10.0 INTEGRATED WATER CYCLE MANAGEMENT PLAN – GILBERT & SUTHERLAND

DOCUMENT CONTROL

DOCUMENT 10927_IWCMP_RDY1F.docx
TITLE Integrated Water Cycle Management, Kings Forest Stage 1 Project Application, Kings Forest, New South Wales
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SYNOPSIS This report provides advice on the conceptual design of a stormwater management system for the Kings Forest Stage 1 Project Application area, with a particular focus on the Precinct 5 detailed development. This report reviews the previously provided conceptual integrated water cycle and stormwater management measures and assesses their applicability to the subject application, in particular Precinct 5. It describes assessments of the stormwater management measures proposed in this Application to ensure that the stormwater runoff from the proposed development meets Tweed Shire Council's water quality objectives.

REVISION HISTORY

REVISION #	DATE	EDITION BY	APPROVED BY
1	12/09	A. Genn	N. Zurig & N. Sutherland
2	2/11	A. Genn	N. Zurig & N. Sutherland
3	4/11	A. Genn	N. Zurig & N. Sutherland
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DISTRIBUTION

	REVISION NUMBER									
Distribution	1	2	3	4	5	6	7	8	9	10
Project 28 Pty Ltd	3	1	1	1						
JBA Planning	-	1	1	1						
G&S file	1	1	1	1						

SUMMARY

Project 28 Pty Ltd commissioned Gilbert & Sutherland Pty Ltd (G&S) to undertake specialist studies and assessments in support of the Stage 1 Project Application for the proposed development of the Kings Forest site at Kings Forest, New South Wales.

A concept plan (MP06_0318) for the proposed Kings Forest Development was approved by the New South Wales Minister for Planning on 19 August 2010 and subsequently amended on 22 December 2010. The Director General of the Department of Planning (DOP) issued amended Environmental Assessment Requirements (DGRs) MP08_0194 for the Stage 1 Project Application on 23 December 2010.

The Kings Forest Stage 1 Project Application No. MP 08_0194 was lodged in November 2011. The Application and Environmental Assessment Report was advertised from December 2011 to January 2012 following which 302 public submissions and 10 agency submissions were received.

As a result of the submissions, amendments to the project have been made. The amended project contains the following key elements:

- Subdivision to create new lots for future development;
  - Bulk earthworks across the site;
  - Road works comprising:
    - construction of the entrance road into the site and associated intersection works on Tweed Coast Road;
    - alignment and construction of the proposed Kings Forest Parkway from Tweed Coast Road via Precincts 4 and 5 through to the western precincts; and
    - alignment and part construction of two proposed roads through SEPP 14 areas to access the southern precincts;
- Development of 2,036 m^2 of floor space for rural supplies development and access arrangements within Precinct 1;
- Construction of subdivision and infrastructure works along the Kings Forest Parkway and within Precincts 1 and 5;
- The Plan of Development for Precinct 5.

This report addresses the amendments to the project and the key issues raised in the submissions and represents a revision of G&S's June 2011 *'Integrated Water Cycle Management Strategy, Kings Forest Stage 1 Project Application'*.

This report examines options for Integrated Water Cycle and Stormwater Management for inclusion in the development of Stage 1, with particular focus on the detailed Precinct 5 area. The Integrated Water Cycle Management (IWCM) approach described herein aims to provide feasible integrated solutions for the management of water supply, wastewater, stormwater and groundwater throughout the site. A number of potential water management measures were investigated for inclusion in the IWCMP and ultimately for adoption in the development of Precincts 1 and 5 of the Kings Forest site.

To establish the context for the IWCM strategy, a Baseline assessment was undertaken to describe the environmental values for the receiving environment, and in particular the water quality within Blacks Creek and Cudgen Creek. Water quality objectives were established based on existing water quality data in an effort to ensure that the identified environmental values are preserved during and following the proposed development of the site.

This report addresses the issues raised in the DGRs dated 23 December, 2010 in relation to Integrated Water Cycle Management (DGR Nos. 7.1, 7.2 & 7.3) with particular reference to Stormwater Management. The proposed IWCM measures are consistent with the IWCMP prepared in support of the approved concept plan. Subsequent design of precincts 1 and 5 have informed a more detailed assessment of the stormwater management devices required to manage stormwater quality resulting from the proposed development. As such, this report provides further stormwater quality assessments in accordance with Tweed Shire Council's specifications and the Healthy Waterways, Water Sensitive Urban Design Technical Guidelines dated June 2006.

G&S used the MUSIC computer model to assess the effectiveness of the proposed stormwater quality treatment devices in managing the quality of stormwater runoff from the site after completion of the development. This comparison indicated that provided the recommended water quality management measures are properly installed and maintained, the water quality of runoff from the proposed development would achieve Council's desired objectives, resulting in no decline in the water quality within the receiving environments.

LIST OF DRAWINGS

DRAWING NO.	DESCRIPTION
10927-301	Site location
10927-302	Water quality sampling locations
10927-303	Precinct 5, proposed development plan
10927-304	Precinct 5, proposed MUSIC catchment plan
10927-305	Precinct 5, proposed MUSIC devices
10927-306	Precinct 5, proposed commercial development area
10927-307	Bioretention filter detail

GLOSSARY

TERM	MEANING
Australian Height Datum (AHD)	National reference for relative height measurement in Australia.
Average Recurrence Interval (ARI)	The average or expected length of time between exceedances of a given variable, such as rainfall.
Bund	An embankment constructed around an area to prevent the inflow or outflow of liquids. Also called Bunding.
Catchment	The area above a given point which contributes to the runoff.
Clay	Very fine-grained sediment or soil (often defined as having a particle size less than 0.002 mm, or 2 microns, in diameter).
Ephemeral	A stream that flows briefly only in direct response to precipitation in the immediate locality and the channel of which is at all times above the watertable.
Erosion	The process by which material (such as rock or soil) is worn away or removed (as by wind or water).
Groundwater	The water contained in interconnected pores located below the watertable in an unconfined aquifer or located in a confined aquifer.
Intermittent	A stream in which the flow is seasonal, usually in response to rainfall in the immediate area (see ephemeral).
Loam	Medium-textured soil composed of approximately 10% to 25% clay, 25% to 50% silt and less than 50% sand.
pH	The degree of acidity or alkalinity measured on a scale of 1 to 14 with 7 as neutral. From 0 to 7 is acidic; from 7 to 14 is alkaline.
Sand	Sediment composed of particles within the size range 63 microns to 2 millimetres.

TERM	MEANING
Scouring	The action of removing sediment from stream banks, particle by particle. This is a more destructive process than collapse when viewed over time due to incremental effects.
Sediment	Unconsolidated, fine-grained material (typically derived from the weathering of rocks), that is transported by water and settles on the floor of seas, rivers streams and other bodies of water.
Silt	Sediment having particles finer than sand and coarser than clay (i.e. 2 to 63 microns).
Sub-catchment	A smaller area within a catchment drained by one or more tributaries of the main water body.
Suspended Solids (SS)	The concentration of filterable particles in water (retained on a 1.2μm filter) and reported by volume (mg/L).
Total Nitrogen (TN)	Total nitrogen is the sum of the nitrogen present in all nitrogen-containing components in the water column. The nutrients, nitrogen and phosphorus are essential for plant growth. High concentrations indicate potential for excessive weed and algal growth.
Total Phosphorus (TP)	Total phosphorus is the sum of the phosphorus present in all phosphorus-containing components in the water column. The nutrients, nitrogen and phosphorus are essential for plant growth. High concentrations indicate potential for excessive weed and algal growth.
Turbidity	A measure of the cloudiness of water which is determined by the amount of light scattered by suspended particles.

10.1 Introduction

Project 28 Pty Ltd commissioned Gilbert & Sutherland Pty Ltd (G&S) to undertake specialist studies and assessments in support of the Stage 1 Project Application for the Kings Forest development, Kings Forest, New South Wales.

The amended Stage 1 Project Application includes the following key elements:

- Subdivision to create new lots for future development;
    - Bulk earthworks across the site;
    - Road works comprising:
        - construction of the entrance road into the site and associated intersection works on Tweed Coast Road;
        - alignment and construction of the proposed Kings Forest Parkway from Tweed Coast Road via Precincts 4 and 5 through to the western precincts; and
        - alignment and part construction of two proposed roads through SEPP 14 areas to access the southern precincts;
- Development of 2,036 m^2 of floor space for rural supplies development and access arrangements within Precinct 1;
- Construction of subdivision and infrastructure works along the Kings Forest Parkway and within Precincts 1 and 5;
- The Plan of Development for Precinct 5.

The development concept is shown on Drawing No. 113691-PSP-4 (prepared by RPS) included in Appendix 5.

This study was undertaken to provide responses to the Director General's Environmental Assessment Requirements (DGRs) for Project Application No. 08_0194, dated 23 December, 2010.

10.1.1 Scope of report

This report supplements the *'Integrated Water Cycle Management Strategy, Kings Forest Concept Plan'* dated December 2008, prepared by Gilbert & Sutherland (G&S 2008) in support of the concept plan application (reference No. 06_0318) for the proposed Kings Forest Development, which was approved by DOP on 19 August 2010 and subsequently amended on 22 December 2010.

This application seeks approval to undertake bulk earthworks across the majority of the site including the future golf course area. Construction phase erosion and sediment control measures would be installed to protect the water quality in the surrounding environment. These areas would be revegetated or otherwise stabilised on completion of the earthworks. Accordingly, permanent stormwater management devices are not required for this phase of the works.

This report focuses on the first stage of urban development and the commercial site to the east of Tweed Coast Road. It describes the environmental conditions in Cudgen Creek and Blacks Creek and the potential impacts to the Environmental Values (EVs) of the receiving environment (as defined in the ANZECC 2000 Guidelines). Thereafter, a stormwater quality treatment train is assessed in accordance with the Healthy Waterways, Water Sensitive Urban Design (WSUD) Technical Design Guidelines (2006) and with reference to the interim water quality objectives (WQOs) established on the basis of Tweed Shire Council's water quality data. Whilst Tweed Shire Council (TSC) is not the determining authority for this application, the associated *Development Design Specification D7, Stormwater Quality* quidelines provide a useful yardstick, and formed the basis for the stormwater quality assessments carried out in previous versions of this report. Notwithstanding, the D7 specifications have been used to inform design considerations in achieving the overarching WQOs specified in the WSUD Technical Design Guidelines (2006).

In particular, this report addresses DGRs 7.1, 7.2 and 7.3. For ease of reference, these DGRs are reproduced below (in Italic text) interspersed with comments (in Roman text) describing where to find the information within this report.

> *7.1 Address and outline measures for Integrated Water Cycle Management (including stormwater) based on Water Sensitive Urban Design principles and which addresses impacts on the surrounding environment, drainage and water quality controls for the catchment.*

These details are provided in Section 10.3 of this report.

> *7.2 A detailed plan of erosion and sediment controls at construction and operational stages to ensure that the water quality of SEPP 14 Wetlands on the site remain unaffected.*

A detailed Erosion and Sediment Control Plan has been prepared by Gilbert & Sutherland and should be viewed in conjunction with this report.

> *7.3 A Stormwater Management Plan is to be provided which includes a detailed design layout plan for the preferred stormwater treatment train showing location, size and key functional elements of each part of the system must be submitted with each development application for subdivision. MUSIC modelling must be undertaken to demonstrate appropriate water quality objectives are being achieved. The Plan is to demonstrate, through the provision of monitoring and adaptive management plans and commitments, that any proposed surface water/stormwater pollution reduction devices will be monitored to determine their pollutant removal efficiencies and the need for further treatment of drainage to ensure the preservation of water quality in Cudgen Creek and Blacks Creek.*

The assessment of stormwater quality and the effectiveness of remedial measures is presented in Section 10.4 and 10.5 of this report. The proposed stormwater management procedures are described in the separate G&S report titled 'Stormwater Management Plan, Kings Forest Stage 1, Project Application, Kings Forest, New South Wales' (July 2012).

10.1.2 Aims and objectives

The information herein is provided to meet the DGRs described above. Accordingly, this report provides details for the stormwater management measures to be installed in Precincts 1 & 5 of the Stage 1 development.

This report addresses those issues related to soil and water management, with particular emphasis on stormwater quality control. The report is based on Healthy Waterways WSUD Technical Design Guidelines (2006), relevant TSC D7 specifications and MUSIC (Version 5) computer modelling of likely changes to annual stormwater sediment and nutrient loads due to the proposed development. The MUSIC modelling has been conducted in accordance with the Water by Design (WbD) MUSIC Modelling Guidelines, Version 1.0 (2010).

In addition, the report has been revised to address the relevant submissions received in response to the public exhibition of the Project Application.

10.1.3 Response to submissions

This revised report addresses the amendments to the project and the key issues raised in the submissions.

Submitter: Department of Planning

Issue: The department supports council's request for the installation of a treatment basin at the outlet of the low flow pipe, for containment of contaminants prior to discharge to Blacks Creek

The department also supports council's request for further assessment of the potential impacts of the residual stormwater pollutants, particularly sediment and nutrients entering Blacks Creek and the connected estuarine system

Response: The stormwater treatment train has been revised to include a treatment basin at the outlet of the low flow pipe, to treat discharge upstream of Blacks Creek.

Further assessment of the potential impacts of residual stormwater contaminants has been

undertaken and is discussed in Section 10.2 of this report.

Issue: Provide clarification of terms used on Drawing No. 10468.3.6 'Vegetated Swales' and 'Bioretention Trenches'

Response: The drawings have been updated to use terminology preferred by Tweed Shire Council and to be consistent with the text in the report.

Issue: Provide further discussion on the relative pollutant removal efficiencies of these different systems and the space that each requires.

Response: The relative pollutant removal efficiencies were investigated and options for stormwater quality treatment were selected on this basis and on the basis of the civil design for Precincts 1 & 5. This report assesses the effectiveness of the proposed stormwater treatment train and demonstrates that the proposal exceeds the requirements of Tweed Shire Council's Urban Stormwater Quality Management Plan.

