6.4 d Northern Precinct Stormwater Management Plan DesignFlow

Ella Bay Northern Precinct

STORMWATER MANAGEMENT PLAN
(Water Sensitive Urban Design Strategy)

DesignFlow

Prepared for Satori Resorts Ella Bay Pty Ltd

March 2011

Document Control Sheet

Report Title:	Ella Bay Northern Precinct – Stormwater Management Plan (Water Sensitive Urban Design Strategy)
Suggested Reference:	Ella Bay Northern Precinct – Stormwater Management Objectives (DesignFlow, 2009)
Version:	Final
Client:	Satori Resort Pty Ltd
Author(s):	Andrew O'Neill, Jason Sonneman, Shaun Leinster
Reviewed By:	Shaun Leinster
Approved By:	Shaun Leinster
Signed:	
Date:	29/03/2011
File Location:	S:/Projects/4049 Ella Bay
Circulation:	Electronic Copies:
	Printed Copies:

Disclaimer

This document has been prepared solely for the benefit of the client identified below, and is issued in confidence for the purposes only for which it is supplied. Unauthorised use of this document in any form whatsoever is prohibited. No liability is accepted by DesignFlow Consulting Pty Ltd, or any employee, contractor or sub-consultant of this company with respect to its use by any other person.

This disclaimer shall apply not withstanding that the document may be made available to other persons for an application for permission or approval to fulfil a legal obligation.

Potential implications of climate change
Unless expressly stated otherwise, historical climate data has been used in, or underpins, the analyses that are presented in this report. The historical climate is not necessarily a valid indicator of future climate, which may contain prolonged periods that are wetter or drier than the historical record used for this analysis. There is significant uncertainly surrounding how climate, and in particular, rainfall, will be impacted by various levels of greenhouse gas accumulation in the atmosphere. Rainfall has a much greater spatial variability than temperature and some areas are likely to become wetter whilst other areas become drier. Further to this there may be changes in the seasonality and intensity of rainfall. Such changes in climate could affect the conclusions and recommendations of this report.

Inherent natural variability in soils and plants
Where particular types of soils are recommended, such recommendations are based on information provided by soils suppliers, laboratories and published industry guidelines. There can be inconsistencies in the behaviour of soils under field conditions compared to laboratory conditions, and, for both natural and blended soils, many soils are non-homogenous and properties and behaviour can be variable. Where particular plant species have been recommended, such recommendations are based on botanical knowledge and observations of similar species growing in similar, but not identical conditions. Plants can be sensitive to subtle changes in climate, hydrology, soil and surrounding ecological conditions. Further to this, plant health is often closely linked to the level of maintenance provided. No warranty or guarantee, whether explicit or implied is made with respect to the suitability or performance of soils or plant species recommended in this report

Acknowledgements:

Table of Contents

1 INTRODUCTION

The proximity of the proposed Ella Bay development (Figure 1) to sensitive aquatic ecosystems adjacent to the site means analysis of any changes to the water cycle as a result of development must be undertaken to ensure protection of these systems. In this regard, the planning and design of the Ella Bay development will be guided by the principles of Water Sensitive Urban Design (WSUD). It is envisaged that WSUD will be used extensively to create a development zone that promotes sustainable and integrated management of land and water resources, which incorporates best practice stormwater management, water conservation/reuse and environmental protection.

Figure 1 Location and Extent of Ella Bay Development Site & Northern Precinct

1.1 THIS DOCUMENT

This report presents the Stormwater Management Strategy (and WSUD Strategy) which will form the basis for the implementation of WSUD within the development. The site will be developed in a number of stages. Stage 1 is the portion of the site to the north of Farm Creek.

The WSUD Strategy has been established on the basis of delivering good urban design and landscape outcomes through collaboration with the urban designers and landscape architects (DBI). The WSUD principles adopted are consistent with the policies on urban water cycle management as described in the *State Planning Policy for Healthy Waters* (DERM, 2010) and the development principles outlined in the development principles of the *Far North Queensland Regional Organisation of Councils (FNQROC) Regional Development Manual*.

This Ella Bay Stormwater Quality Management Strategy (and WSUD Strategy) document is provided as a response to correspondence from the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC; formerly Department of Water, Environment, Heritage and Arts (DEWHA) (refer following section).

1.2 HOW THIS DOCUMENT RESPONDS TO THE DSEWPC REQUESTS

DSEWPC CORRESPONDENCE / REQUEST			DESIGNFLOW RESPONSE
DATE	ITEM	DETAILS	
1 August 2008	Water balance	Water balance for the site, in particular to ensure that the water regime of the northern wetland area and coastal swales that support habitat for listed species would not be affected by the development.	The focus of the stormwater strategy has been to ensure the environmental flows to the significant wetland located to the northern of Ella Bay. This involves reuse of additional runoff created by impervious surfaces, capture and treatment of stormwater and diversion where required. Refer Section 3 for objectives, Section 4 for a description of the strategy and Section 5 for modeling results.
	Water quality	Quality of water discharges into the GBRWHA and into creek systems to ensure habitat for listed frog species and for the protection of the water quality in the GBRWHA. Availability of draft GBRMPA water quality guidelines was also informed and we undertook to provide a copy to Satori for consideration of water quality aspects.	The stormwater strategy has established best practice stormwater management objectives for the site including stormwater quality. These objectives apply to the discharge points of the stormwater from the development catchments. The intent of the stormwater objectives is to ensure the relevant ambient water quality objectives listed in relevant policy is achieved. As outlined in ANZECC, the ambient concentrations are not meant to be used as discharge criteria but rather to assess the health of the receiving waterway. Specific stormwater discharge objectives need to be established and applied to the stormwater discharge. Refer to DesignFlow (2009) and Section 3 of this report for further clarification of the stormwater management objectives that have been established for the Ella Bay site.
22 May 2008	7. Water Quality Control	To control pollution of stormwater a treatment system including constructed wetlands, and bio-retention ponds has been suggested in consultants reports. However, the Master Plan provided does not indicate location of such systems. Given that the majority of the impact mitigation measures proposed for maintaining or enhancing the water quality from the Ella Bay site are linked to staging of the development, is important that design details of at least one stage of the development (stage to be developed first) incorporating all features be provided to understand the scale and nature of the development.	This document presents the details of proposed stormwater management strategy for the Northern Precinct of Ella Bay. The strategy was resolves in collaboration with the urban designers and landscape architects to ensure there is appropriate space for the individual stormwater elements. Details of the strategy are provided in Section 4.
	8. Water Balance	The report by EnSight on water balance for the project does not provide quantitative data. If all rainwater is to be collected in rainwater tanks, what are the downstream hydrological impacts? How are the environmental water flows to the streams, wetland and beach swale areas be maintained? There is no quantitative analysis of environmental water flows in relation to the water availability and water use in the three urban water streams of potable water, waste water and stormwater, and potentially groundwater.	The focus of the stormwater strategy has been to ensure the environmental flows to the significant wetland located to the northern of Ella Bay. This involves reuse of additional runoff created by impervious surfaces, capture and treatment of stormwater and diversion where required. Refer Section 3 for objectives, Section 4 for a description of the strategy and Section 5 for modeling results.
	14. Reef water quality protection plan	As you are aware, the Australian and Queensland governments have developed a Reef Water Quality Protection Plan for the long term protection of the water quality in the Great Barrier Reef area. Any discharges into the Great Barrier Reef marine area should meet the objectives of this plan.	The stormwater strategy has established best practice stormwater management objectives for the site including stormwater quality. These objectives apply to the discharge points of the stormwater from the development catchments. The intent of the stormwater objectives is to ensure the relevant ambient water quality objectives listed in relevant policy is achieved. As outlined in ANZECC, the ambient concentrations are not meant to be used as discharge criteria but rather to assess the health of the receiving waterway. Specific stormwater discharge objectives need to be established and applied to the stormwater discharge. Refer to DesignFlow (2009) and Section 3 of this report for further clarification of the stormwater management objectives that have been established for the Ella Bay site.

DSEWPC CORRESPONDENCE / REQUEST			DESIGNFLOW RESPONSE
DATE	ITEM	DETAILS	
4 June 2007	Stormwater	The EIS suggests that all stormwater will be treated before being discharged or reused on site (golf course) or for non-potable uses i.e. toilet flushing, gardens etc. Urban sensitive designs will be employed to ensure minimal impacts please note that the MUSIC program and water sensitive designs are often designed for non-tropical environments. The velocity and duration of rainfall in this area is often not considered and contingency to collect and treat the first flush may be the only way to deal with the quantity of the water that will fall on the site in an event.	Refer Section 4 for description of the proposed stormwater strategy. The MUSIC model has been used for the strategy because it represents the best available modeling tool for defining stormwater management solutions. Importantly local rainfall has been used in the model to ensure the climatic conditions are considered. As a result the stormwater treatment solutions are larger than would be expected in sub-tropical climates.
		Nutrient levels from the operation of the golf course should be managed to prevent overtopping during rain events and impacting the receiving waters. Further information on golf course management arrangements is required.	All stormwater runoff from the golf course areas are to be treated in either constructed wetland or bioretention systems in accordance with the objectives listed in Section 3. Please refer to Section 4 for details of the strategy.
		All works associated with construction and operation should be well planned and timed. Materials should not be stock piled on the site as this may have the potential to impact the surrounding areas and the receiving waters. Heavy rains and flooding are unpredictable in the wet tropics and all materials need to be stored and bunded appropriately.	Noted.

