a waterbody heavily impacted by urban and rural land uses.

Shellfish are filter feeders and have the capacity to bioaccumulate some pollutants and grow bacteria within the organism. If unprocessed shellfish (particularly oysters) are eaten raw and the whole organism is consumed there could be some risk to human health, unless a very high standard of water quality is constantly maintained.

As some toxins and bacteria are destroyed in the cooking process or removed in the depuration process, this environmental value relates to cooked fish, cooked shellfish or other commercially grown shellfish.

Potable Water

This environmental value relates to the water being of sufficiently high quality to drink when taken directly from the waterbody, without any sterilisation or treatment. It does not relate to the supply of potable water for treatment nor the ability to drink treated water from the reticulated water mains.

Primary Body Contact Recreation (Swimming and Action Sports)

This environmental value is to protect the waterbody for use in primary human contact activities, such as swimming, bathing or other activities in which the user comes in frequent direct contact with the waterbody and is likely to ingest significant quantities of water.

Secondary Body Contact Recreation (Boating)

This environmental value is to protect the waterbody for use in secondary human contact activities, such as boating, fishing or other activities where there is less frequent (or unintentional) direct contact with the waterbody.

Agricultural Irrigation Water Supply

The ability to use water for irrigation of crops is also a value held for many sections of the Tweed River. Irrigation waters need to be of a particular quality to ensure adequate crop growth, and that neither alteration of the soil structure nor environmental harm is caused. Numerous farms in the study area require irrigation waters for their crops to be viable.

Livestock Drinking Water

The environmental value for livestock drinking water ensures water can be safely used as a drinking water supply for a variety of animals (cattle, pigs, sheep etc.). Water of lower quality may be able to be drunk by livestock for short durations without ill effect, however long term sources of drinking water should meet this environmental value to maintain healthy and successful livestock production.

Homestead Water Supply (Non-potable)

Numerous farmsteads are not connected to reticulated water supply in the Tweed River catchment, and one of their sources for water supply is extraction directly from the Tweed River, or a tributary of the river. This environmental value does not aim to provide potable water (i.e. drinking water with no treatment), which is covered by the potable water supply environmental value. Homestead water supply aims to ensure water can be used for washing, cooking and other domestic purposes safely, however water may need to be sterilised before it is suitable to be used for drinking.

The environmental values are summarised in Table below.

TABLE B-1. ENVIRONMENTAL VALUES DEFINED FOR THE TWEED RIVER

Environmental Value	1. Upper Freshwater	2. Lower Freshwater	3. Upper Estuary	4. Mid Estuary	5. Lower Estuary	6. Terranora Inlet	7. Terranora Broadwater	8. Cobaki Broadwater	9. Other (Bilambil Ck,Cobaki Ck etc.)
Aquatic Ecosystems Protection	4	4	4	4	4	4	4	4	4
Edible Molluscs (Raw)			4	4	4	4	4	4	
Potable Water	4	4							4
Primary Contact Recreation	4	4	4	4	4	4	4	4	4
Secondary Contact Recreation	4	4	4	4	4	4	4	4	4
Agricultural Irrigation Water	4	4							4
Livestock Drinking Water	4	4							4
Farmstead Supply (non potable)	4	4							4

It should be noted that the environmental values defined for all the freshwater segments were identical, and were as follows:

- Aquatic ecosystem protection (AQ);
- Direct potable water (PW);
- Primary body contact recreation (swimming and action sports) (PC);
- Secondary body contact recreation (boating) (SC);
- Agricultural irrigation water supply (AG);
- Livestock drinking water (LG); and
- Homestead water supply (non potable) (HS).

Similarly, all the estuarine segments (3, 4, 5, 6, 7 & 8) had identical environmental values defined, which were as follows:

- Aquatic ecosystem protection (**AQ**);
- Production of commercial shellfish (**CS**);
- Primary body contact recreation (swimming) (**PC**); and
- Secondary body contact recreation (boating) (**SC**).