Submitter: Tweed Shire Council

Issue: TSC recommends that the impact of stormwater on Cudgen Creek, particularly Nitrogen export, be investigated more thoroughly consistent with DGR7.1 which explicitly requires impacts to be assessed on the "surrounding environment". The IWCMP modelling is an indication of the proposals capacity to meet requirements of the Tweed Shire Council's Urban Stormwater Quality Management Plan, but it has not been demonstrated that the development will have no impact on water quality and aquatic habitat values in receiving environments. (TSC, Page 78)

Response: The IWCM has been revised to incorporate an assessment of the receiving environment and potential impacts to the receiving waters (refer to Section 10.2 of this report). The revised IWCM demonstrates that water quality discharged from the site under the treated developed case is equivalent to the water quality of the pre-developed case, and meets Council's deemed to comply requirements and the ANZECC Water Quality Guidelines for Fresh Water (1992). Monitoring points will be established within Cudgen Creek, where access allows, to identify potential impacts to Cudgen Creek and Cudgen Lake. Council's water quality data has been reviewed and has been used to establish interim water quality criteria for receiving waters which are included in the revised SWMP.

10.2 Environmental condition of Cudgen Creek and Blacks Creek

10.2.1 Scope of study

This section reports on the condition of the Premises (the site) and discusses potential impacts to the Environmental Values' (EVs) of the receiving environment. Definitions are in accordance with the meaning of EVs as contained in the ANZECC 2000 Guidelines for fresh and marine water quality, where:

- EVs are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits.

The following EVs are recognised in the ANZECC 2000 guidelines:

- Aquatic ecosystems
- Primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods)
- Recreation and aesthetics
- Drinking water
- Industrial water
- Cultural and spiritual values.

This assessment relies on data collected by TSC to provide an assessment of baseline environmental conditions within the project area, relating to riverine ecosystems.

It is intended that this assessment will be used as a benchmark against which changes in conditions at the site and in the environment downstream of the site will be measured.

10.2.2 Water quality monitoring

TSC have been monitoring water quality at a number of locations within and around the site since June 2008. These locations include:

- CGN1 – Cudgen Creek at the Coast Road Bridge, Kingscliff.
- CGN2 – Cudgen Creek at the Old Bogangar Road Bridge, Casuarina.
- CGN3 – Cudgen Creek, approximately 500m downstream of Cudgen Lake

Monitoring location CGN3 represents waters upstream of the site. Locations CGN1 and CGN2 represent water quality within the creek downstream of the site, and during development could be expected to reflect impacts from waters discharging from the site. Monitoring locations are shown on Drawing 10927-302.

10.2.3 Environmental Values of the site

Cudgen Creek and Blacks Creek are identified as having the following EVs:

- Aquatic ecosystem, and
- Recreation and aesthetics.

10.2.4 Water quality assessment

Turbidity and suspended solids

TSC monitoring showed that turbidity levels and suspended solids concentrations were generally low at all monitoring locations along Cudgen Creek. Maintaining low turbidity and suspended solids levels is critical to maintaining the ecological function of the riverine environment. Increases in suspended solids can restrict light penetration, reducing water clarity, visibility and limiting photosynthesis in aquatic plants. Suspended particles may also clog fish gills and remove important in-stream habitats for vertebrate and invertebrate species (through settling and smothering impacts)[1].

Large areas of the King's Forest development site will remain exposed and unstabilised during the bulk earthworks and building/construction phases. This poses a threat to the Aquatic ecosystem EVs of the site. However, protection of the Cudgen Creek ecosystem and connected estuarine and marine environments against the potential impacts of turbidity could be achieved through the implementation and maintenance of effective erosion and sediment controls, as defined in the site's Erosion and Sediment Control Plan (ESCP).

[1] Waterwatch Australia (2002) *Module 4 – physical and chemical parameters: Turbidity*. Australian Govt.

pH

Median pH values ranged from 6.50 to 7.90 - within a close range of neutral. Maintaining pH at a constant, near neutral level is important for the health of aquatic species. Significant changes to pH outside the normal range for an organism can cause stress and even death[2]. pH may also impact on the solubility of heavy metals, with flow on impacts to aquatic species and potentially humans[3]. pH changes (particularly reductions in pH) can result in enhanced toxicity of several pollutants, including ammonia, cyanide and aluminium[4]. Changes in pH may be associated with the oxidation of Acid Sulfate Soils (ASS) and the inflow of acidic stormwater. pH should ultimately be maintained at a range of 6.5 to 9.0 to preserve current riverine processes and EVs[5].

The proposed development of the site does not involve significant disturbance of acid sulfate soils, therefore these pH related issues should be avoided. If acid sulfate material is encountered throughout development of the site then it should be managed through implementation of a comprehensive Acid Sulfate Soil Management Plan (ASSMP).

Dissolved oxygen

Median dissolved oxygen (DO) concentrations met the ANZECC 2000 guideline (6 mg/L) at all monitoring locations along Cudgen Creek. However, DO did drop below this level on a number of occasions throughout the monitoring period. Low DO concentrations can result in adverse effects on many aquatic organisms, and may also increase the toxicity of common pollutants, including zinc, lead, copper and ammonia[6]. Low DO concentrations are natural in lowland, slow moving river systems, but also may be associated with excessive plant growth and algal blooms (through the associated effects of decomposition). Controlling nutrient inputs and maintaining the balance of in-stream flora is therefore the best approach for preserving adequate concentrations of DO.

Low DO can also be an indicator of the secondary oxidation of ASS, oxidation of MBOs (monosulfidic black ooze) and of the oxidation and precipitation of dissolved iron, which is associated with the oxidation of ASS. However, the proposed development of the site does not involve significant disturbance of ASS, therefore most of these issues should be avoided. If acid sulfate material is encountered throughout development of the site then it would be managed through implementation of the approved ASSMP.

Total nitrogen

Total nitrogen (TN) concentrations in Cudgen Creek were within the range specified in the ANZECC 2000 guidelines for natural rivers and streams (0.1 to 0.75mg/L)[7]. Maintaining moderate levels of TN is important for maintaining the natural balances of plant and algae growth in riverine systems and their downstream estuaries. High concentrations of TN, in conjunction with other factors, are often associated with algal blooms[8]. Algal blooms potentially produce toxins and also can cause large deficits of dissolved oxygen, impacting on aquatic species, livestock and humans[9]. Limiting TN inputs is therefore critical for maintaining current riverine processes and balances.

TN concentrations may be elevated by inputs of nutrient rich runoff and sediment. Controlling onsite erosion and stormwater run-off from areas of high fertiliser use is essential for maintaining current TN concentrations and therefore protecting the EVs of the Cudgen Creek ecosystem. This is best achieved through implementation and maintenance of management devices defined in the site's ESCP and IWCMP.

Total phosphorous

High concentrations of total phosphorus (TP) are also associated with algal blooms and excessive

[2] Waterwatch Australia (2002) Module 4 – physical and chemical parameters: pH. Australian Govt.
3 Waterwatch Australia (2002) Module 4 – physical and chemical parameters: pH. Australian Govt.
4 ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Government.
5 ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.
6 ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.

[7] ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.
8 Department of Sustainability, Environment, Water, Population and Communities (2012) National Pollutant Inventory – total Nitrogen: Environmental Effects. Australian Govt.
9 Waterwatch Australia (2002) Module 4 – physical and chemical parameters: Phosphorus. Australian Govt.

in-stream plant growth. The ANZECC 2000 guideline specifies a total phosphorus value of 0.01 to 0.1mg/L for natural rivers and streams[10]. Median total phosphorus concentrations were within this range at all sampling locations along Cudgen Creek. As with TN, limiting TP inputs is critical to contolling in-stream plant growth and algal blooms, and their associated negative impacts (as discussed above).

TP concentrations may be elevated by inputs of nutrient rich runoff and sediment. Controlling onsite erosion and stormwater run-off from areas of high fertiliser use is essential for maintaining current TP concentrations and therefore protecting the EVs of the Cudgen Creek ecosystem. This is best achieved through implementation and maintenance of management devices defined in the site's ESCP and IWCMP.

Chlorophyll-a

Chlorophyll-a concentrations ranged from 0.4 to 13 µg/L along the length of Cudgen Creek, with medians of 1.15, 2.00 and 2.40 calculated at CGN1, CGN2 and CGN3. High concentrations of chlorophyll-a are generally associated with high algal cell counts. In turn, high algal cell counts are generally associated with high TN and TP[11].

Controlling TN and TP inputs, as discussed above, is critical to the management of algae and chlorophyll-a and therefore protecting the EVs of the Cudgen Creek ecosystem.

Aluminium

Aluminium is toxic to fish, amphibians and phytoplankton, with toxicity increasing at low (<5.5) and high pH (>9).[12] Aluminium is present in riverine ecosystems through the natural leaching of soil and rock,[13] but may be oxidised and precipitated in low pH waters.

The ANZECC 2000 guidelines specify a trigger value of 55 µg/L in waters with pH >6.5 and 0.8 µg/L in waters with pH <6.5. Maintaining aluminium at or below these levels will ensure the ongoing suitability of the riverine environment for fish, amphibians, crustaceans, algae and plant species[14]. Aluminium levels in the Cudgen Creek system currently range from 0.01 µg/L to 3.77 µg/L.

As toxicity of Aluminium is associated with pH, maintaining the pH at an acceptable level is central to its management. Protection of the Cudgen Creek ecosystem against toxic aluminium levels is therefore best achieved through avoidance of ASS that may lower pH in the river system. If acid sulfate material is encountered throughout development of the site then it should be managed through implementation of a comprehensive ASSMP.

Iron

Iron is an essential trace element for both plants and animals. There is little documented evidence for toxicity effects from high iron concentrations, with most species more likely to suffer from deficiency related impacts. However, acute toxicity to aquatic insects has been reported at iron concentrations ranging from 320 µg/L to 16,000 µg/L[15].

Iron levels in the Cudgen Creek system currently range from 0.01 µg/L to 14 µg/L. Increases in total iron concentration to the level of toxicity is considered highly unlikely under proposed site activities.

Salinity

Maximum salinity concentrations increased towards the mouth of Cudgen Creek, with CGN1 showing significantly higher concentrations then the other monitoring locations. CGN1 ranged from 1.0 to 41.20ppt (median of 30.30ppt), while both

CGN2 and CGN3 ranged from 0.10 to 34.90 and 33.10ppt (medians of 1.90 and 2.65ppt). These large differences show that salinity concentrations within the creek are impacted by tidal exchange which is most significant near the estuary mouth at CGN1. Median salinity concentrations at CGN1

[10] ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.
11 Department of Sustainability, Environment, Water, Population and Communities (2012) National Pollutant Inventory – total Nitrogen: Environmental Effects. Australian Govt.
12 ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.
[13] Department of Water (2011) Swan region water quality monitoring and evaluation. Govt. of Western Australia.
14 ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.
15 ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.

are typical of an estuarine/marine environment[16], while median concentrations at CGN2 and CGN3 indicate a fresh water environment.

A summary of water quality conditions at each sampling location is provided below in Tables 10.2.4.1, 10.2.4.2 and 10.2.4.3 below. Complete results tables for each parameter are provided in tables A1.1, A1.2 and A1.3 (Appendix 2).

Interim Water Quality criteria
It is proposed that site specific water quality data would be collected over a minimum of twelve months, to capture the range of seasonal variation, and that this data would be used to establish water quality criteria for the purpose of comparison with construction and operational phase water quality results. Prior to this data being collected, the water quality criteria presented in Table 10.2.4.4 would be adopted for the receiving waters.

Table 10.2.4.4 Interim water quality criteria for monitoring locations CGN2 and CGN3

Parameter	Criteria
pH	6.5-9
Turbidity	<25 NTU
Suspended solids	<25 mg/L
Dissolved oxygen	>6 mg/L
Chlorophyll-a	<10 µg/L
Total Aluminium	<0.3 mg/L
Total Iron	<0.8 mg/L
Total Nitrogen	0.75 mg/L
Total Phosphorous	0.05 mg/L
Salinity	<35 ppt
Litter and gross pollutants	No man made material >5mm in any dimension
Oil and/or grease	No visible film, no detectable odour

Additional monitoring would be undertaken during the baseline data collection phase to supplement the data-set provided by Council & to establish monitoring points within Blacks Creek and at various locations within the site.

10.2.5 Conclusions

The baseline water quality conditions for Cudgen Creek have been assessed and characterised based on data collected by TSC. The monitoring locations represent waters entering the site and discharging from the site. Potential impacts associated with changes to current water quality conditions have also been discussed.

Management of these potential impacts and preservation of the Cudgen Creek ecosystem's EVs is largely accomplished by ASS management, effective erosion and sediment control and stormwater management, details of which are provided in the relevant G&S reports.

[16] ANZECC (2000) *Guidelines for Fresh and Marine* Water Quality – Aquatic Ecosystems. Australian Govt.

Table 10.2.4.1 Summary of water quality conditions at CGN1, as recorded by TSC

Parameter	Units	Minimum	Maximum	Median	Average
pH	pH	6.10	8.60	7.90	7.71
Turbidity	NTU	0.50	17.00	2.10	3.47
Suspended solids	mg/L	2.40	20.00	6.00	7.87
Dissolved oxygen	mg/L	4.20	8.80	6.40	6.33
Chlorophyll a	µg/L	0.40	4.40	1.15	1.61
Salinity	ppt	1.00	41.20	30.30	26.49
Temperature	mg/L	16.40	28.80	22.55	22.17
Total aluminium	mg/L	0.03	1.06	0.14	0.20
Total iron	mg/L	0.01	2.43	0.11	0.39
Total nitrogen	mg/L	0.01	0.20	0.05	0.07
Total phosphorous	mg/L	0.01	0.20	0.05	0.07
Chloride	mg/L	420	25,000	17,300	14,745
Sulphate	mg/L	60	4,228	1,339	1,636

Table 10.2.4.2 Summary of water quality conditions at CGN2, as recorded by TSC

Parameter	Units	Minimum	Maximum	Median	Average
pH	pH	4.60	7.90	6.50	6.62
Turbidity	NTU	1.30	21	6.50	8.13
Suspended solids	mg/L	1.60	24	6.35	7.31
Dissolved oxygen	mg/L	3.60	9.40	6.25	6.15
Chlorophyll a	µg/L	0.60	13.00	2.00	3.49
Salinity	ppt	0.10	34.90	1.90	7.92
Temperature	mg/L	14.90	28.70	22.40	21.87
Total aluminium	mg/L	0.03	2.80	0.24	0.42
Total iron	mg/L	0.10	12.00	0.79	1.84
Total nitrogen	mg/L	0.23	1.40	0.51	0.65
Total phosphorous	mg/L	0.01	0.18	0.03	0.05
Chloride	mg/L	35	17,500	1,065	4,220
Sulphate	mg/L	7.60	1,781	142	506

Table 10.2.4.3 Summary of water quality conditions at CGN3, as recorded by TSC

Parameter	Units	Minimum	Maximum	Median	Average
pH	pH	4.40	8.20	6.70	6.45
Turbidity	NTU	0.90	21	4.60	6.44
Suspended solids	mg/L	1.20	23	4.50	6.28
Dissolved oxygen	mg/L	3.80	9.70	6.30	6.64
Chlorophyll a	µg/L	0.60	9.90	2.40	3.26
Salinity	ppt	0.10	33.10	2.65	6.82
Temperature	mg/L	15.10	29.30	22.40	22.00
Total aluminium	mg/L	0.01	3.77	0.26	0.65
Total iron	mg/L	0.01	14	0.50	1.38
Total nitrogen	mg/L	0.17	1.74	0.51	0.64
Total phosphorous	mg/L	0.01	0.21	0.05	0.07
Chloride	mg/L	31	16,750	1,340	3,806
Sulphate	mg/L	13	1,813	182	484

10.3 Integrated Water Cycle Management (IWCM)

10.3.1 The IWCM concept

IWCM can be described as a way of managing water in which all components of the water system (water supply, wastewater, stormwater and groundwater) are integrated to optimise the use of the resource. The objectives of IWCM are to ensure that the community's water needs are met, whilst minimising environmental impacts and maximising the efficient use of this finite resource.