2 APPRAISAL OF SITE CHARACTERISTICS

Successful WSUD strategies respond to the specific characteristics and conditions of a site and the local and regional receiving environments. The following sub-sections provide a summary of site characteristics considered important in defining the WSUD Strategy for Ella Bay.

A site inspection of the wetlands and waterways at the proposed Ella Bay development was undertaken by DesignFlow on the 15th and 16th of April, 2009.

Figure 2 Photos of the Ella Bay site

As illustrated in Figure 3, the site is characterised by a large wetland mosaic complex to the north (Northern Wetland) and a series of wetlands (Wetland Swale) that run in a northerly direction in a swale behind the beach to the east of the site. There are also several smaller wetlands present in shallow alluvial depressions located throughout the site.

2.1 VEGETATION

The wetland and waterway plant communities at the site have been severely degraded by the invasion of Pond Apple (*Annona glabra*). The presence of Pond Apple in the Northern Wetland and Wetland Swale areas is of particular concern, as several pure stands of the Pond Apple have now developed, and further incursion of this weed into these wetland areas will continue to threaten the remaining wetland communities. Pond Apple and Lantana (*Lantana camara*) are also present along Farm Creek, and constitute a threat to the condition of the riparian communities in these sections. For more information please refer to the Vegetation Survey prepared by 3D Environmental (2009). The extent of the vegetated zones, in particular the wetlands are illustrated in Figure 3.

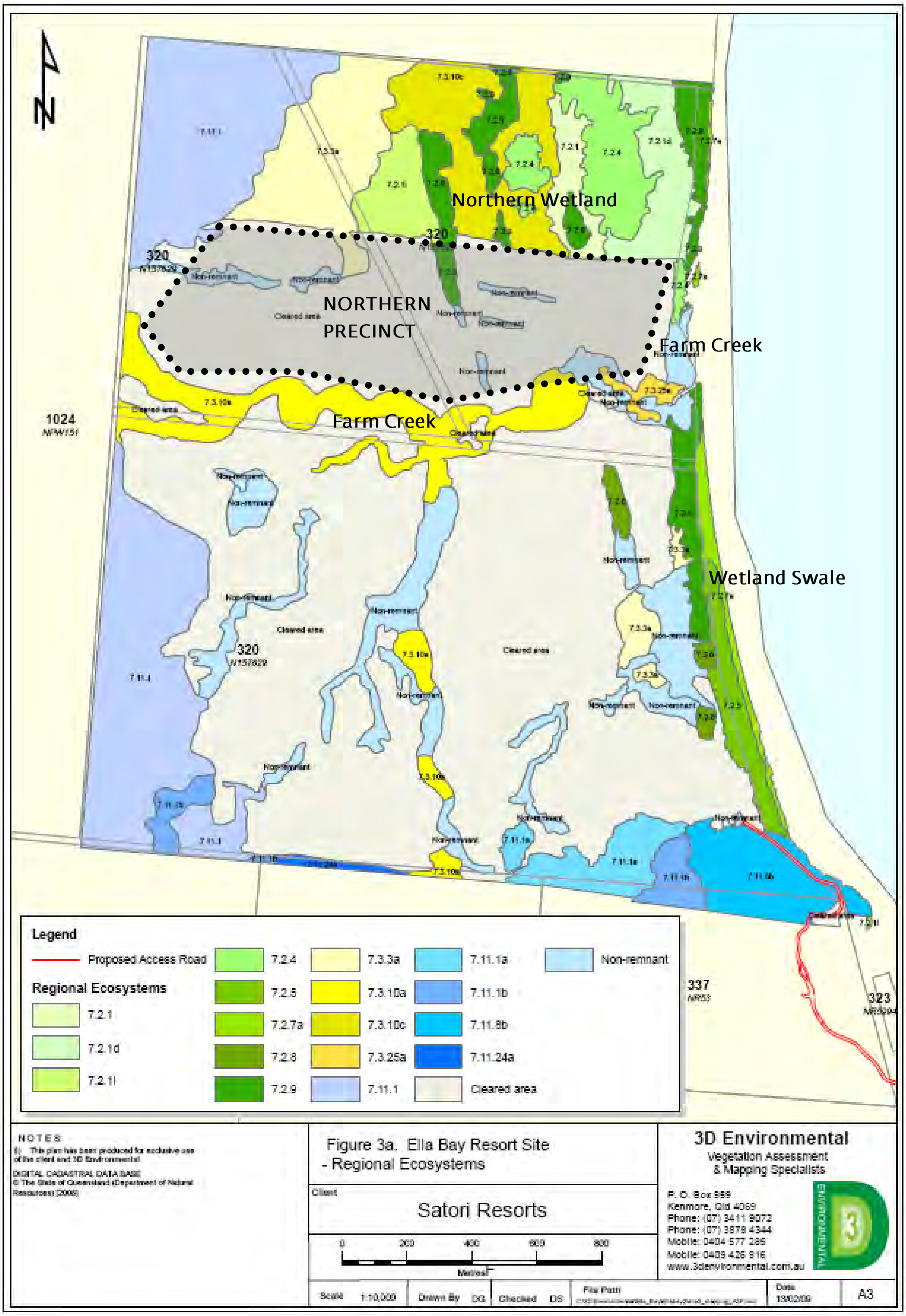


Figure 3 Extent of wetland areas (taken from 3D Environmental, Vegetation Survey Report 2009)

2.2 RECEIVING WATERWAYS

Stormwater from the Northern Precinct enters either Farm Creek or the Northern Wetland. The following sections describe these waterways as well as the Wetland Swale which accepts stormwater flow from remainder of the Ella Bay site (not the Northern Precinct).

2.2.1 Farm Creek

Farm Creek bounds the southern and eastern sections of the Northern Precinct.

Farm Creek and the tributary are densely vegetated with diverse riparian communities that extend between 5-15 m from the edges of the waterways. The Farm Creek channel is stable due to the presence of the riparian vegetation. Minor erosion has occurred along a short reach (50m) in the lower section of Farm Creek. It would appear that the removal of the riparian vegetation in this section has destabilised the stream embankments causing active bank erosion and subsequent mass slumping (Figure 4).

The floodplain levels adjacent to Farm Creek and the tributary are extremely flat. There appears to have been no formal drainage implemented at the site. However, minor modifications have been made to a small drainage line in the northern section of the site, where runoff from the floodplain appears to have been diverted away from Farm Creek towards the Northern Wetland.

Figure 4 Farm Creek: bank erosion

2.2.2 Northern Wetland

The Northern Wetland bounds the northern boundary of the site. The wetland is comprised of a wetland mosaic of patches of Open forest (dominated by *Melaleuca quinquenervia*) interspersed with Mesophyll vine forest (dominated by *Archontophoenix alexandre*) in the drainage depressions, and Sclerophyll vine forest (dominated by *Lophostemon suaveolens*) in the higher sections.

The Melaleuca dominated Open forest and the Mesophyll vine forest are characterised by moist depressions interspersed with shallow bodies of surface water (generally less than 100 mm depth) during the wet season. The wetland areas are frequently inundated during the wet season (0-200 mm depth). The presence of surface water within the Open forest and Mesophyll vine forest wetland areas is maintained throughout the year by a combination of surface water runoff from the northern section of the site, catchment areas to the west of the wetland areas and groundwater discharges.

The northern wetland accepts runoff from a large 836ha catchment (Golder Associates, 2007) of which only 31.8ha exists within the Ella Bay development footprint.

Previous groundwater investigations by Golder Associates (2007) indicates that although surface flow does enter the Northern Wetland from the Ella Bay site (31.8ha), there is very little groundwater interaction.

Wetland Classification

Based upon the Queensland Wetlands Programme classification system, the dominant wetland types at the proposed Ella Bay development site in both the Northern Wetland and the Wetland Swale areas are commensurate with the Coastal Melaleuca Swamp Wetlands wetland management profile (Queensland Wetlands Programme, 2009).

Wetland management profiles developed under the auspices of the Queensland Natural Heritage Trust Wetlands Programme are designed to provide general information and management recommendations for individual species, ecosystems and cultural heritage in Queensland.

Coastal melaleuca swamp wetlands

Melaleuca swamps are non-tidal, wooded wetlands that occur in or near coastal areas of Queensland. They can be temporarily inundated with water for three to six months of the year, as they occupy the depressions, drainage lines and dune swales within the landscape (Queensland Wetlands Programme, 2009b).

Coastal melaleuca swamp wetlands are characterised by vegetation communities that are able to tolerate a high frequency of inundation during the wet season, such as many *Melaleuca* species. Melaleuca swamp wetlands have a relatively high tolerance to increased nutrient loads, provide an effective buffer against erosion, are efficient sinks of nutrients and act to retain flood waters (Queensland Wetlands Programme, 2009b).

The management of wetland hydrology is a critical element in preserving wetland function and structure. Limited information is available on the hydrological characteristics of Coastal Melaleuca Swamp wetlands. It is generally recognised that Coastal Melaleuca Swamp wetlands are sensitive to hydrological changes; whereby decreases or increases to natural water flow can cause the coastal *Melaleuca* swamp wetlands to deteriorate, dry out and disappear or become larger and wetter (Queensland Wetlands Programme, 2009b).

As part of the *Water Sensitive Urban Design Solutions for Catchments above Wetlands (May 2007)* published by the Hunter and Central Coast Regional Environmental Management Strategy, Ecological Engineering (2007a) derived a wetland classification system that enables different wetland types to be distinguished, and the appropriate supporting hydrology and water quality parameters to be determined for each wetland type. This is particularly important where remnant wetlands exist below existing or proposed urban developments, and where catchment urbanisation can lead to alteration of the water regime. Members of the DesignFlow team were employed at Ecological Engineering when this classification scheme was established and are well versed in its application.