Other environmental values identified in the Lower Tweed Estuary Management Plan (Public Works Department, 1991) include the following:

- Ecological significance including natural habitat areas within the river and foreshore areas (**EC**);
- Visual amenity (**VA**);
- Provision of recreation facilities (**RF)**.

Appendix C. TSC USQMP (2000) Audit

TABLE C-1. TWEED SHIRE COUNCIL USQMP (2000) AUDIT RESULTS

Option Rank	Option No	Description	Completion Status	Comment and further recommendations
1	OP21	Develop specific guidelines for stormwater management during subdivision, construction and operational stages of all new development, especially within the Terranora Broadwater catchment	Complete. NSW Blue book. Tweed USQMP reviewed, D7 reviewed.	An internal review of compliance and regulation mechanisms should be undertaken.
2	OP1	Environmental audit and education campaign in the South Murwillumbah industrial estate to facilitate change of practices.	Completed through the SEA Project in 2003-4.	
3	OP16	Environmental audit and education campaign in the Tweed Heads South industrial estate to facilitate change of practices.	Completed through the SEA Project in 2003-4.	
5	OP27	Targeted education campaign aimed at residential areas adjacent to canals in Tweed Heads and Pottsville.	Not completed in a targeted way for canal residents, though several stormwater education campaigns were developed and run by Council and the State Government 2000 - 2010.	
6	OP24	Install CDS or similar on stormwater line running onto Cabarita Beach	Complete	The effectiveness and appropriateness of this device needs to be reviewed.(ask Steve Paff to clarify)
8	OP32	Council to develop and implement strict guidelines for staff and contractors for grass mowing and slashing.	Complete	A review and refresher should be undertaken, with specific measures developed for various parts of the organisation
10	OP6	Lavender Creek Drain – design and construct an integrated stormwater quality improvement design including trash racks, sediment basins and revegetation.	Completed, though wetland has been decommissioned.	The design of the artificial wetland was flawed and caused ongoing maintenance problems. The costs to redesign and rebuild the structure exceed the potential benefits provided by it.
11	OP17	Investigate and mitigate source of high faecal coliforms in Water Street open drain.	Completed. A sewage pump station overflow has been rectified.	
12	OP36	Increased regulation and enforcement of stormwater	Ongoing work required.	An internal review of compliance and regulation

Option Rank	Option No	Description	Completion Status	Comment and further recommendations
		quality issues – particularly building works and industrial areas.		mechanisms should be undertaken.
13	OP35	Develop a DCP to manage stormwater quality and quantity on new developments and regulate (crate specific position to regulate and educate) including requirement for production of a stormwater facilities operational management strategy.	Complete (D7) and recently reviewed as part of this process.	
14	OP38	Develop and implement Environmental Management Strategies for Council Staff and provide training.	Complete	A review and refresher should be undertaken, with specific measures developed for various parts of the organisation
15	OP10	Trial litter baskets in side pits in commercial and residential areas around Tweed Heads and monitor over one year.	Complete	The effectiveness and appropriateness of this device needs to be reviewed.(ask Steve Paff to clarify)
17	OP23	Investigate location of stormwater pipe breach upstream of Jack Julius Park stormwater line and relay pipe (reduced maintenance cost for CDS Unit installed)	Not completed	
20	OP29	Continue Tweed Stormwater Awareness Campaign	Complete	Various education initiatives continue via sustainable living centre and catchment education trailer for students. Program could be revisited to assess requirements for a revised and focused program.
21	OP37	Develop and implement a licencing and monitoring program for all onsite sewage management facilitates within the Shire.	Complete	
24	OP25	Develop and implement an operational management strategy for the Bogangar Drainage Canal and other sedimentation ponds, stormwater wetlands.	Not complete	Development of an operational management strategy for SQIDs is a major component of this plan review which will need to be resourced and implemented by Council
33	OP26	Upgrade Sewer Pumping Station at Creek Street.	Complete	
35	OP22	Develop and implement an operational management strategy for the Western	Complete – though under review	