IWCM can involve the integration of a number of concepts for re-use, reduction and recycling of water. These options may include (but are not limited to):

- demand management – e.g. the use of water efficient appliances;
- rainwater (roof runoff) collection and re-use (household or community scale);
- stormwater collection and reuse;
- aquifer storage and recovery; and
- effluent recycling (sewer mining).

The optimum IWCM solution for any community will typically involve a combination of these options, based on existing infrastructure, local climate and site-based constraints. Economic and social factors may also contribute to the selection of appropriate IWCM options.

10.3.2 IWCM at Kings Forest

A preliminary assessment of potential IWCM options for Kings Forest was undertaken to identify individual components that may be appropriate to the site. However, the final IWCM strategy will not be limited to these options alone and should further strategies become apparent during the planning and design process, these may also be investigated and included in the final plan.

From the options identified, an IWCM strategy has been developed for analysis and modeling, the results of which are reported on in this report.

A key component of the strategy is the installation of rainwater tanks on individual lots. Runoff from the roofs of all such dwellings will be collected and stored in the rainwater tanks for domestic re-use, including toilet flushing, laundry cold water and outdoor uses in accordance with both BASIX requirements and Tweed Shire Council's Rainwater Tank Policy (adopted 2 November 2005).

Communal rainwater tanks will also be investigated as an option for collection and storage of runoff for use in landscape and open space irrigation within higher density residential precincts.

Overflow from the rainwater tanks and runoff from the remainder of the development is intended to be treated by means of constructed wetlands, bioretention swales and basins, or other devices in accordance with WSUD guidelines. These may be augmented by the inclusion of infiltration systems, porous pavements and grassed filter strips into the treatment train.

A reticulated potable water supply system (town water) will be provided to households and businesses for kitchen, bathroom and laundry hot water uses. If required, this supply may also be utilised for top-up of domestic rainwater tanks when the tank level falls below 15%.

Investigations into the feasibility of demand management measures to conserve water by reducing both town water usage and the volume of wastewater generated, will be undertaken. This will include the use of the Water Efficient Labeling and Standards (WELS) rated water-efficient devices (including taps, showerheads, toilets, dishwashers and washing machines) to further reduce demand across the development.

The feasibility of options for recycled water reticulation will be reviewed as the project proceeds, with the potential to distribute recycled water supply should an appropriate source of recycled water become available prior to civil works commencing. The integration of treated effluent back into the development remains an option for future stages proposed under the concept plan.

Stormwater infrastructure will complement opportunistic re-use strategies wherever possible.

A significant advantage with the site is the high permeability of the Pleistocene sand dunes, with the potential for stormwater infiltration.

Stormwater quality treatment will be provided for rainfall runoff by means of various bioretention facilities within each sub-catchment in accordance with Tweed Shire Council's 'deemed to comply' requirements.

MUSIC modelling has been used to demonstrate the proposed development will have no adverse impacts on the quality of waters discharging from the site. A discussion of the proposed stormwater quality treatment options is provided in Section 10.4.

10.3.3 IWCM in Precinct 5

The options described above have been investigated and their applicability in Precinct 5 assessed. A brief description of the applicability of the options follows.

In October 2010, TSC adopted a 'Demand Management Strategy' prepared by MWH that recommended:

> *For greenfield areas, namely Cobaki Lakes, Bilambil Heights, Terranora and Kings Forest developments Council adopts Scenario 1.*
>
> *Scenario 1 being:*

- *A voluntary rainwater tank connected to external uses, toilet flushing and cold water to washing machines:*
  - *Single Dwellings minimum 5,000L rainwater tank with a minimum 160m^2 roof area connected to it.*
  - *Multi Dwellings & other buildings Rainwater tanks to be provided on a similar basis connecting 80% to 90% of the roof.*
- *New dwellings on a voluntary basis will have a minimum of dual flush toilets as well as 3 star shower heads and taps. Noting that BASIX is most likely to achieve this.*
- *The introduction of Reduced Infiltration Gravity Sewers (RIGS) in new development.*

The adoption of this strategy in effect of rules out the potential for the use of recycled effluent, in this precinct. In addition, a conventional gravity sewer system will be constructed, i.e. the Reduced Infiltration Gravity Sewers (RIGS) will not be adopted.

The NSW Building Sustainable Index (BASIX) and the national WELS scheme mandate the installation of water efficient fixtures in new developments. This is further reinforced by the Kings Forest Development Code. These controls will ensure that rainwater storage tanks will be installed throughout the development. Furthermore, the TSC requirements for 'eligible rainwater tanks' (defined in TSC's Development Design Specification D7 Stormwater Quality) will be met to ensure that the tanks form part of the stormwater treatment train. This is discussed in more detail in Section 10.4 of this report.

A Water Sensitive Urban Design (WSUD) approach has therefore been adopted in the design of the development and its associated stormwater management system. This stormwater management system has been designed after careful consideration of the development's impacts on the groundwater system and the groundwater dependent ecosystems (GDE). The groundwater impacts are described in a separate report by G&S titled '*Groundwater Assessment, Kings Forest Stage 1 Project Application, Kings Forest, New South Wales, July 2012*'.

The majority of Precinct 5 is underlain by sandy materials which contain a shallow perched fresh water aquifer. However the depth to indurated sands is relatively shallow, which limits the potential for groundwater extraction and use by means of spear pumps. While the installation of spear pumps may be possible, their use will not be encouraged in Precinct 5 because of their potential impact on GDEs. Their inclusion as part of the Precinct 5 IWCM strategy is therefore not appropriate.

As there are no rural living areas in Precinct 5, the potential for grey water harvesting and reuse has not been investigated and does not form part of the IWCM strategy in this precinct.

There is little likelihood that recycled effluent will be made available in this precinct due to TSC's adoption of the Demand Management Strategy mentioned above. The installation of purple pipes for effluent reuse is therefore not part of the IWCM strategy for this precinct.

In summary, the IWCM strategy for this precinct will include the following components:

- Rainwater storage tanks on each allotment to supply water to external uses, toilet flushing and laundry cold water as described in the Kings Forest Development Code.
- The implementation of the BASIX requirements and the inclusion of three star WELS rated fixtures to reduce water demand in all new developments.
- Design of the project to include WSUD elements as described in Section 10.4 of this report for the management of stormwater runoff.

10.4 Stormwater quality assessment approach

10.4.1 Prescriptive approach

Tweed Shire Council (TSC) has provided detailed guidance on the methods to be adopted in assessing and designing water quality management measures in its *'Tweed Urban Stormwater Quality Management Plan'* (TUSQMP) and its 'Development Design Specification, D7, Stormwater Quality' (D7). In the previous version of this report G&S adopted the 'deemed to comply' solution provided in D7. For the purposes of detailed design, and in recognition of submissions received from statutory authorities and other interested parties, the D7 guidelines were adopted only where appropriate, and in conjunction with the overarching WSUD Technical Design Guidelines (2006).

The WQOs for the site runoff during the operational phase of the development have been based on the load reduction targets identified in Section 1.5 of the WSUD Technical Design Guidelines (2006). Details of the modelling approach to assessing the performance of the proposed treatment train are discussed in Section 10.4.2.

An assessment of the pollutant loads emanating from the development area in its existing state (Base Case) was also undertaken. This information was used to inform investigations into the receiving environment, and associated potential ecological impacts emanating from the change in land use (i.e. from the Developed Case after completion of the construction phase).

10.4.2 Modelling approach

To assess the likely impacts of runoff from the proposed development on water quality, the eWater Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 5 computer model was used.

MUSIC is a water resources package with components for generating surface and subsurface runoff, non-point source pollutant export and pollutant transporting and routing. It is specifically designed for the analysis of the effects of planned land use changes and for the evaluation of best management practice stormwater quality improvement devices. The input data requirements are described below.

Model input data
This model requires the input of rainfall and evapotranspiration data. The rainfall data must be in the form of 6 minute time-step pluviometer records. This information was obtained for Murwillumbah from TSC's web site. Suitable records were provided for the period from 01/01/1978 to 31/12/1978. The total rainfall for this period was 1693mm.

An analysis of a daily time-step rainfall data set spanning the period from 1890 to 1994 for the Tweed Heads weather station (which is considered appropriate for this study in terms of proximity and relief) provided the following annual rainfall data:

Driest Year	693mm
10th percentile year	1,199mm
Average year	1,699mm
Median year	1,672mm
90th percentile year	2,236mm
Wettest year	3,194mm

It should be noted that in the above analysis the results are statistical annual totals and may not necessarily refer to an actual historical year. A continuous model run using the MUSIC dataset provided would therefore be expected to yield satisfactory results. This is because the average rainfall (1,693mm) of the dataset is similar to the long term average (1,699mm). Average monthly potential areal evapotranspiration values were obtained from the Tweed Shire Council's D7 (Table 3) and are presented in Table 10.4.2.1.

Table 10.4.2.1 Evapotranspiration data

Month	Evapotranspiration (mm)
Jan	165
Feb	135
Mar	135
Apr	100
May	70
Jun	60
Jul	60
Aug	75
Sep	105
Oct	135
Nov	150
Dec	165

Runoff parameters

Relevant parameters for rural residential and forested land uses were sourced from Water by Design's MUSIC Modelling Guidelines, (Table 3.7) and are presented in Table 10.4.2.2.

Table 10.4.2.2 Rainfall/Runoff Parameters

Parameter	Land Use		
	Forest	Rural	Urban
Field capacity (mm)	80	80	200
Infiltration coefficient a	200	84	211
Infiltration exponent, b	1	3.3	5
Rainfall threshold (mm)	1	1	1
Soil storage capacity (mm)	120	98	500
Initial storage (%)	10	10	10
Daily recharge (%)	25	100	28
Daily baseflow (%)	3	22	27
Daily seepage (%)	0	0	0

Water quality parameters

The water quality parameters modeled were:

- suspended sediment;
- total nitrogen; and
- total phosphorus.

The sediment and nutrient export parameters were adopted from the WbD MUSIC Modelling Guidelines and Tables 3.8 and 3.9 in the Guidelines and are reproduced in Table 10.4.2.3 (following page).

It should be noted that the rainfall to runoff model and the pollutant export expressions have not been calibrated for local catchments. This means the modelling results cannot be expected to produce accurate assessments of the amount of pollutants likely to be exported from the proposed development. However, the results do provide useful assessments which enable comparisons of the effectiveness of various stormwater management strategies.

An assessment of the pervious and impervious proportions for the urban areas in each catchment was carried out to provide input for the model using the recommendations in Section 3.3.3 of WbD (2010).

Modelling undertaken

The MUSIC model was used to develop a basic model for the stormwater treatment system by comparing the Untreated Developed Case with the Treated Developed Case during the operational phase (after completion of the construction phase). This process enabled verification that the water quality objectives (pollutant load reduction targets) would be satisfied by the proposed treatment devices.

Further simulation of the existing environment (Base Case) was conducted for comparison with models representing the anticipated environment subsequent to the change in land use (Developed Case after completion of the construction phase). This modelling was used to inform investigations into the nature of the receiving habitat and ecosystems, and to assess the net impact of the development on existing environmental conditions.

The modelled scenarios were as follows:

- Base Case
- Developed Case WITHOUT treatment measures.
- Developed Case WITH treatment measures.

Details of the stormwater treatment methods recommended and the results of the MUSIC modelling are provided in Section 10.5. The MUSIC model layout is shown in Appendix 3.

It should be noted that until further guidance from the Water by Design Steering Committee is published, modelling of all bioretention treatment devices throughout the site adopted interim bioretention nodes from MUSIC Version 3, within the latest MUSIC Version 5 model.

10.4.3 Site description and proposal

Site location
The site location is shown on Drawing No 10927-301 and the proposed development is shown in Drawing No. 10927-303. The site is located off Depot Road, Kings Forest, New South Wales.

Receiving environment
Runoff from this development flows in a generally easterly or southerly direction via a number of unnamed ephemeral gullies and SEPP14 wetlands into Cudgen Creek. Cudgen Creek flows from Cudgen Lake which lies to the south-east of the site to its mouth at Kingscliff, approximately 4.5km to the north-east of the site.

Surface water quality monitoring in the Cudgen and Blacks Creeks has been undertaken by the TWC (as reported in Section 10.2 of this report), has been used to determine the baseline water quality conditions in the receiving environment relevant to the site. A key objective of the various water management strategies and plans is to ensure that there is no worsening of the water quality in the receiving waters resulting from this development, during the construction or operational phases.

Site investigations indicate that Wallum Froglets and Wallum Sedge Frogs are present on the site. Their habitat has been assessed by the ecologists (James Warren & Associates) as comprising:

- core breeding areas located in and adjacent to water holes located on the more elevated Pleistocene soils and
- foraging areas that extend to include the lower lying areas in the Holocene soils.

This observation confirms the preferred habitat is in areas of organic acid soils rather than inorganic acid sulfate soils.