The wetland classification system proposed by Ecological Engineering (2007a) is based upon the; dominant vegetation, dominant substratum, water chemistry and typical life forms. All wetland types present within Australia were integrated into the classification system, and the classification system compared to other classification schemes.

Based upon the proposed classification system, the dominant wetland types present at the proposed Ella Bay site (**Coastal Melaleuca Swamp wetlands**) were judged to be commensurate with the **Wet Forest Swamp** classification (Ecological Engineering, 2007a). Wet forest swamps are flooded on a regular or seasonal basis, and are generally dominated by Melaleuca species (Ecological Engineering, 2007a). The typical frequency of drying/exposure of the wetland substrata in wet forest swamps ranges between once every 1-3+ years (Ecological Engineering, 2007a). The average duration of drying in wet forest swamps varies between 2-6 months per year, however this is expected to be significantly lower in areas with high rainfall occur during the dry season such as Ella Bay. Wet forest swamps are adapted to regular inundation, and are able to cope with inundation depths ranging between 0-2 m (Ecological Engineering, 2007a).

2.2.3 Wetland Swale

The Wetland Swale does not accept runoff from the Northern Precinct but a description of the swale system is provided here to guide future design of the southern precincts.

The Wetland Swale complex comprises of *Melaleuca quinquenervia* closed forest in the wetter alluvial depressions and brackish-saline areas to the north, *Melaleuca leucadendra* open forest and Mesophyll forest (dominated by *Syzygium forte*) on the coastal dunes to the south, and a coastal Foredune complex (dominated by shrubland and *Casuarina equisetifolia*) on the dunes between the swale depression and Ella beach (Figure 5).

Runoff from the south-eastern area of the site enters the Wetland Swale complex via a large shallow alluvial depression that extends onto the floodplain above the swale complex. The depression is characterised by a mosaic of vegetation communities consisting of non-remnant shrubland and forest communities dominated by *Hibiscus tiliaceus* and dense infestations of Pond Apple (*Annona glabra)*, with isolated patches of Mesophyll vine forest (*Archontophoenix alexandrae*) and *Melaleuca leucadendra* forest present.

The Wetland Swale is characterised by widespread interspersed areas of shallow surface water (0-150 mm depth). Surface water enters the swale diffusely from the shallow alluvial depression and from the adjoining floodplain, and drains freely through the swale in a northerly direction towards the mangrove dominated intertidal area at the mouth of Farm Creek. Water levels in the Wetland Swale are maintained by a combination of surface runoff, groundwater discharges and infiltration back to the beach dune system.

It appears that groundwater discharges to the Wetland Swale results in permanent low flows within the Wetland Swale (and the adjoining alluvial depression area) during the wet season, however the flows often cease during the dry season due to the reduction in groundwater inflows.

Flooding occurs in the Wetland Swale when there is surface runoff. The zonation of the vegetation along the margins of the swale depression indicates that water levels temporarily rise by up to 300 mm during the wet season; however residence times for flooding will be low due to the direct connection of the swale complex to lower section of Farm Creek. Flooding may persist in the swale complex following rain due to higher water levels in the lower sections of Farm Creek and also from higher groundwater infiltration rates. It is expected that the coastal dunes are also occasionally over topped by king tides, leading to temporary inundation of the Wetland Swale with saline water.

Figure 5 Areas within the Wetland Swale

2.2.4 Hydrology of Northern Wetland & Wetland Swale

Water levels within both the Northern Wetland and Wetland Swale complex are expected to persist as shallow permanent pools during the wet season, but significantly lower during the dry season due to evapotranspiration or infiltration via the sand dunes to Ella Bay.

The upper substratum in the Northern Wetland and Wetland Swale complexes comprise of a thick layer (up to 50 mm depth) of organic material (decomposing leaves and litter). This suggests that decomposition of organic material occurs slowly and that the surface soils in these areas remain relatively moist throughout the dry season.

There is currently no hydrologic data available for Farm Creek, although anecdotal evidence indicates that there is no outflow connection to Ella Bay during the dry season. There is also evidence from historical aerial photography that the entrance of Farm Creek into Ella Bay experiences spatial variation up to 750 m from where the creek meets the beach (BMT-WBM, 2007).

2.3 CLIMATE

To define the hydrologic characteristics of the Ella Bay site, an understanding of the key climatic conditions was required. This was undertaken through review of historical meteorological (rainfall and evaporation) patterns and the following observations were made (refer Figure 6):

- Based on modelling of human-induced climate change undertaken by CSIRO, it is predicted that over the coming decades Queensland will experience an overall reduction in annual rainfall with longer periods of dry weather and rainfall falling in a reduced number of storms but with higher intensity and increased variability. Climate change is unlikely to affect the selection of vegetation for WSUD systems but should influence decision making in relation to the broader landscape such as the selection and maintenance of street trees.

- Rainfall averages at South Johnstone Station experiences a tropical climate, with an annual average of 3300 mm, around 50% of which falls between January and March
- Evaporation exceeds rainfall on average 4 months a year (August to November) however these months experience around 90 to 140mm rainfall per month, so as expected, drying is not a dominant process in this climate

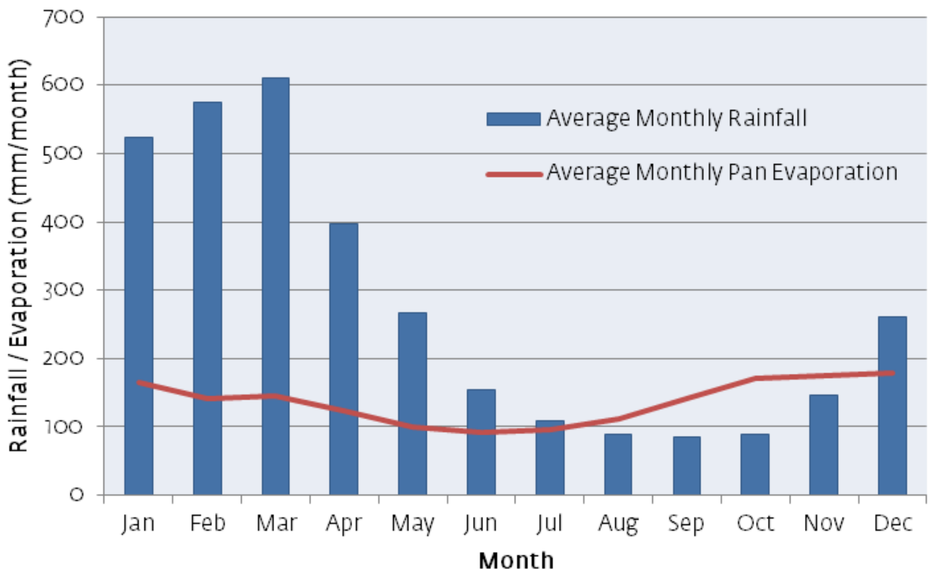


Figure 6 Rainfall Characteristics for South Johnstone

2.4 TOPOGRAPHY

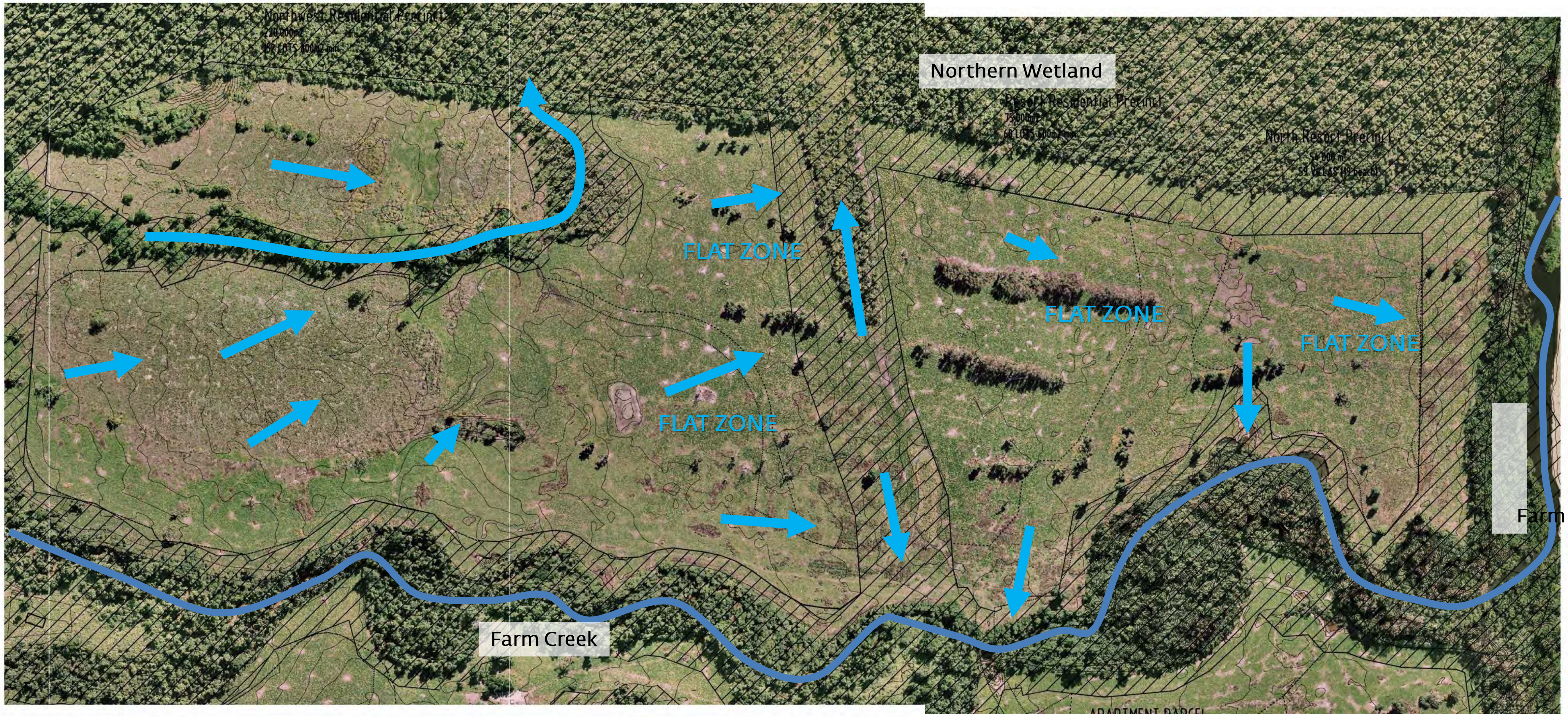
The site grades generally from west towards the coast in the east, from a high point at the western boundary around RL 10.0 to the lowpoint in the east at RL 2.0. There is a gully which runs from south to north through the middle of the northern precinct (refer Figure 7).