Option Rank	Option No	Description	Completion Status	Comment and further recommendations
		Drainage Scheme.		
2	OP1	Environmental audit and education campaign in the South Murwillumbah industrial estate to facilitate change of practices	Complete	SEA project
3	OP16	Environmental audit and education campaign in the Tweed Heads South industrial estate to facilitate change of practices	Complete	SEA project
4	OP13	Slipway in Southern Boatharbour to adopt Best Management Practices to comply with industry requirement for stormwater management.	Completed in 2009	
5	OP27	Targeted education campaign aimed at residential areas adjacent to canals in Tweed Heads and Pottsville.	Not completed in a targeted way for canal residents, though several stormwater education campaigns were developed and run by Council and the State Government 2000 - 2010.	
7	OP8	Construct a trash rack and reed bed at inflow to Knox Park Lake	Complete	
8	OP32	Council to develop and implement strict guidelines for staff and contractors for grass mowing and slashing.	Complete	A review and refresher should be undertaken, with specific measures developed for various parts of the organisation
9	OP7	Trial litter baskets in side pits in commercial and recreational areas around Murwillumbah, monitor over one year.	Not completed	
10	OP6	Lavender Creek Drain – Design and construct an integrated stormwater quality improvement design including trash racks, sediment basins and revegetation.	Completed, though wetland has been decommissioned.	The design of the artificial wetland was flawed and caused ongoing maintenance problems. The costs to redesign and rebuild the structure exceed the potential benefits provided by it.
12	OP36	Increased regulation and enforcement of stormwater quality issues – particularly building works and industrial areas.	Ongoing work required.	An internal review of compliance and regulation mechanisms should be undertaken.
16	OP9	Redesign main Kingscliff stormwater drainage system to incorporate trash	Not complete	

Option Rank	Option No	Description	Completion Status	Comment and further recommendations
		racks and artificial wetlands		
18	OP12	Install CDS or similar on Brett Street drain prior to outfall into Southern Boatharbour	Not complete	
19	OP18	Stabilise banks and increase vegetation along length of Water Street open drain.	Not complete	
21	OP37	Develop and implement a licencing and monitoring program for all onsite sewage management facilities within the Shire	Complete	
22	OP39	Encourage stormwater friendly buildings through incentives for installation of rainwater tanks, infiltration techniques and other retention and detention techniques on individual buildings.	Complete through rainwater tank policy and incorporation of WSUD in D7	
25	OP33	Implement a green waste collection service (four times per year)	Complete	
26	OP30	Provide dog faeces bins in appropriate locations especially dog off-leash areas, Jack Evans Boatharbour, Southern Boatharbour and Seagulls Estate and Tweed Coast areas.	Not complete	
27	OP5	Develop a management plan for maintenance of Condong Creek in conjunction with Council and the Drainage Union to reduce spraying, slashing of Creek	Initiated in conjunction with land care – some success but not comprehensive	
28	OP28	Prioritise bank erosion sites and provide accesses to Mooball Creek at specified locations.	Complete	Works managed through coastal estuaries management program
29	OP31	Identify sites for retention and provision of grassed swales and infiltration basins wherever possible adjacent to roads and carparks	Not complete	
30	OP15	Construct a high quality stormwater treatment device on the stormwater line coming out of "the Grove", Tweed Heads	Not complete	

Option Rank	Option No	Description	Completion Status	Comment and further recommendations
31	OP4	Stabilise bank erosion along Condong Creek (can be in conjunction with revegetation)	Not complete	
34	OP11	Investigate source of poor water quality in Florence Street Drain and develop appropriate action strategy.	Not complete	
37	OP2	Revegetate Condong Creek banks	Not complete	
38	OP14	Review street sweeping practices in Keith Compton Drive and other locations with street trees	Complete	
39	OP34	Rate rebates for appropriate riparian revegetation on private land	Not complete	
23	OP9	Design and install stormwater quality improvement devices in Golden Links Estate, Murwillumbah	Not completed	
36	OP20	Build artificial wetlands at base of Bilambil Heights development	Not complete	

Appendix D. Derivation of Operational Phase Stormwater Quality Objectives

Best Practice Approach

Derivation of the 'best practice' stormwater quality objectives for the Tweed adhered to three underpinning principles as summarised in the table below.