Care will be taken to enhance and expand the core habitat areas and to protect the water quality and hydrological regime there and in the SEPP14 wetland areas.

Existing development
The site has been selectively cleared. A large portion of the site was used as a pine plantation which has recently been harvested and removed. There are a number of dams, dwellings and farm sheds on the subject land.

Table 10.4.2.3 Pollutant Export Parameters (Log_{10} values, from Tables 3.8 and 3.9 in the WbD MUSIC Modelling Guidelines)

Land use	Parameter	Suspended Sediment		Total Nitrogen		Total Phosphorus	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Forest	Mean	0.511	1.900	-0.590	-0.075	-1.790	-1.100
	Std Deviation	0.280	0.200	0.220	0.240	0.280	0.220
Rural	Mean	0.530	2.260	-0.520	0.320	-1.540	-0.560
	Std Deviation	0.240	0.510	0.390	0.300	0.380	0.280
Urban Road	Mean	1.000	2.430	0.200	0.260	-0.970	-0.300
	Std Deviation	0.340	0.390	0.200	0.230	0.310	0.310
Urban Roof	Mean	N/A	1.300	N/A	0.260	N/A	-0.890
	Std Deviation	N/A	0.390	N/A	0.230	N/A	0.310
Urban Balance	Mean	1.000	2.180	0.200	0.260	-0.970	-0.470
	Std Deviation	0.340	0.390	0.200	0.230	0.310	0.310

Proposed development

The present application is for approval for the following elements, comprising the amended Stage 1 Project Application:

- Subdivision to create new lots for future development;
    - Bulk earthworks across the site;
    - Road works comprising:
        - construction of the entrance road into the site and associated intersection works on Tweed Coast Road;
        - alignment and construction of the proposed Kings Forest Parkway from Tweed Coast Road via Precincts 4 and 5 through to the western precincts; and
        - alignment and part construction of two proposed roads through SEPP 14 areas to access the southern precincts;
- Development of 2,036 m^2 of floor space for rural supplies development and access arrangements within Precinct 1;
- Construction of subdivision and infrastructure works along the Kings Forest Parkway and within Precincts 1 and 5;
- The Plan of Development for Precinct 5.

The total area of the proposed development included in the modelling within Precinct 5, as shown on Drawing No. 10927-303 is approximately 45.16ha. This area is inclusive of a parcel of land to the north of the site allocated for the construction of a proposed school. This area is not included within the Precinct 5 subdivision boundary, however, stormwater runoff generated from this area has been incorporated into the stormwater treatment train due to a shared catchment and drainage configuration.

Precinct 5 is consistent with the Kings Forest Concept Plan that proposes the creation of a residential community inclusive of associated educational, social, commercial, sporting and recreational amenities. The concept plan also includes substantial areas of open space that would provide substantial riparian buffer areas to the SEPP14 wetlands, Cudgen Creek and Cudgen Lake.

The proposed development of Precinct 5 would comprise the construction and/or installation of the following components:

- bulk earthworks for future development areas (which would be revegetated or otherwise stabilised)
- site earthworks;
- roads and other services;
- stormwater drains, swales and retention and detention basins;
- sewer reticulation mains;
- water reticulation mains;
- underground electricity distribution cables;
- telecommunication cables;
- dwellings; and
- landscaping.

Once the development has been completed, all disturbed portions of the site will be rehabilitated or covered by some form of improvement protecting the soils from erosion, hence minimising the transport of suspended solids from the site. These improvements will include structures, paved areas, lawns and landscaping.

Catchment description

A review of aerial photographs of the site, confirmed by site inspection, indicates the site has been severely disturbed by previous clearing, agricultural use, grazing and silvicultural activities. The proposed park areas within the modeled catchments which represent the site in its present state have therefore been represented in the MUSIC model by the rural land use.

A plan showing indicative catchment boundaries for the site and its surrounds is given in Drawing No. 10927-304.

Generally the ‘urban’ land use has been used to represent roads, driveways and pathways, the building envelopes and surrounds. This land use has been split into ‘Roof’, ‘Road’ and ‘Balance’ areas as required by the WbD MUSIC Modelling Guidelines (2010).

The rural land use has been used to represent the open space areas, the impervious area of which has been set to zero.

The areas of the various land uses included in the MUSIC model to represent the site when fully developed are shown in Table 10.4.3.1.

Table 10.4.3.1 Developed site MUSIC catchment characteristics

MUSIC catchment	Rural Area (ha)	Urban Area (ha)	Total Area (ha)
1a	1.281	6.339	7.620
1b	0.000	2.150	2.150
1c	0.000	3.410	3.410
1d	1.250	19.80	21.05
1e	0.000	3.620	3.620
1f	0.000	0.250	0.250
C1 (School)	3.530	3.530	7.060

The estimated impervious area and effective area fraction impervious for the urban MUSIC catchments are set out in Table 10.4.3.2.

10.4.4 Water Quality Objectives (WQOs)

The WQOs for the site runoff during the operational phase of the development have been based on the load reduction targets identified in Section 1.5 of the WSUD Technical Design Guidelines (2006). These sediment and nutrient load reduction targets are detailed in Table 10.4.4.1.

Table 10.4.4.1 Developed Treated Case Load Reduction Targets

	Suspended Solids	Total Phosphorus	Total Nitrogen
Target	80%	60%	45%

Descriptions of the catchments before and after completion of the development are included in Section 10.4.3. Details of the stormwater treatment methods recommended and the results of the MUSIC modelling are provided in Section 10.5.

10.4.5 Stormwater quality assessment prescriptive approach

Tweed Shire Council encourages developers to adopt the principles of Integrated Water Cycle Management (IWCM) where practical. Council also encourages implementation of Water Sensitive Urban Design (WSUD) and provides a range of options for managing stormwater quality in Table 7.11-WS of its 'Development Design Specification D7'. A range of options were discussed in the IWCM Concept Plan prepared by G&S (*'Integrated Water Cycle Management Strategy, Kings Forest Concept Plan', Dec. 2008*), The selected IWCM strategy for Precinct 5 (as reported in Section 10.3.3 of this report) includes rainwater storage tanks on each allotment, the implementation of BASIX requirements and the inclusion of three star WELS rated fixtures in all dwellings, and bioretention swales and basins to reduce nutrient and pollutant loads on the receiving water bodies.

Table 10.4.3.2 Urban land use split details

MUSIC catchment		Area (ha)	Imperv %
1a	Roof	0.663	100%
	Road	3.837	60%
	Balance	1.178	30%
1b	Roof	N/A	N/A
	Road	1.093	60%
	Balance	1.057	30%
1c	Roof	0.625	100%
	Road	0.466	60%
	Balance	2.319	30%
1d	Roof	6.510	100%
	Road	3.574	60%
	Balance	9.716	30%
1e	Roof	1.075	100%
	Road	2.122	60%
	Balance	0.423	30%
1f	Roof	N/A	N/A
	Road	0.024	60%
	Balance	0.226	30%
C1	Roof	2.118	100%
	Road	N/A	N/A
	Balance	1.412	30%
Total		38.47	-

Indicative stormwater management areas for the site are shown on Drawing No. 10927-304.

10.4.6 Management instruments - coastal lakes, rivers and catchments

The Integrated Water Cycle Management Strategy (IWCMS) described above demonstrates that water quality objectives can be achieved with indicative locations for devices shown on Drawing No 10927-305.

This IWCMP assesses the proposed stormwater quality treatment train for Precincts 1 & 5 where detailed design and the subdivision layout is available. Future precincts, stages and roads in the balance of the site, will require detailed design works to be completed. Should insufficient water quality treatment area be available to achieve the water quality objectives, then development land would be consumed to:

- provide sufficient treatment area; and
- reduce the pollutant load.

Sufficient area is available for these purposes. Likewise, with stormwater conveyance detention, recharge and/or discharge, land would be consumed to ensure that any upstream or downstream impacts can be managed.

Coastal Lake Assessment Model
The Coastal Lake Assessment Model (CLAM) is addressed by the approved Concept Plan which effectively prevents both stormwater impacts and public access to the lake. The current drainage arrangements ensure that the site is almost wholly drained to the north and east rather than south towards the lake.

The Erosion and Sediment Control Plan, Stormwater Management Plan and Overall Management Plan contained within the Kings Forest Plan of Management, which forms a component of the Preferred Project Application extensively detail the construction and operational phase provisions that will ensure any influence on the lake's water quality is benign. The extent of the ecological buffer to the lake boundary will ensure that direct impacts within the lake's catchment is either prevented or fully ameliorated.

With respect to the prevention of public access to the lake and development within the lake's catchment, this is dealt with by others. However, from a water quality perspective, it is worth noting that the aims and objectives of the CLAM process have been met by the concept plan and in turn the Preferred Project Application.

Statement of Intent for the Coastal Lakes of New South Wales (February 2003)
The Statement of Intent for the Coastal Lakes of New South Wales (February 2003) documents the Government's commitment to the Coastal Lakes Strategy. The strategy describes a process by which coastal lakes need to be assessed for their current environmental condition and carefully managed to ensure potentially detrimental impacts are avoided and ongoing improvements are realised, primarily via the preparation and implementation of Coastal Lake Sustainability Assessment and Management Plans (SAMPs). Responsibility for this process, which is currently in train, lies with the New South Wales State Government, statutory authorities and local councils, however input is required from a diverse range of stakeholders.

The Statement of Intent does not, of itself, establish assessment criteria against which proponents must assess their proposals. We note that a SAMP has not yet been prepared for the Cudgen Lake. The Cudgen CLAM was prepared in part to support the preparation of the SAMP.

As discussed above, the stormwater concept for the site is such that impacts from the development to the Cudgen Lake will be avoided. Accordingly the Cudgen Lake CLAM will not need to be amended as a result of development in accordance with the Kings Forest Concept Plan and the Stage 1 Preferred Project Application.

Northern Rivers Catchment Action Plan
The Northern Rivers Catchment Action Plan adopts the preparation of SAMPs as the mechanism for meeting its stated target of protecting and enhancing the values of estuaries and coastal lakes. The Northern Rivers Catchment Action Plan does not establish assessment criteria against which proponents must assess their proposals and defers the implementation of priority actions until after the preparation of management plans.

Water quality objectives have been identified and interim performance criteria have been

established based on Tweed Shire Council's water quality monitoring database. Additional data will be collected prior to works proposed under the Preferred Project Application to ensure that sufficient baseline data is available to facilitate the identification of impacts resulting form the proposed works.

10.5 Stormwater quality assessment modelling

10.5.1 Stage 1 development area

A detailed layout has been prepared for the Precinct 5 development area that comprises 383 lots (yielding approximately 436 dwelling units).

During the design process, the stormwater treatment train options have been refined to suit the opportunities and constraints presented by the site. In particular, the low relief, sandy soils and proximity of the ground water have been carefully considered in the design of the preferred stormwater management system.

Details and assessment of the preferred stormwater management system are presented in the following sections.

Details of the MUSIC modelling software, the input parameters and the catchments have been provided in sections 10.4.1, 10.4.2 and 10.4.3 respectively.

Base Case
As described in Section 10.4, the Base Case has been represented by the 'Rural' land use in the model.

Table 10.5.1.1 presents the average annual runoff volumes and quantities of suspended sediment, nitrogen and phosphorus predicted to be exported from Precinct 5 of the project (45.16ha) in its undeveloped state.

Table 10.5.1.1 Base Case average annual loads

Runoff (ML/year)	Suspended Sediment (kg/year)	Total Nitrogen (kg/year)	Total Phosphorus (kg/year)
346	14,800	818	107

Developed Untreated Case
The same areas as above were modelled under the same rainfall conditions in a developed state to allow a comparison with the Base Case.

The results of the Untreated Case modelling are shown in Table 10.5.1.2.

Table 10.5.1.2 Developed Untreated Case average annual loads

Runoff (ML/year)	Suspended Sediment (kg/year)	Total Nitrogen (kg/year)	Total Phosphorus (kg/year)
510	103,000	1,060	191

The table above demonstrates the changes in runoff and pollutants that are likely to occur if the development was completed without any stormwater management or treatment measures.

These results indicate that the annual volumetric runoff coefficient for the project is 0.67. The estimated volumetric runoff coefficient (using the procedures provided in Section 2.2 of Cooperative Research Centre for Catchment Hydrology Report 04/8 '*Stormwater flow and quality, and the effectiveness of non-proprietary stormwater treatment measures – a review and gap analysis*' Fletcher *et al* December 2004) is 0.61. This variation is considered acceptable given that the runoff parameters are not calibrated for this site.

Developed Treated Case
The same areas as above were modelled under the same rainfall conditions in a developed state with treatment measures included. In terms of stormwater treatment options, the topography and site soils are the limiting factors. After careful consideration of the design and operating requirements of each management measure, and the constraints imposed by site conditions such as soil type and permeability and slopes, we have selected the treatment trains described in the following sections.

The proposed permanent treatment measures included in the modelling are shown on Drawing No 10927-305 and include:

- rainwater tanks
- bioretention basins

- bioretention swales
- swales/vegetative filter strips, and
- various pre-treatment devices

These treatment measures are described in further detail below.

Rainwater tanks
We have assumed that one or more eligible rainwater storage tanks as defined in TSC's *'Rainwater Tanks Policy'* having a total minimum capacity as shown in Table 10.5.1.3 would be installed by the land owners or builders on each lot to capture runoff from the roof areas in accordance with the State Government's and Council's requirements.

Table 10.5.1.3 Rainwater storage tank capacity to be provided

Development	Tank capacity required
Detached dwellings on lots	5,000L
Attached dwellings & units	3,000L

It is expected that the tanks would be connected to the reticulated drinking water supply system for top-up purposes and that the water would be used for flushing toilets, laundry cold water, outdoor uses and swimming pool top-up. Accordingly a first flush diversion device or filtration unit should be installed in accordance with Council's policy.

Each tank's performance has been assessed using a model that calculates the amount of rainfall captured from the roof area, the amount of runoff, and the amount of water to be drawn from the mains water supply. The impact of the tank on the volume of runoff and pollutant loads has been assessed using the MUSIC model.

The properties of the rainwater tanks (combined together as one node per catchment) used in the modelling are shown in Appendix 4.