2.5 SITE DRAINAGE

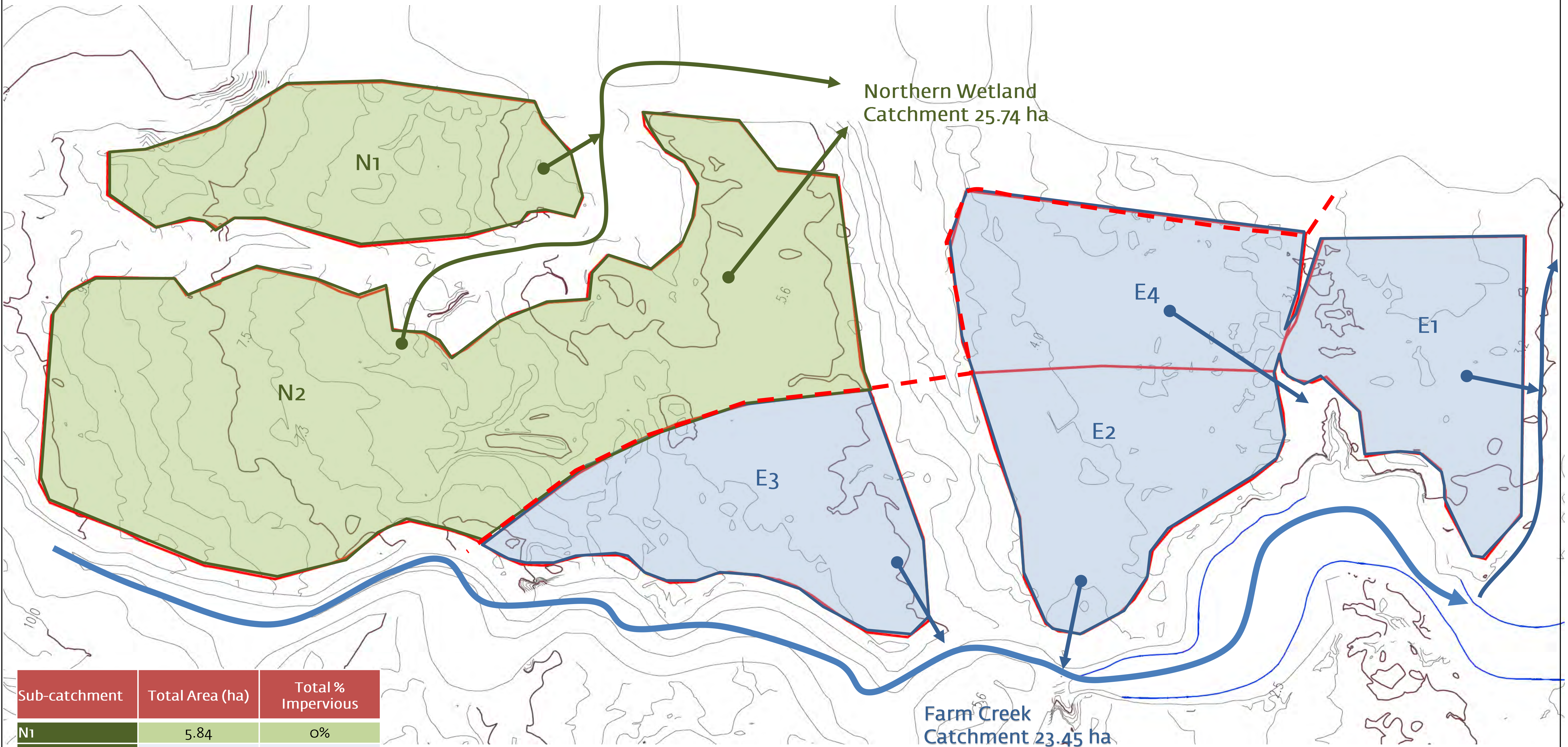
The majority of the surface runoff from the site discharges via well-defined drainage lines into Farm Creek, which flows through the site directly south of the northern precinct in an easterly direction and discharges directly to Ella Bay. A tributary flowing in a northerly direction dissects the remainder of the site and conveys runoff from the south of the site into Farm Creek. Surface water runoff from the northern section of the site flows into the Northern Wetland system (refer Section 3.3) via two well defined shallow depressions. Refer Figure 7 for more information. Currently more than half of the northern precinct area drains to the northern wetland, with the remainder draining to Farm Creek in the south (Figure 8).

2.6 PROPOSED DEVELOPMENT

The proposed land uses at Ella Bay include residential, resorts, village precinct including retail and commercial precincts, day spa, public pool facility, community centre, education facilities, sports oval, golf course and driving range. The site will be developed in a number of stages. Stage 1 (Northern) will be that part of the site to the north of Farm Creek, extending from Ella Bay to the western boundary. Population estimates indicate that the maximum population will be up to 3,304 people (1,274 permanent residents and 2,030 visitors) at peak times, however, on average the numbers will be lower, ie 2,856 people (1,102 permanent residents and 1,754 visitors). There will also be a significant number of day workers and visitors to the site. The masterplan of the northern precinct and the development catchments are shown in Figure 9.

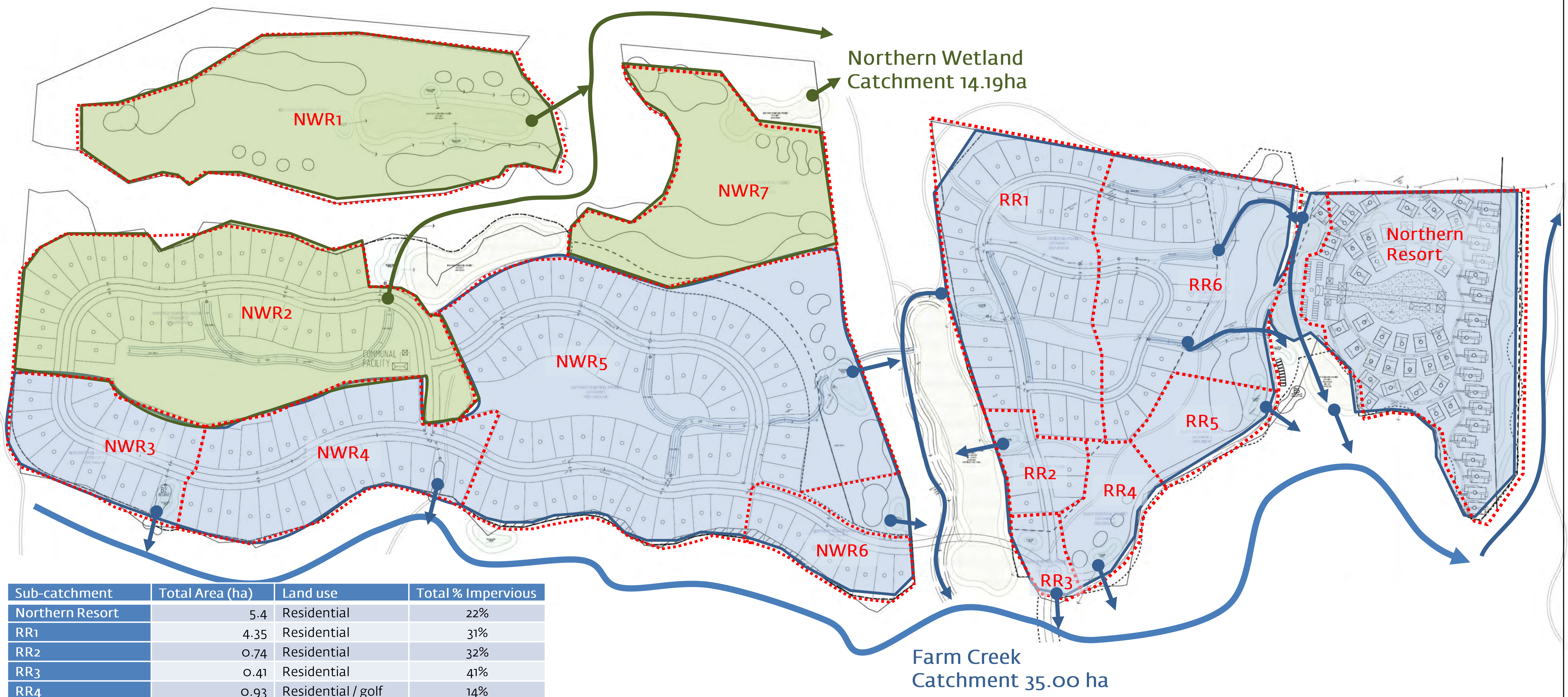


Project: Ella Bay Northern Precinct	Report: Ella Bay Northern Precinct Draft Stormwater Quality Management Plan (DesignFlow, 2010)	Figure 7 Site Topography and Drainage	Date: 30/3/11 Scale: NTS