TABLE D-1 PRINCIPLES UNDERPINNING DERIVAITON OF 'BEST PRACTICE' STORMWATER MANAGEMENT

Principle	Criteria	Clarification
1. Locally relevant	The design objectives must, to the extent possible, be derived using locally relevant information on urban stormwater pollution generation rates and stormwater quality treatment measure performance.	The performance of stormwater quality measures is dictated by the quantity and distribution of rainfall throughout the year. A rainfall dataset has been selected which is representative of the rainfall characteristics of the shire more broadly and is discussed below.
2. Practical	The design objectives must be achievable with more than one design solution.	The stormwater quality objectives for Tweed can be achieved by bioretention and constructed wetland (combined with swale) systems.
3. Best Practice	The design objectives must result in the adoption of the most effective and efficient forms of contemporary stormwater quality treatment infrastructure sized to operate at their respective limit of economic performance (i.e. beyond which any further increase in treatment size will not result in any appreciable increase in treatment performance).	The Tweed objectives have been defined through the creation and interpretation of treatment performance curves for bioretention and constructed wetland systems. The curves were used to establish the best practice objectives as defined in the example (Figure 1) below.

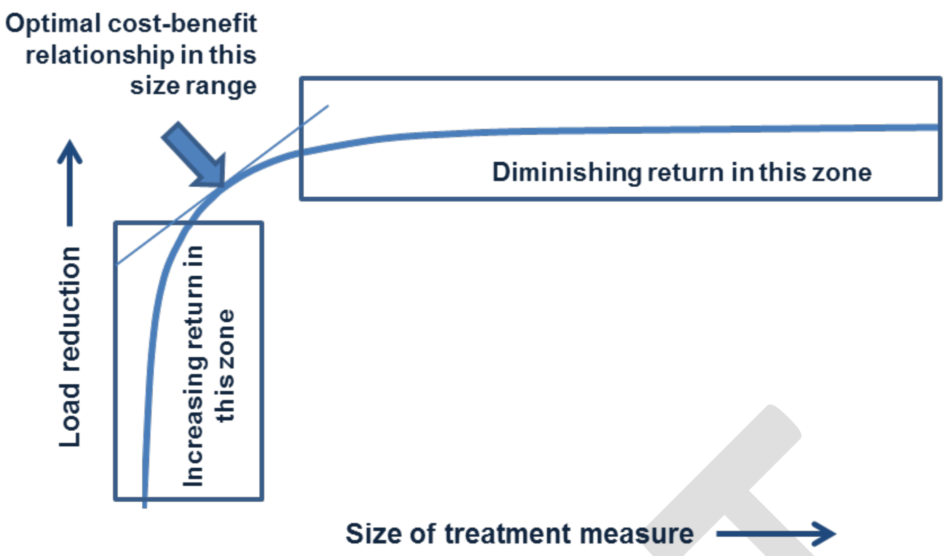

FIGURE. D-1. RELATIONSHIP BETWEEN SIZE OF TREATMENT MEASURE AND POLLUTANT LOAD REDUCTION

Derivation of Stormwater Quality Objectives for the Tweed

The derivation of 'best practice' stormwater quality pollution load reduction objectives for the Tweed adopted the same method used to derive the objectives contained in South-East Queensland Regional Plan (Implementation Guideline No. 7) (Qld DIP, 2009) and the State Planning Policy for Healthy Waters Qld DERM (2011). The method and assumptions are briefly described below with further detail of the method described in Developing design objectives for urban development in South East Queensland (SEQ Healthy Waterways Partnership, 2007).