Bioretention basins and bioretention swales

The bioretention systems would be designed in accordance with QUDM and the Healthy Waterways, WSUD Guidelines.[17]

It is envisaged that these devices would generally be dry. However during (and for a short period after) wet weather, the they may contain water to a depth of 400mm. Where the system is not required to perform a peak flow detention function, a high flow bypass for flows in excess of $Q3_{months}$ would be installed. A combination of weir and pipe outlets would be provided to suit the particular performance requirements of each device.

The floor of the basin would have a minimum grade of 1% towards a low point that would be additionally drained by a system of subsurface perforated drains at 1.5m maximum spacings. This will minimise the occurrence of boggy areas and ensure that the stored water is released within 36 hours.

A low flow drainage system will be provided in the bioretention systems to ensure that water is drained from the basin efficiently. The filter media, transition layer (if required) and the drainage layer materials in the basin would be in accordance with the details shown on Drawing No. 10927-307.

Side slopes of the embankments for the bioretention basins would generally be no steeper than 1 in 4 to facilitate mowing. However, in some situations, slopes may be steeper provided they are retained and landscaped appropriately. The weir width and elevation and the freeboard of the perimeter bunds would be designed to accommodate the required detention storage to a maximum combined total water depth of 1.5m.

Operating characteristics of the basins used in the MUSIC modelling are set out in Appendix 4.

It is intended that the bioretention basins would be landscaped and planted out as 'rain gardens', rather than simply topsoiled and turfed. Species used would be selected from the list of approved species included in Healthy Waterways, WSUD Guidelines Appendix A, Table A1. Preferably,

[17] Healthy Waterways, 2006, Water Sensitive Urban Design Technical Design Guidelines for South East Queensland, Version 1, June 2006, Brisbane.

plants endemic to the area would be used. The landscape architects would provide details of the plant species selection, size and spacing in a landscape plan to be submitted as part of an application for construction certificate (landscaping) approval.

Care would be taken to protect the basin filter media from excessive sediment loads during the construction (including house construction) phase. Appropriate procedures are described in the separate G&S report titled '*Stormwater Management Plan, Kings Forest Stage 1, Project Application, Kings Forest, New South Wales*' (June 2011).

Vegetated filter strips
It is intended that a continuous vegetative filter strip would be constructed along the eastern edge of the proposed development. The vegetated filters are planted with suitable native vegetation to treat shallow overland flow. The flow entering the vegetated buffer zone should be evenly distributed as sheet flow across its upstream end.

The properties adopted for modelling are given in Table 10.5.1.4.

Table 10.5.1.4 Modelled vegetated filter characteristics

Swale No.	**1C**	**1F**
Catchment No.	1c	1f
Area (ha)	3.41	0.254
Inlet Properties		
Low Flow Bypass (m^3/s)	100	100
Storage Properties		
Length (m)	285.0	35.0
Bed slope (%)	0.20	0.20
Base width (m)	10.0	10.0
Top width (m)	12.0	12.0
Depth (m)	0.30	0.30
Vegetation height (m)	0.10	0.10
Seepage loss (mm/hr)	160.0	160.0

Gross Pollutant Traps (GPTs)
GPTs will be installed to treat the stormwater from catchments 1d and 1b. These have been incorporated to provide additional sediment load reduction from stormwater runoff from the aforementioned site catchments.

A GPT is generally defined as a sediment trap incorporating a litter or trash rack. A GPT has the ability to remove sediment, litter and hydrocarbons. While the published literature is quite clear about what comprises a GPT, the term is widely used to encompass a broad range of proprietary devices such as CSR Hume's Humeceptor and Litter Guard, Rocla's Downstream Defender, and Ecosol's various units to name but a few.

The GPT may be a proprietary make (having performance characteristics similar to the Fox Environmental BGPCT, Ecosol 4000 Series or CDS units) or purposefully designed and built to suit the particular conditions.

Pre-treatment measures
Additional pre-treatment measures are required to remove coarse pollutants upstream of the bioretention basins. These devices, which have not been included in the MUSIC modeling, are described briefly herein.

Litter racks will be installed at the outlets of the drainage system to remove litter and other large debris (leaves/branches etc.) to protect the treatment devices downstream. Details of the location and specifications for these devices will be included in the Detailed Stormwater Management Plans.

A coarse sediment forebay is to be provided at each inlet to a bioretention basin. These are to be designed in accordance with the requirements of the Healthy Waterways Technical Design Guidelines. Details are to be provided in the Detailed Stormwater Management Plans to be submitted with the Operational Works package.

Additional Parameters
It should be noted that the final choice of management measures used, their location and size will be subject to detailed survey and design.

The retention of suspended sediment and nutrients is generally calculated by MUSIC using the default parameters of the exponential decay functions for each pollutant.

MUSIC Modelling Results

The modelling results for the development with the recommended water quality management measures in place are shown in Table 10.5.1.5.

The layout of the MUSIC model used for this assessment is included in Appendix 3. The estimated average annual pollutant loads in the stormwater runoff before and after completion of the proposed development, including the proposed treatment measures were compared. This comparison indicates that the proposed treatment measures have the capacity to reduce the average annual suspended sediment, total nitrogen and total phosphorus loads to levels below those from the present land use.

Table 10.5.1.5 Developed WSUD treated case average annual loads

Runoff (ML/year)	Suspended Sediment (kg/year)	Total Nitrogen (kg/year)	Total Phosphorus (kg/year)
444	16,600	557	65.9

In addition to providing a net decrease in pollutant loads discharged from the site from the existing 'base case', the proposed treatment train was found to meet the pollutant load reduction targets specified in the Healthy Waterways Technical Guidelines, Section 1.5. Summaries of the modelling results are presented in Table 10.5.1.6.

Table 10.5.1.6 Average annual load summary

Case	SS	TN	TP
Average annual loads (kg/ha)			
Base	118,000	818	107
Treated	16,600	557	65.9
Change	-85.9%	-31.9%	-38.4%
Developed	103,000	1,060	191
Treated	16,600	557	65.9
Change	-83.9%	-47.6%	-65.6%
Target	-80.0%	-45.0%	-60.0%
Water quality results mg/L			
Treated	2.76	0.664	0.038
Target	6.0	0.75	0.050

The modelling results show that the widely adopted best practice pollutant load reduction targets would be achieved.

As requested in DGR item 7.3 water quality results have been compared with appropriate water quality objectives described in Section 10.2 of this report. In this instance it is considered that the relevant water quality objectives are those specified in the ANZECC 2000 guidelines for natural rivers and streams[18]. As ANZECC provides no recommendation for suspended solids, a suitable target has been sourced from '*Queensland Water Quality Guidelines, 2007*' Table 2.5.1.1 for natural rivers and streams. The modelling results for a flow-based sub-sample as shown in Table 10.5.1.6 indicate that the quality of the runoff would be acceptable.

Stormwater treatment with respect to additional pollutants may require refinement on a location specific basis, depending on the particular sensitivity of individual receiving environments. For example, the interception of any groundwater would require the treatment device to be lined, specific ecosystems may require additional treatment or flow adjustment and individual species may require relocation. Such requirements will need to be met at the detailed design stage for each device.

One of the future options, west of Precinct 4, is to partially treat the urban stormwater using GPTs, before diffusely discharge the stormwater into the SEPP 14 (the holocene organosols). This could have a number of benefits;

a. The frog core breeding areas within the pleistocene podosols would be effectively protected from alkaline waters associated with urban development.

b. The rehabilitation and enhancement of the freshwater wetlands within the SEPP14 organosol soils would be improved with the use of the stormwater.

c. The (generally) alkaline stormwaters would reduce any effects of the identified potential acid sulfate soils within the organosols.

[18] ANZECC (2000) Guidelines for Fresh and Marine Water Quality – Aquatic Ecosystems. Australian Govt.

Such measures would be the subject of detailed studies and discussion with TSC and the relevant Statutory Authorities. Given that Precinct 4 is in the future development area, this could involve small 'proof of concept' trial areas as demonstration plots. These would be the subjects of future approvals.

10.5.2 Commercial site

This site lies to the east of the Tweed Coast Road and the conceptual layout of the proposed development is shown on Drawing No 10927-306.

It is intended that stormwater runoff from this part of the development would be treated before release by means of a treatment train that complies with the requirements of TSC's Development Design Specification D7, Stormwater Quality. The proposed development occupies less than 5ha of the site, thus it is classified as a small development. Therefore a suitable gross pollutant trap would be installed to capture sediment and hydrocarbons from the paved areas. It is also intended that rainwater storage tanks would be provided generally in accordance with Council's Rainwater Tank Policy and that the stored water would be used for toilet flushing and external uses.

10.5.3 Bulk earthworks areas

These are areas for future development that include;

- the future golf course area; and
- the balance of the site to the west of the entry road.

The current project application includes an application to undertake bulk earthworks in these areas. Further development in these areas will be the subject of future project development applications. Construction phase erosion and sediment control measures would be installed to protect the water quality in the surrounding environment during the bulk earthworks construction phase. Refer to the Erosion and Sediment Control report prepared by G&S. These areas would be revegetated or otherwise stabilised on completion of the earthworks. Accordingly, permanent stormwater management devices are not required for this phase of the works as details would be provided in future development applications

10.6 Conclusions

10.6.1 Erosion and sediment control

A separate erosion and sediment control plan has been prepared by Gilbert & Sutherland for submission as part of this project application. Details of temporary erosion and sediment controls for the areas to be disturbed are shown on drawings that have been prepared by Mortons Urban Solutions and submitted for approval as part of this application. Prior to commencement of construction in any stage, erosion and sediment controls should be installed in accordance with these details.

10.6.2 IWCM strategy

A number of IWCM options were described in the Integrated Water Cycle Management Plan that was submitted in support of the Concept Plan application. These have been further investigated as described in Section 10.3.3. Investigation into other IWCM options which become apparent throughout the planning process will also be undertaken.

The IWCM approach will aim to amalgamate a number of the techniques and options identified in order to achieve the most feasible solution for management of water supply, wastewater, stormwater and groundwater resources throughout the development.

10.6.3 Water quality management

A number of stormwater management options were examined as described in Section 10.3 of this report. From these, a number of treatment devices have been selected for inclusion in this precinct. These include:

- Rainwater storage tanks on each allotment;
- Bioretention basins and bioretention swales within selected road reserves and prescribed flood mitigation zones;
- Gross pollutant traps near the discharge points of catchments 1b and 1d; and
- Vegetated filter strips along the eastern boundary of the proposed development.

Stormwater management measures should be installed as described in Section 10.5.1 and as shown on drawings numbered 10927-305 to 307. Provided the details of these devices are appropriately refined in the detailed design phase and are properly installed and maintained, the estimates detailed in Section 10.5 indicate that the quality of the stormwater runoff from the site during the operational phase can meet the stated objectives.

Careful management will be required to ensure that the projected quality levels are achieved and maintained particularly during the construction phases. These details are considered in the separate G&S report titled ‘Stormwater Management Plan, Kings Forest Stage 1, Project Application, Kings Forest, New South Wales’ (February 2011).

The developers of the structures on the individual allotments should also be encouraged to implement the principles of ‘Water Sensitive Urban Design’ in their developments to ensure a two phase treatment system is in place to complement the proposed stormwater management measures.

10.6.4 Management instruments - coastal lakes, rivers and catchments

The development proposed in this project application is consistent with the Kings Forest Concept Plan previously submitted to DOP. In terms of stormwater and water quality impacts, development in accordance with the Kings Forest Concept Plan does not conflict with the objectives and principles established by:

- the Statement of Intent for the Coastal Lakes of New South Wales (February 2003); and
- the Northern Rivers Catchment Action Plan.

Further, the Concept Plan prevents stormwater impacts on the Cudgen Lake and restricts public access to the waterbody. Accordingly the Cudgen Coastal Lake Assessment Model (CLAM) will not require amendment as a result of development of Kings Forest Stage 1 in accordance with the Concept Plan.

10.7 Appendix 1 – Drawings

400 800 1200 1600
metres

SCALE

ORIENTATION
NORTH

LEGEND

Kings Forest Development boundary

Precinct 5 boundary

SOURCES

Image base: Google Earth Pro, May 2010

Proposed lots: RPS, 'Precinct 5 - Concept Layout', 17 August 2012

Proposed development footprint: Moretons, 10 August 2012

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PROJECT
KINGS FOREST

CLIENT
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DRAWING
STORMWATER MANAGEMENT PRECINCT 5 SITE LOCATION

SCALE	DRAWN	CHECKED
1:32 000@A3	DJY	NTZ
DATE	**PROJECT NO**	**DRAWING NO**
27/07/2012	10927	301

ROBINA
PO Box 4115 Robina QLD4230
Email robina@access.gs
07 5578 9944
www.access.gs

250 500 750 1000 1250
SCALE metres

ORIENTATION
NORTH

LEGEND

Sampling location

Site boundary

SOURCES

Image base: Google Earth Pro 2012

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DRAWING
TWEED SHIRE COUNCIL
WATER QUALITY SAMPLING
LOCATIONS

SCALE	DRAWN	CHECKED
1:25 000@A3	KAB	NTZ
DATE	**PROJECT NO**	**DRAWING NO**
07/09/2012	10927	302

50 100 150 200 250
SCALE metres

ORIENTATION
NORTH

LEGEND

- Proposed stormwater drainage
- Proposed lot boundaries
- Precinct 5 boundary
- Kings Forest Development boundary

SOURCES

Image base: NearMap, June 2012
Proposed lots: RPS, 'Precinct 5 - Concept Layout', 17 August 2012
Proposed development footprint: Moretons, 10 August 2012