Sub-catchment	Total Area (ha)	Total % Impervious
N1	5.84	0%
N2	19.9	0%
Total N	25.74	0%
E1	5.4	0%
E2	5.53	0%
E3	6.48	0%
E4	6.04	0%
Total E	23.45	0%
TOTAL	49.19	0%

Project:	Report:	Figure 8:	Date:
Ella Bay Northern Precinct	Ella Bay Northern Precinct Draft Stormwater Quality Management Plan (DesignFlow, 2010)	Pre-development Catchments	30/3/11
ELLA BAY Far North Queensland	DesignFlow		Scale: NTS



Sub-catchment	Total Area (ha)	Land use	Total % Impervious
Northern Resort	5.4	Residential	22%
RR1	4.35	Residential	31%
RR2	0.74	Residential	32%
RR3	0.41	Residential	41%
RR4	0.93	Residential / golf	14%
RR5	0.96	Residential / golf	15%
RR6	4.19	Residential / golf	18%
NWR1	5.84	golf	0%
NWR2	6.42	Residential	23%
NWR3	1.93	Residential	32%
NWR4	3.18	Residential	30%
NWR5	10.02	Residential/ golf	23%
NWR6	1.51	Residential / golf	26%
NWR7	3.31	Golf	0%
TOTAL	49.19		20%

Project:
Ella Bay Northern Precinct

Report:
Ella Bay Northern Precinct Draft Stormwater Quality Management Plan (DesignFlow, 2010)

Figure: 9
Development Layout and Catchments

Date:
30/3/11
Scale:
NTS

3 DESIGN OBJECTIVES

The proximity of the Ella Bay development site to sensitive aquatic ecosystems such as Farm Creek and the Northern Wetland, coupled with the increases in imperviousness and associated increases in flows and water-borne contaminants requires a carefully considered WSUD Strategy aimed at supporting the intended land uses whilst also affording protection to the receiving ecosystems. The objectives of the Ella Bay WSUD Strategy have been developed with the aim of delivering on the key principles of WSUD outlined in Section 1.1 and outlined in the report *Ella Bay Stormwater Management Objectives* (DesignFlow, June 2009), other than a minor adjustment to the stormwater quality objectives.

The objectives that have been set are in accordance with the *State Planning Policy for Healthy Waters* (2010), *Best Practice Environmental Management Guidelines: Urban Stormwater* (DERM, 2010) and current best practice knowledge on the protection of wetlands.

3.1 POTABLE WATER CONSERVATION

There is no external potable water connection to the Ella Bay development. The primary source of drinking (potable) water will be rainwater harvested from roof catchments.

Given the high rainfall in the area this offers a reliable source of water. Water conservation initiatives will be implemented throughout the design of the development to minimise demands and ensure the reliability of the supply.

Refer to Ella Bay Integrated Water Management Strategy (Bligh Tanner, June 2009) for further detail on the potable water strategy at Ella Bay.

3.2 STORMWATER QUALITY

To ensure the protection of Farm Creek, the northern wetland and the wetland swale (plus related tributaries), stormwater quality objectives have been adopted for both the *Construction Phase* and *Operational Phase*. The *Construction Phase* refers to the time period covering the construction of base sub-division infrastructure (i.e. Infrastructure Construction Stage) and Building Stage for each stage of development. *Operational Phase* refers to the time period following completion of Building Stage (i.e. when the development area is in a stable landscaped condition).

3.2.1 CONSTRUCTION PHASE

The primary focus of stormwater management during the *Construction Phase* is erosion and sediment control. The stormwater management objectives for the *Construction Phase* take the form of best-practice concentration-based discharge standards. The performance criteria are limited to those parameters that are directly linked to construction site activities. As the criteria are discharge standards, they apply to runoff events or pumped discharges (during dewatering of siltation basins) from the development site. The criteria for stormwater discharged from the site during the *Construction Phase* are listed in Table 1 and represent our understanding of the construction phase objectives for medium-large scale construction sites in Queensland which will be presented in the remake of the Environmental Protection Policy (Water).

Table 1– Criteria for Stormwater Discharged from Site during construction phase for medium-large construction sites

POLLUTANT/ISSUE	STORMWATER DESIGN OBJECTIVES[1]
Coarse sediment	Retain coarse sediment on site
Fine sediment (Total Suspended Solids -TSS)	Reasonable and practical measures should be taken to capture runoff from disturbed areas. Concentrations of TSS in water discharged (either by runoff or dewatering of siltation basins) should be less than 50mg/l.
Turbidity[2]	Turbidity in discharge waters should be <10% higher than receiving water turbidity (measured directly upstream of discharge point).
Nutrients (eg. N and P)	Construction phase nutrient management should occur via appropriate sediment management.
pH	Subject to the mobility of specific elements that may be present on site, pH of waters discharged from site must be between 6.5 and 8.5.
Dissolved oxygen	Dissolved oxygen concentration > 80% saturation.
Litter and gross pollutants	Prevent discharge of litter from site entering stormwater system/internal watercourses by ▪ Minimising litter production ▪ Containing litter on site by the provision and maintenance of rubbish bins with appropriate lids
Hydrocarbons and other contaminants[3]	Discharge of hydrocarbons and other contaminants should be prevented from site by: ▪ At-source control of contaminants. ▪ Preventing entry of contaminants into stormwater system or internal watercourses. ▪ Disposing of waste must to authorised facilities. ▪ Storing hydrocarbons according to Australian Standard AS1940. ▪ Ensuring that discharged waters have no visible oil or grease sheen
Wash down areas	Prevent entry of wash down water into stormwater system or internal watercourses that discharge from site.
Cations and anions	As required under an approved Acid Sulfate Soil Management Plan, including aluminium, iron and sulphate.
Stormwater Quantity	Take all reasonable and practical measures to minimise changes to the hydrology of the receiving environment. Protection of in stream habitat and flood characteristics by: ▪ managing peak flows for the 1-year and 100–year ARI event ▪ managing run-off volumes entering receiving waters ▪ preventing uncontrolled release of contaminated stormwater.

[1] Compliance release limits for rainfall events less than the design storm event – (based on the 80%ile 5day rainfall depth).
[2] Site-specific calibration of turbidity must be performed.
[3] Refer to the contaminant list in the *Environmental Protection Regulation 1999*.

3.2.2 OPERATIONAL PHASE

A discussion paper has been prepared for Satori Resorts Ella Bay Pty Ltd in response to an information request from the Department of the Environment, Water, Heritage and the Arts (DEWHA) relating to stormwater management of the proposed Ella Bay development. The document (*Ella Bay Stormwater Management Objectives* (DesignFlow, 2009)), summarises the move from concentration-based objectives to load reduction objectives for the assessment of stormwater quality management strategies.

The stormwater quality management objectives that apply to the Operational Phase of the Ella Bay development have been established in consideration of the location of the site and sensitive receiving waterways. Refer to *Ella Bay Stormwater Management Objectives* (DesignFlow, 2009) for a presentation of the derivation of the stormwater quality objectives for the Ella Bay development site.

The *State Planning Policy for Healthy Waters* (DERM, 2010) dictates load reduction objectives outlined in Table 2 apply to developments with greater than 25% impervious cover. Assessment of Ella Bay Northern Precinct indicates that only part of the site is strictly subject to these load-reduction objectives. However, the stormwater management strategy for Ella Bay Northern Precinct has aimed to achieve load reduction objectives from the whole development footprint including areas less than 25% impervious to provide a high level of protection for the receiving environment. The aim of this is to ensure best practice stormwater management has been delivered within the Northern Precinct and to ensure the ambient water quality objectives are preserved.

The *State Planning Policy for Healthy Waters* (DERM, 2010) objectives for the site region including Ella Bay are listed in Table 2. Detailed testing completed as part of developing this stormwater strategy indicates the TSS and TP are readily achieved even at imperviousness of less than 25%. However, to strictly meet the 40% TN objective, constructed wetlands need to be sized at around 14% of catchment area. Wetlands of this size are well beyond the limits of economic performance and thus are not considered best practice. There are a number of reasons why wetlands are very large at Ella Bay to achieve a 40% TN objective:

- **Low imperviousness.** To achieve pollutant load reductions from sites with low imperviousness (such as the Ella bay Northern Precinct site) requires much larger systems. This is because the difference in pollutant concentrations (and therefore loads) discharged from pervious zones (mostly baseflow) is lower than concentrations from impervious surfaces (surface flow). The SPP objectives were based on sites with 40% imperviousness which means that the Ella Bay site (<25%) is not directly comparable with these objectives.

- **New modelling software.** A new version of the water quality modelling software (MUSIC) has been released since the pollutant load reduction objectives were derived, which has resulted in slightly lower treatment effectiveness of the treatment elements.