Australian Runoff Quality (2005, p.7-5) states that the ANZECC Guidelines propose the application of physico-chemical conceptual time series models as a means of summarising our best understanding of the pathways and transformation processes of key stressors such as TSS, TP and TN. The computer model MUSIC (Model for Urban Stormwater improvement conceptualisation) has been used to complete continuous simulation of a continuous period of Tweed rainfall and evapotranspiration. The MUSIC modelling was completed in accordance with the SEQ MUSIC Modelling Guidelines with the key assumptions listed in the table below. The development scenarios assessed included:

- Urban Residential (10 lots per hectare)
- Urban Residential with rainwater tanks (10 lots per hectare)
- Industrial

Pollutant removal curves were generated for each of the scenarios and are presented in the follow figures. It can be observed from figures that both bioretention and wetland technologies exhibit a limited increased in pollutant removal (i.e. diminishing rate of return) and the optimal performance can be identified. For bioretention basin the optimal performance is between 1 – 2% of the development catchment area. For constructed wetlands when combined with a swale the optimal performance exists around 6% of the development catchment area.

TABLE D-2. MUSIC MODELLING PARAMETERS

Parameter	MUSIC version 4.0
Rainfall	• Short timestep: 6-minute • Long time period: 10 years • Representative location (refer Figure):Murwillumbah (1609mm/yr) • Representative years (long-term average =):1975-1985 (1577 mm/yr)
Evaporation	Murwillumbah PET, 1356 mm/yr
Source nodes	
Impervious properties	*SEQ MUSIC Modelling Guidelines* (Water by Design, 2010)
Pollutant export	*SEQ MUSIC Modelling Guidelines* (Water by Design, 2010)
Moisture stores	*SEQ MUSIC Modelling Guidelines* (Water by Design, 2010)
Treatment nodes	
Rainwater tanks	5 kL tank per dwelling, 131 L/hh/d indoor and 70 kL/yr outdoor re-use demand (other parameters in accordance with *SEQ MUSIC Modelling Guidelines* (Water by Design, 2010)
Bioretention	Interim node for bioretention (Water by Design: http://waterbydesign.com.au/interimnode/) Filter area = surface area, 0.3m extended detention, 0.6m filter depth, 200mm/hr saturated hydraulic conductivity, 0.5mm median particle diameter.
Constructed Wetland	Inlet pond volume 150 m3 (required to capture minimum 80% coarse sediment before entering wetland), 0.5m extended detention depth, 0.3m permanent pool depth, approx. 48 h notional detention time
High flow bypass swale	1m base width, 5m top width, 50m long, 2% grade, 250mm vegetation height, low flow bypass according to wetland outlet flow rate