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DRAWING
STORMWATER MANAGEMENT PRECINCT 5 PROPOSED DEVELOPMENT PLAN

SCALE	DRAWN	CHECKED
1:5 000@A3	DJY	NTZ
DATE	**PROJECT NO**	**DRAWING NO**
07/09/2012	10927	303

50 100 150 200 250
SCALE metres

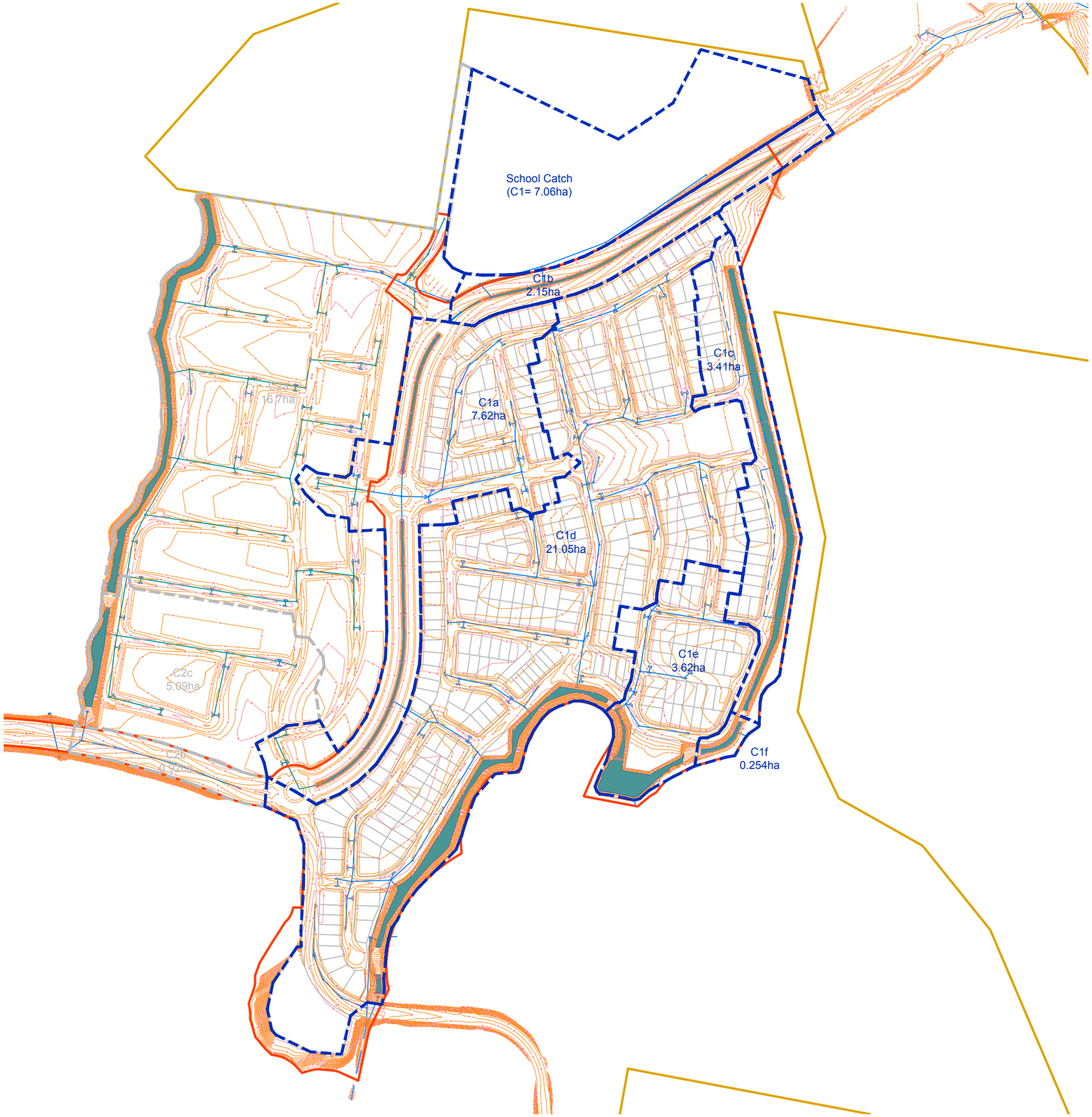
ORIENTATION
NORTH

LEGEND

- MUSIC catchment boundary
- Proposed stormwater drainage
- Proposed lot boundaries
- Precinct 5 boundary
- Kings Forest Development boundary

SOURCES

Image base: NearMap, June 2012
Proposed lots: RPS, 'Precinct 5 - Concept Layout', 17 August 2012
Proposed development footprint: Moretons, 10 August 2012



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DRAWING
STORMWATER MANAGEMENT PRECINCT 5 PROPOSED MUSIC CATCHMENT PLAN

SCALE	DRAWN	CHECKED
1:5 000@A3	DJY	NTZ
DATE	**PROJECT NO**	**DRAWING NO**
07/09/2012	10927	304

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PO Box 4115 Robina QLD4230
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50 100 150 200 250
SCALE metres

ORIENTATION
NORTH

LEGEND

- Proposed bioretention basin or bioretention swale
- Proposed vegetative filter strip
- MUSIC catchment boundary
- Proposed stormwater drainage
- Proposed lot boundaries
- Precinct 5 boundary
- Kings Forest Development boundary

SOURCES

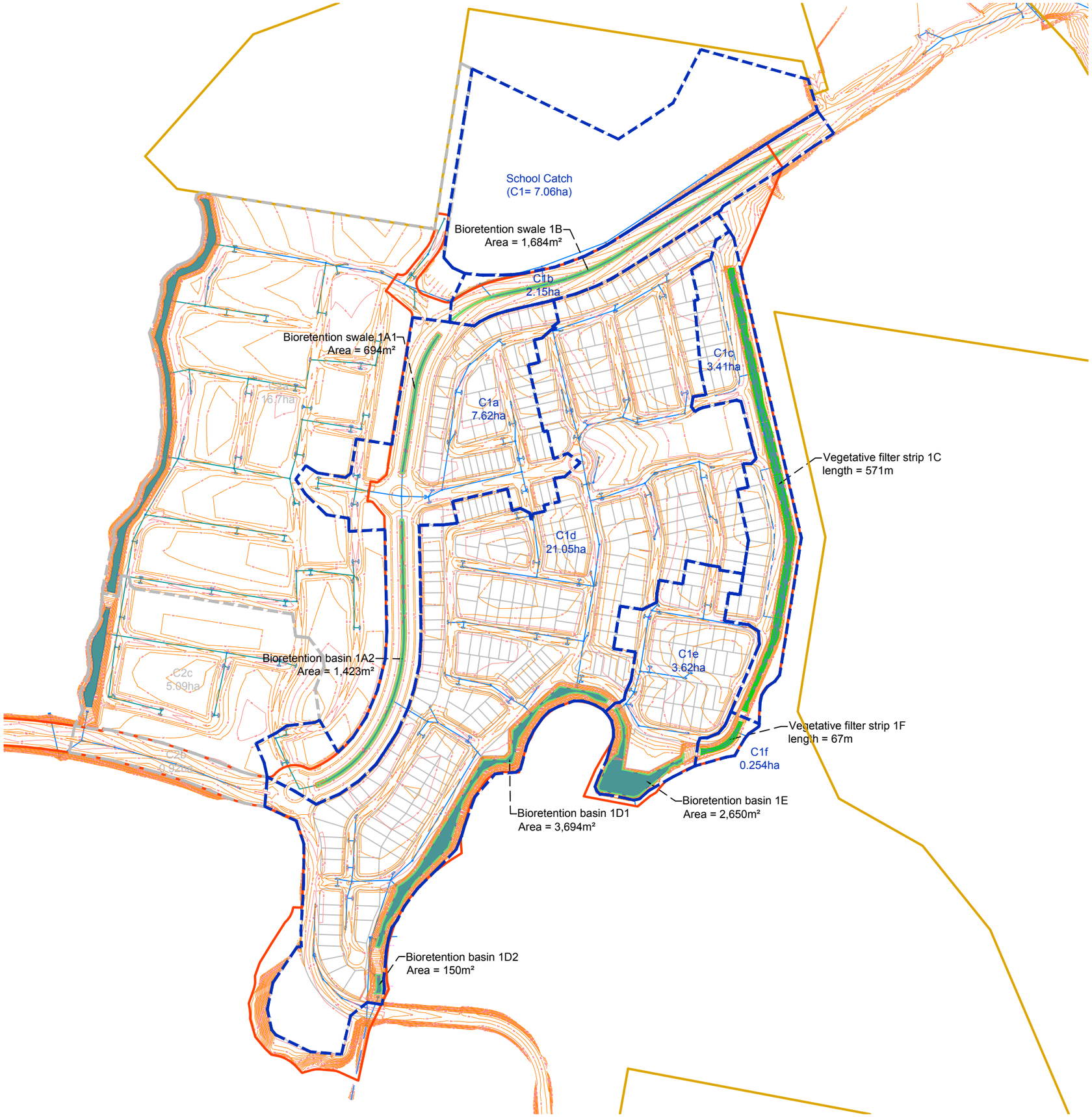
Image base: NearMap, June 2012

Proposed lots: RPS, 'Precinct 5 - Concept Layout', 17 August 2012

Proposed development footprint: Moretons, 10 August 2012

NOTES

Other treatment devices:
GPTs will be included at suitable locations near the outlets points of catchments 1b and 1d prior to discharge from site.



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DRAWING
STORMWATER MANAGEMENT PRECINCT 5 PROPOSED MUSIC TREATMENT DEVICES

SCALE	DRAWN	CHECKED
1:5 000@A3	DJY	NTZ
DATE	**PROJECT NO**	**DRAWING NO**
07/09/2012	10927	305

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50 100 150 200 250
SCALE metres

ORIENTATION
NORTH

LEGEND

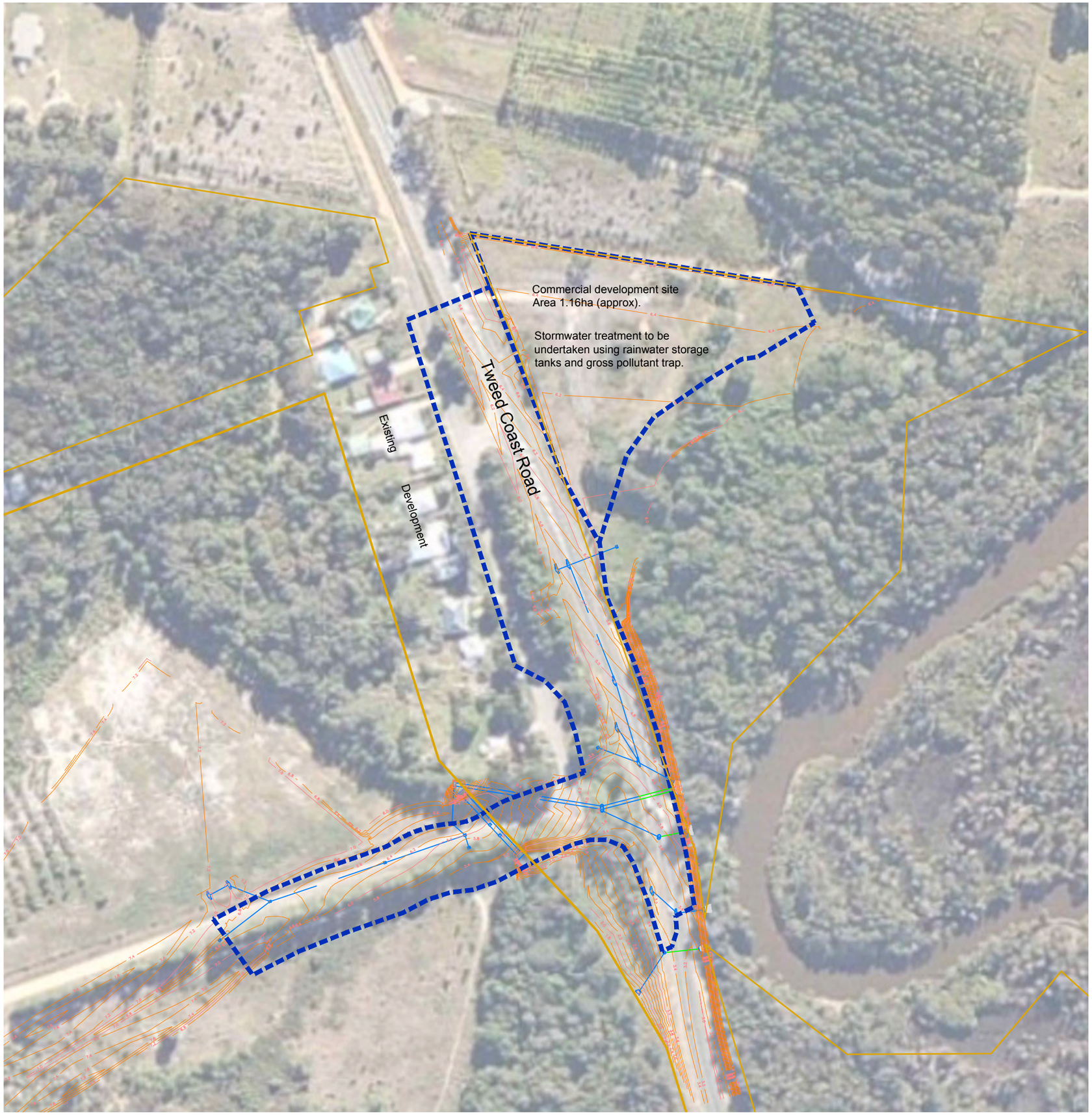
- Catchment boundary
- Proposed stormwater drainage
- Precinct 5 boundary
- Kings Forest Development boundary

SOURCES

Image base: NearMap, June 2012

Proposed lots: RPS, 'Precinct 5 - Concept Layout', 17 August 2012

Proposed development footprint: Moretons, 10 August 2012



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DRAWING
STORMWATER MANAGEMENT PRECINCT 5 PROPOSED COMMERCIAL DEVELOPMENT AREA

SCALE	DRAWN	CHECKED
1:2 000@A3	DJY	NTZ
DATE	**PROJECT NO**	**DRAWING NO**
07/09/2012	10927	306

NOT TO SCALE

ORIENTATION
NORTH

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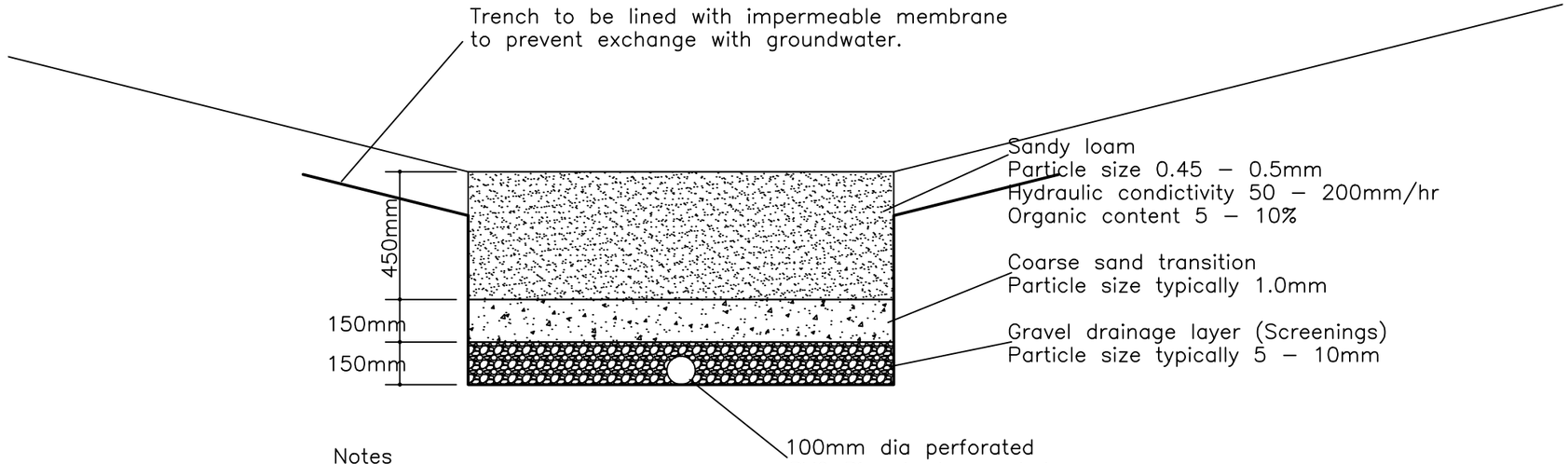

Notes
Filter conductivity to be measured in accordance with AS4419:2003.
Filter organic content to be measured in accordance with AS1289 4.1.1.