- **Different rainfall.** The pollutant load reduction objectives for the wet tropics were derived using rainfall from Cairns (2006 mm/yr). The most appropriate rainfall for the Ella Bay development site is the South Johnstone Research Station, which experiences 3300 mm rainfall per year (around 40% more rain annually). The increased volume of runoff results in much larger treatment systems which will not manage stormwater nitrogen loads to the required reduction target of 40% unless sized well beyond the limits of economic performance. As noted in the correspondence from the DSEWPC, the rainfall experienced in this region presents a unique challenge.

- **Flat site.** The pollutant load reduction objectives were derived using bioretention at 1.5% of the catchment area. The grades over much of the Northern precinct of Ella Bay however precludes bioretention (which actually needs to be in the order of 1.8% to achieve the objectives). This means wetland need to be used. Wetlands have a number of ancillary benefits over bioretention, however the size of these systems typically becomes very large in the wet and dry tropics when reductions in total nitrogen are set too high. A study for Mackay Regional Council also concluded that slightly lower objectives for TN load reduction should be considered when wetlands are the dominant type of stormwater treatment system in a strategy (please refer to http://www.mackay.qld.gov.au/__data/assets/pdf_file/0005/58244/Stormwater_Quality_Performance_Curves_and_Stormwater_Quality_Objectives_for_Mackay.pdf for details).

Overly large wetlands will result in a number of issues which are important to consider:

- **Maintenance / Amenity.** Constructed wetlands afford a number of benefits above and beyond stormwater quality improvement (such as habitat), however careful maintenance particularly during establishment is required to ensure that weeds do not invade these systems. Larger systems are more difficult to maintain and weed problems can be exacerbated.

- **Water level variation.** Detailed modelling will need to be conducted prior to design to ensure that water level regime is appropriate and sustainable. It should be noted that wetlands that are large with respect to their catchment are more susceptible to water level drawdown over the dry season. This may result in loss of wetland vegetation, and an associated reduction in performance and amenity.

In response to these concerns, an alternative set of objectives has been developed for this site. Derivation of the alternative objectives has followed the exact same process DERM and AECOM used to derive the objectives in the State Planning Policy for Healthy Waters (DERM, 2010). Please refer to the AECOM (2008) *Queensland Best Practice Environmental Management Guidelines - Urban Stormwater Technical Note: Derivation of Design Objectives* for details of the method.

Detailed modelling of rural and urban catchments with 0, 25% and 50% impervious was conducted to assess the size of bioretention or wetland required to meet the pollutant load reduction objectives. The rural landuse has been adopted for the golf course as we expect the stormwater loads from the golf course to be similar to rural (i.e. irrigated wastewater).

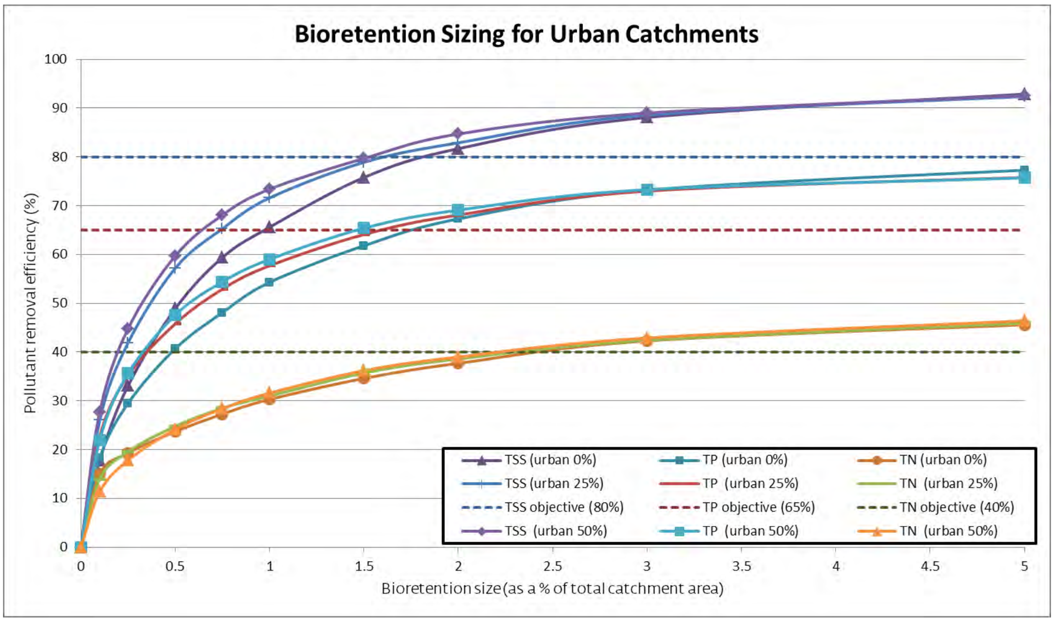
As shown in Figures 10 and 11, to meet the objectives (80/65/40), bioretention needs to be between 1.8% and 2.5% of the catchment area, and wetlands 11% to 15+% of the catchment area. The pollutant reduction objectives have been set based on bioretention at 1.5% of the catchment area, as this is typically the point of diminishing return performance versus cost. The objective with a slightly reduced TN objective (35%), could be achieved with bioretention sized at around 1.5% of the catchment area and constructed wetlands sized at 8-11% of the catchment area. This is therefore considered an appropriate objective for the Ella Bay site based on these best practice principles (i.e. low % impervious and economic limit of performance). These objectives, shown in Table 2 below are very similar to the SPP objectives; however the annual TN load reduction objective has been reduced slightly from 40% to 35%.

The load based objectives outlined in Table 2 have been applied to Ella Bay along with the comparison objectives outlined in the following section.

Table 2 – Criteria for Stormwater Discharged from Site (*Operational Phase*)

Constituent	Discharge Criteria (% reduction in post development mean annual load)	
	SPP	Adopted
Total Suspended Solids	80	80
Total Phosphorous	65	65
Total Nitrogen	40	35*
Gross Pollutants	90	90

* Slight reduction in TN reduction objective proposed



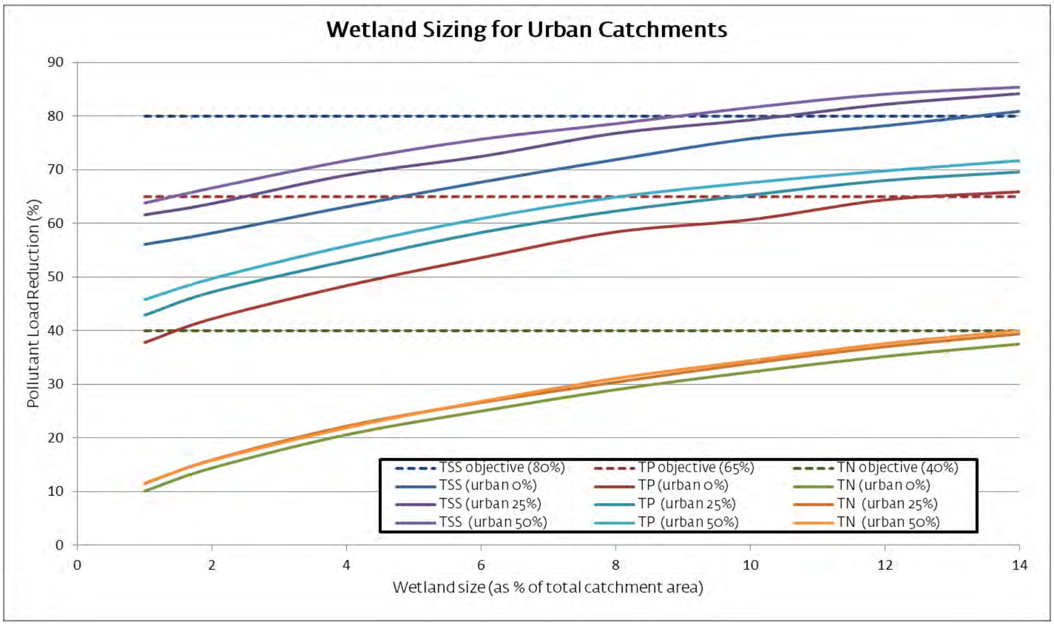
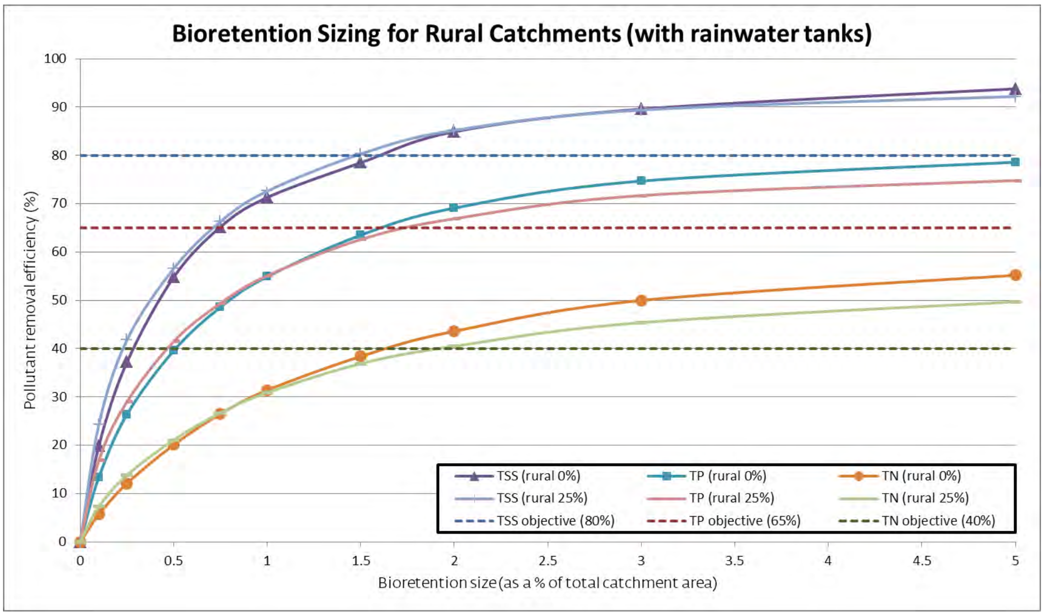