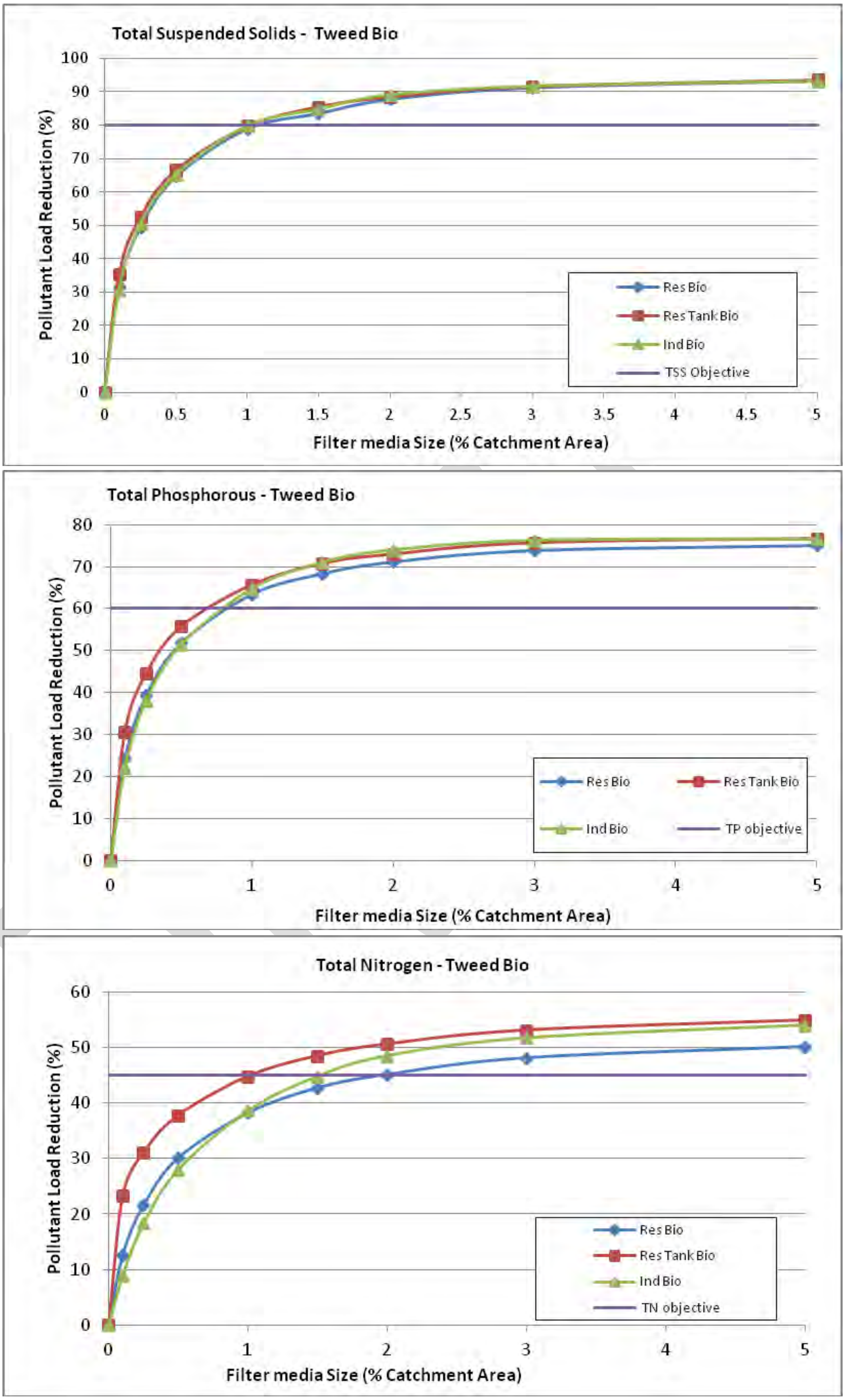

FIGURE D-2. BIORETENTION PERFORMANCE CURVES

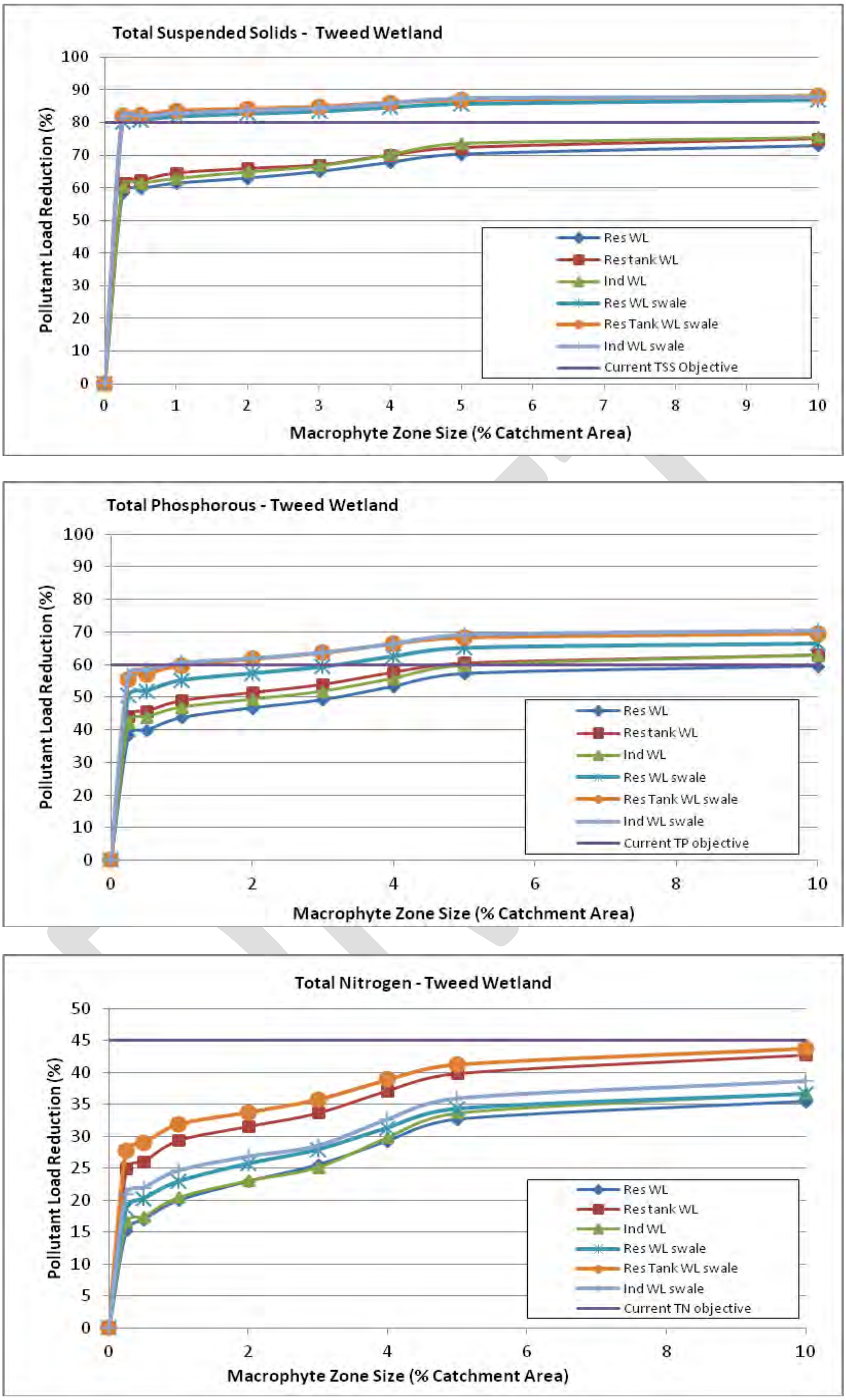

FIGURE D-1. CONSTRUCTED WETLAND PERFORMANCE CURVES

The Objectives

The bioretention and wetland treatment performance curves were reviewed to derive the stormwater quality objectives. The point of diminishing return (of pollutant load removal) for bioretention is reached when the size of bioretention is 1-2% of the catchment area. The table below provides the objectives of the basis of this size bioretention. When constructed wetlands are used, the size required to meet these objectives is >10% of the catchment area which is considered beyond the limits of economic performance. It is therefore proposed that the TSS and TN objectives should be slightly relaxed so that wetlands may be considered on sites where they are the appropriate stormwater quality management response and bioretention systems cannot be used (due to level or other constraints).

TABLE D-3. STORMWATER QUALITY OBJECTIVES

Parameter	Mean annual load reduction (compared to unmitigated)
Total suspended solids (TSS)	80% *
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	45% **
* When adopting wetlands only, the TSS and TN objectives may be relaxed to 75% and 40%, respectively	