BIORETENTION BASIN/TRENCH FILTER ZONE DETAIL

Not to Scale

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PROJECT
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DRAWING
STORMWATER MANAGEMENT PRECINCT 5 BIORETENTION FILTER DETAIL

SCALE	DRAWN	CHECKED
NTS	DJY	NTZ
DATE	PROJECT NO	DRAWING NO
07/09/2012	10927	307

10.8 Appendix 2 – TSC water quality results

Table A1.1 Complete of water quality conditions at CGN1, as recorded by TSC

Date	pH	Turbidity	Suspended solids	Dissolved oxygen	Chlorophyll a	Salinity	Temperature	Total aluminium	Total iron	Total nitrogen	Total phosphorous	Chloride	Sulphate
Units	pH	NTU	mg/L	mg/L	µg/L	ppk	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
16/06/08	7.5	--	5.8	6.4	0.5	21.6	19.9	--	--	0.44	0.20	--	--
11/08/08	8.3	3.5	5.1	8.8	<0.4	17.1	16.8	0.16	0.13	0.39	0.05	10,060	1,100
1/10/08	8.3	1.5	20	7	<0.4	32.1	22.6	0.17	<0.01	0.27	0.02	25,000	2,792
1/12/08	8.1	1.6	3.7	5.9	1.8	35.4	23.3	0.20	0.04	0.10	0.01	20,900	2,401
23/02/09	6.9	5.8	7.5	5.2	2.3	11.5	28.8	0.19	0.64	0.78	<0.01	5,900	917
20/04/09	6.1	5.2	17	6.2	<0.4	8.2	22.5	0.16	2.43	0.88	<0.01	5,242	620
29/06/09	6.6	15	14	6.6	1.3	3.6	16.4	1.06	1.64	0.74	0.18	1,690	228
24/08/09	8.1	1.1	3.8	5.9	0.5	38.4	23.1	0.03	0.07	0.17	<0.05	19,300	2,692
19/10/09	8.2	1.8	20	6.1	2.1	39.3	22.9	0.04	0.07	0.12	0.05	21,000	2,175
21/12/09	8.4	0.5	2.8	6.1	0.9	41.2	24	<0.01	0.01	0.16	<0.05	20,200	2,003
22/02/10	7.5	2.1	5.6	5.2	2.7	23.7	26.4	0.08	0.1	0.56	<0.05	12,100	1,585
19/04/10	7.9	0.9	5.5	6.4	0.4	35.7	23.8	0.03	0.03	0.11	<0.05	19,850	2,657

Date	pH	Turbidity	Suspended solids	Dissolved oxygen	Chlorophyll a	Salinity	Temperature	Total aluminium	Total iron	Total nitrogen	Total phosphorous	Chloride	Sulphate
22/06/10	7.3	3	3.1	7.1	0.5	19.2	18.2	0.34	0.5	0.27	<0.05	9,350	990
23/08/10	7.4	2.8	3.7	7.3	0.6	18.7	18.2	0.40	0.12	0.33	<0.05	10,050	1,197
18/10/10	6.2	17	6.5	6.7	4.2	1	20.3	0.81	1.48	0.60	0.05	420	60
20/12/10	7.9	2.7	2.8	4.2	1.9	30.2	25.1	<0.01	0.18	0.37	<0.05	17,300	4,228
20/12/10	8	2.6	2.4	4.2	1	30.4	25.1	<0.01	0.18	0.42	<0.05	17,300	3,161
21/02/11	8.6	0.7	6.2	5.6	1	39	22.6	0.03	0.02	0.11	<0.05	20,650	1,268
21/02/11	8.6	0.8	6.6	5.7	0.9	38.9	22.5	0.04	0.03	0.13	<0.05	21,200	1,290
18/04/11	8.1	1.1	4.8	7	1	35.1	22.3	0.07	0.05	0.11	<0.05	20,200	1,772
18/04/11	8.1	1.2	4.6	6.8	1	34.7	22.2	0.08	0.06	0.11	<0.05	19,650	2,372
20/06/11	6.9	2.3	8	7.3	<0.4	20.7	17.4	0.18	0.23	0.20	<0.05	10,050	1,000
15/08/11	7.9	1.4	6.7	7.3	0.5	33.6	19.6	0.08	0.06	0.17	<0.05	18,800	1,905
17/10/11	8.1	2	12	6.7	3.6	36.2	21	0.11	0.06	0.17	<0.05	19,700	1,441
17/10/11	8.1	2.1	14	6.6	4.4	36.2	21.1	0.09	0.06	0.20	<0.05	20,000	1,339
19/12/11	7.6	4.2	7	6.9	2.2	15.6	24.9	0.17	0.29	0.36	<0.02	8,250	698
13/02/12	7.6	8.4	16	5.5	1.4	20.1	26.5	0.15	1.33	0.45	0.02	10,700	960
16/04/12	7.7	2.5	5.2	6.4	1.9	24.3	23.2	0.12	0.25	0.27	0.02	13,250	1,322

Table A1.2 Complete of water quality conditions at CGN2, as recorded by TSC

Date	pH	Turbidity	Suspended solids	Dissolved oxygen	Chlorophyll a	Salinity	Temperature	Total aluminium	Total iron	Total nitrogen	Total phosphorous	Chloride	Sulphate
Units	pH	NTU	mg/L	mg/L	µg/L	ppk	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
16/06/08	7.6	--	7.7	7.3	1.4	1.2	17.7	--	--	0.69	0.18	--	--
11/08/08	5.9	1.3	7.6	9.4	1.4	1	15.1	0.68	0.42	0.48	0.07	500	117
1/10/08	7.6	3.4	12	6.7	2.8	21	23.3	0.12	<0.01	0.48	0.01	15800	1722
1/12/08	6.1	6.5	4	5.9	0.6	2.8	26	0.53	0.76	0.66	0.02	1360	195
23/02/09	5.9	11	4.5	3.6	1.1	0.9	27.4	0.36	2.23	1.12	0.06	400	73
20/04/09	5.9	19	24	5.7	6.2	0.1	21.3	0.32	12	1.23	0.032	62	19
29/06/09	6.5	18	11	6.3	1	<0.1	15	0.23	1.64	1.02	<0.01	35	13
24/08/09	7.1	1.3	2.8	5.3	3	23.5	24.9	0.03	0.25	0.34	<0.05	12300	1614
19/10/09	7.6	1.7	12	5.5	1.6	34.9	23	0.06	0.10	0.23	0.05	17500	1781
21/12/09	7.8	1.7	2.8	5.2	1.5	34.6	25.9	0.03	0.12	0.46	<0.05	17100	1772
22/02/10	6.5	5.8	5.7	4.6	2	8.5	27.3	0.24	0.59	1.31	<0.05	4500	652
19/04/10	6.4	7.2	3.5	6.3	3.4	6.8	22.2	0.18	0.71	1.40	<0.05	3650	679
22/06/10	4.6	9.2	10	7.4	6.1	0.6	16.7	1.33	1.11	0.44	<0.05	180	72
23/08/10	5.4	5.4	8.8	7.6	4.3	1.3	17.1	2.80	0.84	0.51	<0.05	600	142

Date	pH	Turbidity	Suspended solids	Dissolved oxygen	Chlorophyll a	Salinity	Temperature	Total aluminium	Total iron	Total nitrogen	Total phosphorous	Chloride	Sulphate
18/10/10	5.4	18	8	6.3	6.2	0.2	19.4	0.72	1.61	0.50	<0.05	80	20
20/12/10	6.8	7.2	1.6	4	1.9	10	25.3	0.12	0.81	0.61	<0.05	5050	685
21/02/11	6.9	9.8	6.3	5.2	5.6	7.5	28.7	0.16	1.67	0.71	0.05	3570	388
18/04/11	7.9	5.9	8.4	6.6	13	10.6	21.1	0.26	0.73	0.47	<0.05	5500	556
20/06/11	6.5	4.3	3	7.8	0.9	0.5	14.9	0.23	0.50	0.27	<0.05	198	45
15/08/11	7.4	4.6	4	7.9	1.2	12.4	18	0.17	0.30	0.30	<0.05	6700	806
17/10/11	6.4	5.4	4.7	6.2	2	1.9	22.6	0.20	0.71	0.36	<0.05	1065	139
19/12/11	6.2	9.7	6.4	6.9	2	0.5	24	0.37	1.41	0.45	0.02	282	53
13/02/12	6.9	21	11	3.7	10	0.2	25.8	0.28	9.48	0.88	0.03	77	7.6
16/04/12	7.5	9.6	5.7	6.2	4.5	1.1	22.1	0.30	2.44	0.59	0.02	550	90

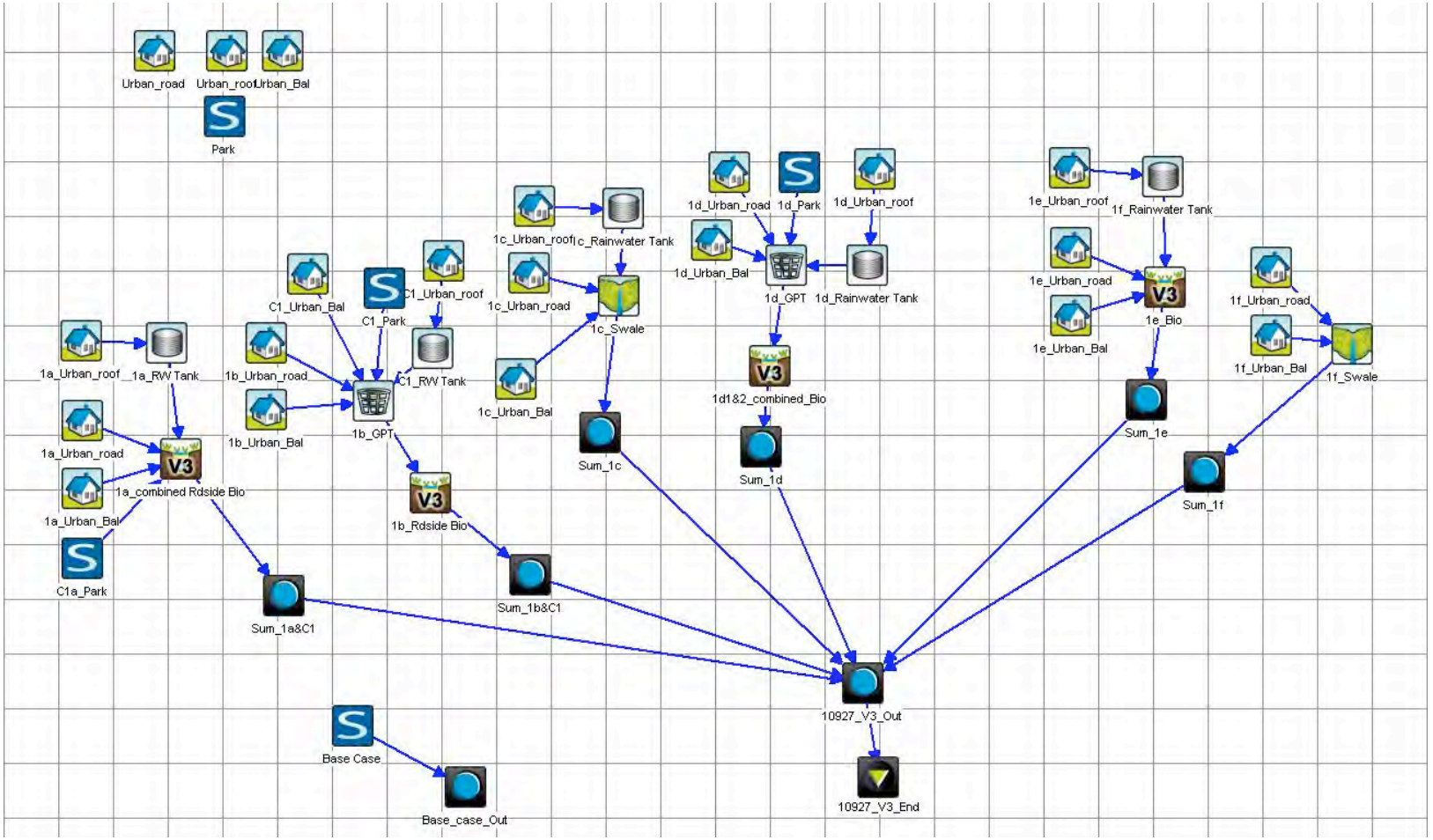
Table A1.3 Complete of water quality conditions at CGN3, as recorded by TSC