Figure 10 Stormwater treatment performance curves – urban catchment



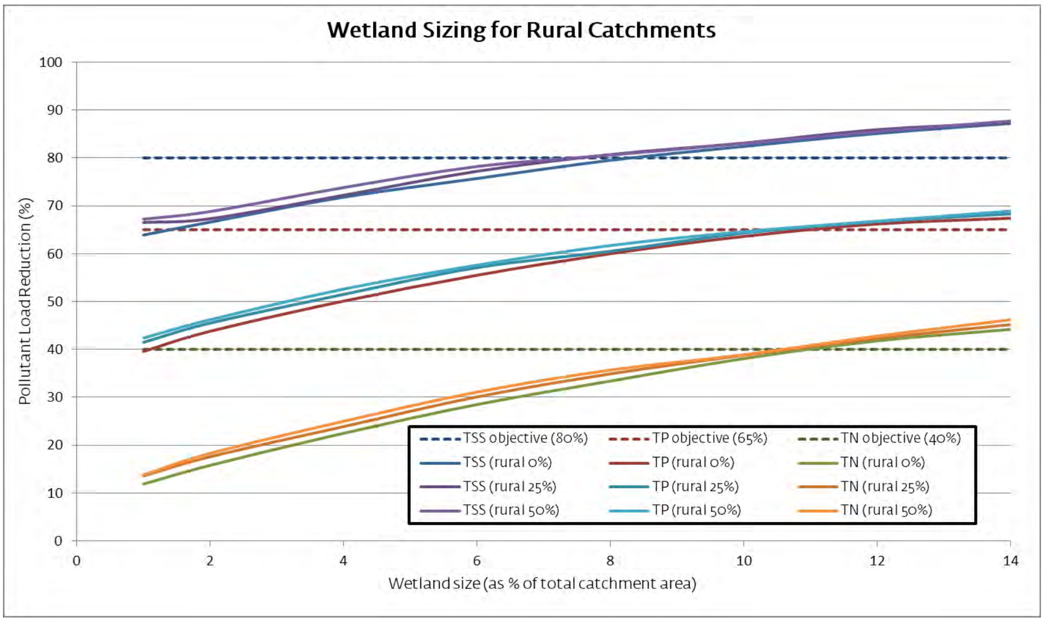


Figure 11 Stormwater treatment performance curves – rural catchment

Comparison objectives

As outlined in DesignFlow (2008) and ANZECC, concentration objectives and non-worsening objectives do not directly apply to stormwater discharge. Nevertheless, the performance of the proposed stormwater treatment should be compared with concentration and non-worsening objectives. This has been achieved through the following:

1. Non-worsening objectives – Comparison of the developed and mitigated TSS, TP and TN loads with forest, agriculture and rural loads. This site is disturbed and heavily populated with wallabies so is probably representative rural or agricultural landuse but we have provided forest as well for transparency.

2. Concentration objectives - The following objectives are derived from the *Queensland Water Quality Guidelines 2009* (DERM, 2009b) Guideline Values for the Wet Tropics and have been adopted as the most locally-relevant objectives to the Ella Bay Development site:

	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Water Quality Objectives (for wetlands)	15	0.01 – 0.05	0.35 – 1.20
Water Quality Objectives (for freshwater lowland streams)	15	0.01	0.24

3.3 HYDROLOGIC OBJECTIVES

Refer to *Ella Bay Stormwater Management Objectives* (DesignFlow, 2009) for a presentation of the derivation of the hydrologic objectives for the wetlands at the Ella Bay development site. The following objectives have been applied to flow entering the Northern Wetland:

1. Preserve the dry duration during dry season (avoid drying out):
   - Preserve the pre-development 30-day low flow duration frequency curve for the dry season (July to November).
   - Preserve the low flow spells frequency curve for the dry season.
2. Preserve the wet duration during year (avoid over wetting):
   - Preserve the pre-development 30-day high flow duration frequency curve for entire year (all months).

Achieving compliance of the hydrologic management objectives should be demonstrated by the post-development flow duration curves and spell frequency curves achieving similar shapes and slopes. For the “drying duration” curves, if the curves indicate slightly wetter conditions then this can be considered as compliance as the critical requirement is not to dry out the wetland.

3.4 FRESHWATER SUPPLIES FOR CASSOWARY DURING THE DRY SEASON

In 2009, Ella Bay Developments (with NRA Environmental Consultants) conducted a dry season surface water availability survey on and adjacent to the Ella Bay site (Ella Bay Developments, 2009). The results of this study indicate that surface water is severely limited for Cassowaries in the area during the dry season.

Thus a key objective of the stormwater management strategy for the Ella Bay site includes the introduction of appropriate freshwater sources for Cassowary during the dry season (i.e. permanent wetlands).

3.5 LANDSCAPE INTEGRATION

Many WSUD measures associated with the harvesting, treatment, storage and reuse of stormwater involve infrastructure that is readily incorporated into the built form and local landscape. Integration of public spaces with conservation corridors, stormwater management systems and recreational facilities is a principle of WSUD. It can provide opportunities for passive recreation (such as a constructed wetland system in a park area) as well as enhancing educational opportunities in regard to promoting stormwater and waterways as valuable resources. WSUD systems can also be used to create interesting streetscapes and reduce irrigation demand as they self-irrigate. The stormwater management elements that will apply to the Ella Bay development site have been conceived to readily integrate into the landscape of public realm zones and add value to the experience of visitors and residents.

3.6 SUMMARY

The WSUD Strategy for the Ella Bay has been established with the aim of achieving the objectives summarised in Table 3.

Table 3 Summary of WSUD Objectives

<table>
<tr><th>WSUD Objectives</th><th>Performance Measure and Target</th></tr>
<tr><td>Construction Phase Stormwater Quality</td><td>

Coarse Sediment – retain 100% on site
Fine sediment (Total Suspended Solids (TSS)) - 80%ile (5-day rain depth) < 50mg/L
Turbidity of discharged water < 10% higher than direct upstream receiving environment)
pH = 6.5 - 8.4 (subject to specific site conditions)
Dissolved Oxygen - 80%ile (5-day rain depth) > 80% saturation
No visible hydrocarbon sheen in discharged waters
Isolate washdown areas and storage of contaminants from stormwater to prevent discharge
Capture of all litter & gross pollutants
Prevent uncontrolled discharge of stormwater and increases in peak flows to preserve stream health and flooding characteristics

</td></tr>
<tr><td>Potable Water Conservation</td><td>All potable water conservation to be delivered by re-use of recycled wastewater for irrigation and toilet flushing, and rainwater tanks for laundry, kitchen and bathroom use.</td></tr>
<tr><td>Operational Phase Stormwater Quality</td><td>
Best practice stormwater quality management in the Wet Tropics (slightly modified from the SPP objectives):

Reduction in post development total suspended solids loads of > 80%
Reduction in post development total phosphorus loads of > 65%
Reduction in post development total nitrogen loads of > 35%
Reduction in post development gross pollutants loads of > 90%

Comparison Objectives are to be considered as listed below:

Non-worsening objectives – Comparison of the developed and mitigated TSS, TP and TN loads with forest, agriculture and rural loads.
Concentration objectives - comparison with the concentration objectives as listed below.

<table>
<tr><th></th><th>TSS (mg/L)</th><th>TP (mg/L)</th><th>TN (mg/L)</th></tr>
<tr><td>Water Quality Objectives (for wetlands)</td><td>15</td><td>0.01 – 0.05</td><td>0.35 – 1.20</td></tr>
<tr><td>Water Quality Objectives (for freshwater lowland streams)</td><td>15</td><td>0.01</td><td>0.24</td></tr>
</table>
</td></tr>
</table>

WSUD Objectives	Performance Measure and Target
Wetland Hydrology to the Northern Wetland	▪ Preserve 30day low flow duration curve for dry season ▪ Preserve the low flow spells frequency curve for the dry season ▪ Preserve 30day high flow duration curve (annual) ▪ Flow delivery management
Drinking water for Cassowary	Create and maintain surface freshwater supplies for Cassowary during the dry season.
Landscape Integration	The stormwater management elements that will apply to the Ella Bay development site have been conceived to readily integrate into the landscape of public realm zones and add value to the experience of visitors and residents.

4 STORMWATER QUALITY MANAGEMENT STRATEGY

In developing the urban design for Ella Bay site, elements of WSUD were integrated into the design; aquatic and terrestrial ecosystems, roads, water infrastructure, earthworks, landscape and POS function. Importantly, WSUD was a key element in the design process and collaboration with the urban designer/landscape architect (DBI), civil engineers (Bligh Tanner) and broader design team has ensured the proposed development is suitably informed by WSUD.

In this regard there is a wide range of WSUD and stormwater management technology available to deliver the objectives outlined in Section 3. Selection of the most appropriate suite of measures for Ella Bay required the matching of available technology to the climate, site conditions, management objectives and the desired urban form. Performance assessment and review of these options was undertaken with DBI and the design team to refine the range of measures resulting in the preferred WSUD Strategy.