Date	pH	Turbidity	Suspended solids	Dissolved oxygen	Chlorophyll a	Salinity	Temperature	Total aluminium	Total iron	Total nitrogen	Total phosphorous	Chloride	Sulphate
Units	pH	NTU	mg/L	mg/L	µg/L	ppk	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
16/06/08	8.2	--	7.5	8.5	1.9	0.54	19.1	--	--	0.45	0.21	--	--
11/08/08	5.5	2	5.1	9.5	3.4	1.6	16.2	0.7	0.38	0.46	0.07	500	115
1/10/08	7.2	3.2	11	6.8	1.2	18.2	23.8	0.11	0.01	0.50	0.01	13,000	1633
1/12/08	5.5	6.2	5	6.4	0.9	2.8	25	0.48	0.61	0.60	<0.01	1,340	182
23/02/09	6.5	8.8	7	5.5	1.1	1.2	29.3	0.18	1.12	0.80	0.05	555	95
20/04/09	6.4	18	23	5.9	4.8	0.1	22.4	0.27	14	1.28	0.034	51	16
29/06/09	6.2	21	13	6.2	2.5	0.7	15.1	0.98	2.64	0.51	<0.05	31	13
24/08/09	6.9	1.9	6	4.9	2	18.4	24	0.04	0.37	0.43	<0.05	10,200	6
19/10/09	7.4	2	13	5.2	2.3	33.1	23.3	0.06	0.10	0.25	0.05	16,750	13
21/12/09	7.5	2	3.3	4.8	0.6	30	26.1	0.01	0.15	0.78	<0.05	14,900	3.3
22/02/10	5.1	3.3	3.6	5.4	1.3	8.6	26.5	1.81	0.47	1.30	<0.05	4,600	3.6
22/02/10	5.1	3.2	4.3	5.5	1.1	8.6	26.5	1.60	0.34	1.31	<0.05	4,450	4.3
19/04/10	7.5	4.8	4.4	7.4	6.6	5.3	22.4	0.16	0.43	1.74	<0.05	2,750	4.4
22/06/10	4.4	2.7	4	8.5	5.6	0.4	16.7	1.51	0.50	0.35	<0.05	240	4

Date	pH	Turbidity	Suspended solids	Dissolved oxygen	Chlorophyll a	Salinity	Temperature	Total aluminium	Total iron	Total nitrogen	Total phosphorous	Chloride	Sulphate
23/08/10	4.4	0.9	1.8	8.2	5.6	1.3	17.8	3.77	0.45	0.40	<0.05	615	1.8
18/10/10	5.3	16	4	6.5	9.9	0.2	20	0.77	1.35	0.40	<0.05	71	4
20/12/10	6.9	8.9	1.2	3.8	1.3	3.3	24.9	0.27	1.15	0.53	<0.05	1,635	1.2
21/02/11	6.9	11	8.3	6	8.4	2.5	28.4	0.20	2.85	0.66	<0.05	1,130	8.3
18/04/11	7.8	8	3	5.4	4.1	6	20.9	0.26	0.79	0.62	<0.05	3,200	3
20/06/11	7.3	1.9	1.6	9	2.6	0.3	15.1	0.20	0.25	0.17	<0.05	115	1.6
15/08/11	7.9	4.8	3.4	9.7	2.8	4.8	18.5	0.19	0.55	0.22	<0.05	2,620	3.4
17/10/11	6.1	4.6	4.6	7	1.8	2.2	22	0.13	0.53	0.27	<0.05	1,170	4.6

10.9 Appendix 3

10.9.1 MUSIC model arrangement



10.10 Appendix 4

10.10.1 Bioretention basin and bioretention swale characteristics

Basin No	1A1	1A2	1B	1D1	1D2	1E
Bioretention type	Swale	Basin	Swale	Basin	Basin	Basin
Catchment No.	1a	1a	1b	1d	1d	1e
Area (ha)	7.62	7.62	2.15	21.05	21.05	3.62
Inlet properties						
Low flow bypass (m^3/s)	0.0	0.0	0.0	0.0	0.0	0.0
High flow bypass (m^3/s)	100.0	100.0	100.0	100.0	100.0	100.0
Storage properties						
Extended detention depth (m)	0.40	0.40	0.40	0.40	0.30	0.30
Surface area ($m^{2)}$	694.0	1423.0	1684.0	3694.0	150.0	2650.0
Seepage loss (mm/hr)	0.0	0.0	0.0	0.0	0.0	0.0
Infiltration properties						
Filter area (m^2)	694.0	1423.0	1684.0	3694.0	150.0	2650.0
Filter depth (m)	0.5	0.5	0.5	0.5	0.5	0.5
Filter median particle dia. (mm)	0.45	0.45	0.45	0.45	0.45	0.45
Saturated hydraulic conductivity (mm/hr)	180.0	180.0	180.0	180.0	180.0	180.0
Depth below underdrain pipe (% of filter depth)	0.0	0.0	0.0	0.0	0.0	0.0
Outlet properties						
Overflow weir width (m)	2.0	2.0	20.0	20.0	20.0	20.0

10.10.2 Modeled rainwater tank characteristics (lumped per catchment)

Tank No. (as per MUSIC model)	1a	C1	1c	1d	1f
Inlet Properties					
Low Flow Bypass (m^3/s)	0.0	0.0	0.0	0.0	0.0
High Flow Bypass (m^3/s)	100.0	100.0	100.0	100.0	100.0
Storage Properties					
Volume below overflow pipe (kL)	159.00	254.16	75.00	822.00	129.0
Depth above overflow (m)	0.20	0.20	0.20	0.20	0.20
Surface area (m^2)	80.0	127.1	37.5	411.5	64.5
Outlet properties					
Overflow pipe diameter (mm)	655.0	828.0	450.0	1490.0	590.0
Re-use properties					
Use stored water for irrigation or other purpose	✓	✓	✓	✓	✓
Annual demand (kL/yr) scaled by daily PET	3,975.0	6,354.0	1,875.0	19,875.0	3,225.0
Daily demand (kL/day)	0.0	0.0	0.0	0.0	0.0
Monthly distribution of annual demand (kL/year)	0.0	0.0	0.0	0.0	0.0

10.11 Appendix 5 – Reference drawings

KINGS FOREST - PRECINCT 5

RESIDENTIAL PRODUCT MIX

TERRACES
- Build to both boundaries
- Rear loaded
- Min. Lot Size : 150m²
- Min. Frontage : 8m
- Min. depth 24m

PLEXES
- Attached Dwelling
- Front loaded parking
- Min. Lot Size : 450m²
- Min Frontage : 18m , Corner : 20m
- Min. Depth : 20m

ZERO - Lot Dwellings
- Detached Dwellings
- Build to one side boundary
- Front loaded parking
- Min. Lot Size : 240m²
- Min. Frontage : 8m with rear lane : 10m with front access, Corner : 10m with rear lane, 12m with front access
- Min. depth : 24m

TRADITIONAL Detached Dwelling
- Detached Dwelling
- Garage may Zero to side boundary
- Front loaded parking
- Min. Lot Size : 400m²
- Min. Frontage : 15m, Corner : 18m
- Min. Depth : 25m

DEVELOPMENT SUMMARY			
LOT CATEGORY	NUMBER OF ALLOTMENTS	NUMBER OF DWELLINGS	PERCENTAGE OF DWELLINGS
TOWNHOUSES	1	20	5%
TERRACES	44	44	10%
PLEXES	25	54	13%
ZERO - LOT DWELLING	192	192	44%
TRADITIONAL DETACHED DWELLINGS	121	121	28%
TOTALS	383	431	100%

LEGEND :

STAGE BOUNDARY

(P) ELECTRICAL TRANSFORMER (Pad Mount)

KINGS FOREST PARKWAY

CENTRAL PARK 1251Bm²

PARK 2500m²

590m² (Sewer Lot)

TOWNHOUSE SITE 20 Dwellings

N

CONTEXT - LOCALITY PLAN

LEDA

CLIENT	PLAN
PROJECT 28 Pty Ltd	*PRECINCT 5 - CONCEPT LAYOUT*
	DEPOT ROAD, KINGS FOREST

Level Datum	Date	17 AUGUST 2012
Level Origin	Surveyed	-
	Drafted	BJB
Data Origin (SS/DCAD)	Parish	CUDGEN
113691-bdy(12-08-16)	County	ROUS

SCALE: 1:1500 (A1) 20 0 20 40 60

REVISIONS			
No.	DETAILS	DATE	Init.
A	REVISION	13.7.12	BJB
B	REVISION	1.8.12	BJB
C	REVISION	1.8.12	BJB
D	REVISION	17.8.12	BJB
E			
F			
G			
I			

RPS Australia East Pty Ltd
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ABN 44 140 292 762
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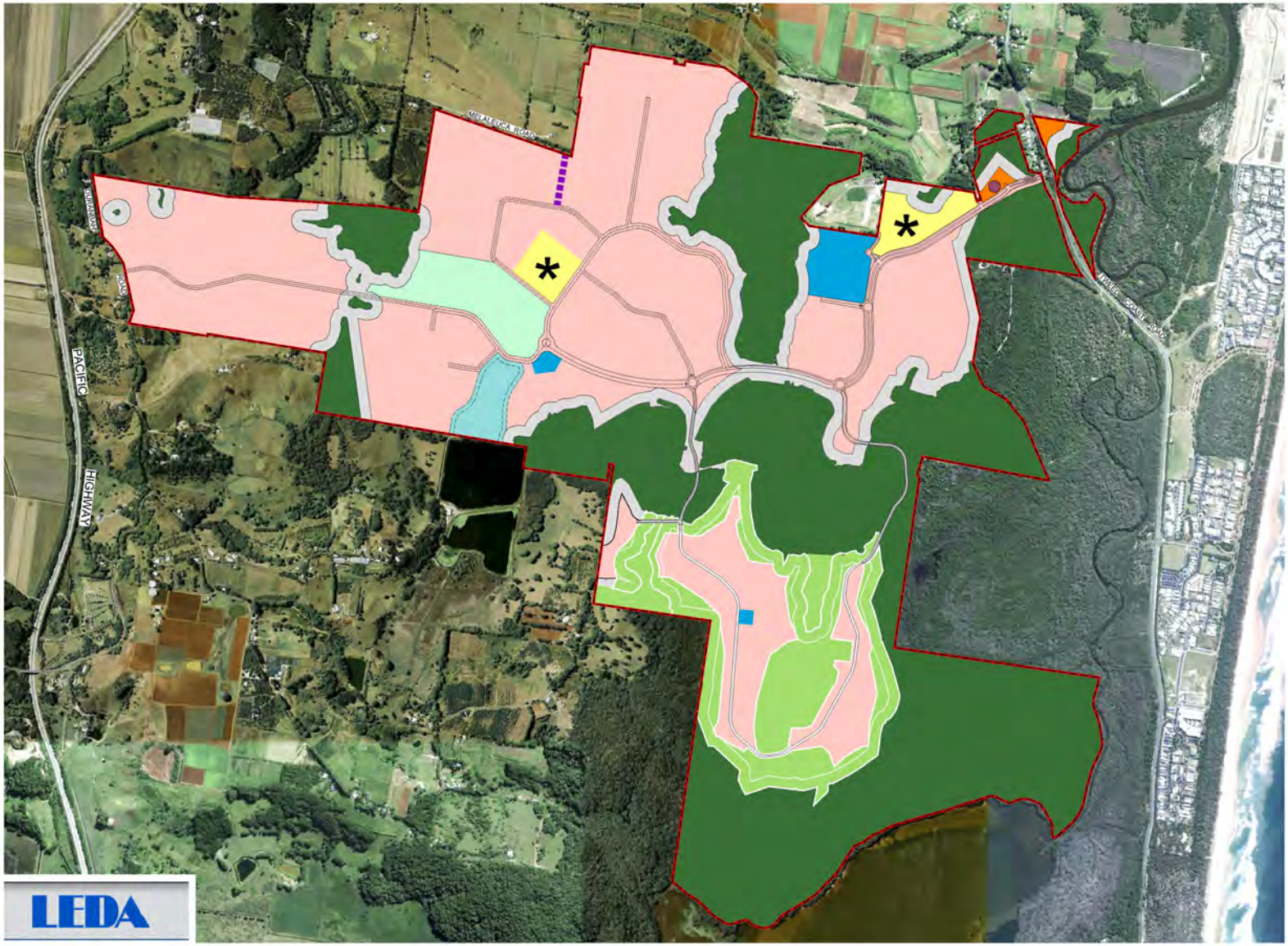
PO Box 1048 Robina DC, Qld 4226
T +61 7 555 36900
F +61 7 555 36999
W rpsgroup.com.au

Local Authority	Plan	Plan Ref	Sheet
Tweed S.C.	A1	113691-LD-1d	1 of 1

DISCLAIMER

IMPORTANT NOTE

This plan was prepared as a preliminary concept plan for planning purposes only. As such all particulars, including lot design, areas and densities, are subject to detailed survey, site investigations and to the requirements of council and any other authority which may have requirements under any relevant legislation. This note is an integral part of this plan.



TOWN CENTRE / NEIGHBOURHOOD CENTRE

RESIDENTIAL

COMMUNITY FACILITIES / EDUCATION

EMPLOYMENT LAND

STRUCTURED OPEN SPACE (ACTIVE)
(Passive open space to council standards, location subject to urban design).

ENVIRONMENTAL PROTECTION AREA
TO BE DEDICATED TO COUNCIL OR NPWS

50m ECOLOGICAL BUFFER
(Includes APZs & Roads where approved)

* STATE SCHOOL SITE

PROPOSED ZONE SUBSTATION
(Subject to County Energy final approval)

POTENTIAL ROAD CONNECTION TO MELALEUCA ROAD

PRIVATE OPEN SPACE

GOLF COURSE AREA
(Encompassing ecological buffers where indicated)

PRIVATE OPEN SPACE INCLUDING LAKE

IMPORTANT NOTE

This plan was prepared as a preliminary concept plan for planning purposes only. As such all particulars, including lot design, areas and densities, are subject to detailed survey, site investigations and to the requirements of council and any other authority which may have requirements under any relevant legislation.
This note is an integral part of this plan.

200 0 200 400 600 800

LEDA

N

CLIENT
PROJECT 28 Pty Ltd

Date	21 AUGUST 2012
Surveyed	-
Drafted	BJB
Parish	CUDGEN
County	ROUS

PLAN

KINGS FOREST
STAGE 1 PROJECT APPLICATION

REVISED CONCEPT PLAN

SCALE: 1:20000 (A3)

REVISIONS

No.	DETAILS	DATE	Init.
A	REVISION	21.8.12	BJB
B			
C			
D			
E			
F			
G			
I			

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Local Authority	DWG Ref	PLAN No.
Tweed S.C.	113691-PSP-4a(CONCEPT PLAN)	01