Table 4 and Figure 12 present the conceptual WSUD Strategy for the proposed Ella Bay and provide the design requirements of the individual WSUD elements (i.e. location, scale and size). Functional descriptions of the individual WSUD elements are provided in the following sections as referenced in Table 4. Each element of the WSUD Strategy has been categorised as either 'Private' or 'Public' by its location (either within the private allotment or on public land) and responsibility/ownership (either privately owned/operated or Council owned/operated).

Table 4 - Summary of Stormwater Management Strategy

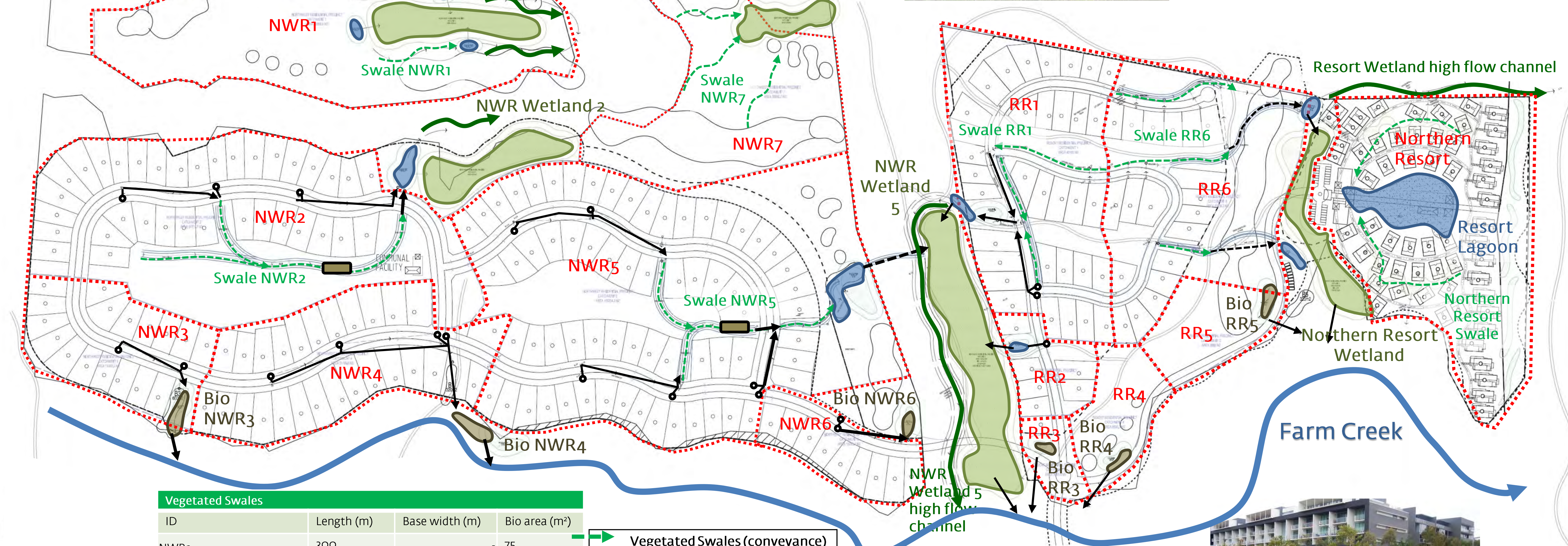
Stormwater Treatment Element	Details	Report Section
Rainwater Tanks	Each dwelling provided with a 10 kL tank (minimum). Rainwater tanks will be installed on all dwellings and connected to laundry, bathroom, hot water and kitchen uses.	4.1
Vegetated Swales	Vegetated swales will be used in many locations throughout the northern precinct to convey and treat runoff. All the swales will include either a bioretention trench or underdrainage trench to actively drain the invert of the swale.	4.2.1
Bioretention Basins	Created as landscape features within precinct parks and integrated into vegetated areas to the north and west of the entry road to accept and treat runoff from areas where there is sufficient level difference to drain the base of the system.	4.2.2
Constructed Wetland	Five constructed wetlands will be integrated into the golf course to treat runoff both from the urban footprint and the golf course in the Northern Precinct.	4.2.3

LEGEND

- Sub-catchment boundary
- Conventional stormwater drainage
- Low flow pipe below swale
- Proposed inlet pond
- Proposed high flow bypass
- Proposed swale
- Proposed wetland
- Proposed bioretention

Constructed Wetlands: Five constructed wetlands have been positioned to treat stormwater runoff from the majority of the development site and golf course. Wetlands process nutrients, provide settlement and filtration in addition to habitat and amenity to residents and visitors. Endemic wetland vegetation to be used.

Constructed Wetlands		
ID	Catchment	Area (m²)
NWR Wetland 1	NWR1	4300
NWR Wetland 2	NWR2	4500
NWR Wetland 7	NWR7	2200
NWR Wetland 5	NWR5, RR1, RR2	10825
Resort Wetland	RR6, Northern resort	4235



Vegetated Swales			
ID	Length (m)	Base width (m)	Bio area (m²)
NWR2	300	1	75
NWR5 swale	300	1	75
NWR7 swales	200	0.5	0
RR1 Swale	100	0.5	0
RR6 Swale	200	3	0
Resort Swales	200	0.5	0

Vegetated Swales (conveyance): to convey runoff in lieu of traditional stormwater kerb, pits and pipes. Swales are to be integrated into open spaces, golf courses and roadways and provide treatment of stormwater. Some swales will have bioretention in the base as a trench to provide additional removal of nutrients.

Vegetated Bypass Channels		
ID	Length (m)	Base width (m)
NWR1	300	1
NWR2	200	4
NWR5	200	10
Resort	200	10

High flow bypass(conveyance): the bypass channels around the wetlands accept and convey flows greater than the capacity of the wetland. These will be densely vegetated and promote shallow flow.

Bioretention Systems			
ID	Catchment area (ha)	Surface area (m²)	% catchment
Bio NWR3	1.93	300	1.55%
Bio NWR4	3.18	450	1.42%
Bio NWR6	1.51	260	1.72%
Bio RR3	0.41	65	1.59%
Bio RR4	0.93	150	1.61%
Bio RR5	0.96	180	1.88%

Bioretention Basin: Bioretention basins are integrated into the development as landscape features in park space or at source in the road reserves to collect runoff and percolate through a prescribed soil filtration media that is densely vegetated. The bioretention systems are to be planted with ground cover species endemic to the region.

N

Project: Ella Bay Northern Precinct	Report: Ella Bay Northern Precinct Draft Stormwater Quality Management Plan (DesignFlow, 2010)	Figure 12 Stormwater Quality Management Strategy	Date: 30/3/11 Scale: NTS

ELLA BAY Far North Queensland

DesignFlow

4.1 POTABLE WATER CONSERVATION

The *Ella Bay Integrated Water Management Plan* (Bligh Tanner, 2010) guides the design principles for potable water conservation on the Ella Bay Development. These reductions will be delivered through water efficiency measures in households, and the re-use of recycled wastewater and rainwater.

4.1.1 Recycled wastewater

Recycled wastewater will be reticulated to allotments for toilet flushing and outdoor use and the golf course for irrigation. Details of the recycled wastewater strategy are provided in other documents (i.e. *Ella Bay Integrated Water Cycle Management Plan*, Bligh Tanner). Given the use of treated wastewater for irrigation we have assumed runoff from these ground levels areas is higher than typical urban stormwater runoff from pervious areas (more typical of rural residential runoff where onsite wastewater management and irrigation occurs).

4.1.2 Rainwater tanks

Rainwater tanks will be provided on all allotments to provide each dwelling with a reliable source water for laundry, hot water, kitchen and bathroom use. Details of the rainwater tanks for each dwelling type are provided in other documents (i.e. *Ella Bay Integrated Water Cycle Management Plan*, Bligh Tanner). Based on these other documents we have adopted a minimum 10kL tank for detached dwellings.

4.2 OPERATIONAL STORMWATER QUALITY MANAGEMENT

Stormwater quality management within Ella Bay is to focus on accepting stormwater from the pit and pipe drainage and treating this water in accordance with the objectives listed in Section 4.2.2 for either reuse or discharge from the site. Stormwater quality treatment is to consist of swales (some with bioretention), constructed wetlands, and bioretention basins integrated into the open space areas as indicated in Figure 12.

4.2.1 Vegetated swale

Vegetated conveyance swales are to be integrated into the open spaces throughout the northern precinct as shown in Figure 12. The swales will have a gentle grade allowing some level of stormwater treatment through the process of sedimentation. Where level allows, some of the swales will have bioretention trenches in the base providing further fine filtration and treatment of stormwater.

4.2.2 Bioretention Basins

Bioretention basins will play a key role in the stormwater strategy by providing treatment of stormwater runoff as shown in Figure 12. Bioretention basins operate by capturing and ponding runoff (0.3 m extended detention depth) and percolating stormwater through a defined filter media (loamy sand topsoil). Filtered stormwater is then recovered at the base of the filter media via a drainage layer containing slotted PVC pipes. The surface of the bioretention basin is densely planted with ground level grasses and rushes and may also contain selected tree species (e.g. *Melaleuca* species). The agitation of the surface of the bioretention system caused by movement of the vegetation and the growth and die off of root systems prevents accreted sediments clogging the surface of the bioretention trench.

Figure 13 below provides a typical section through a bioretention basin.

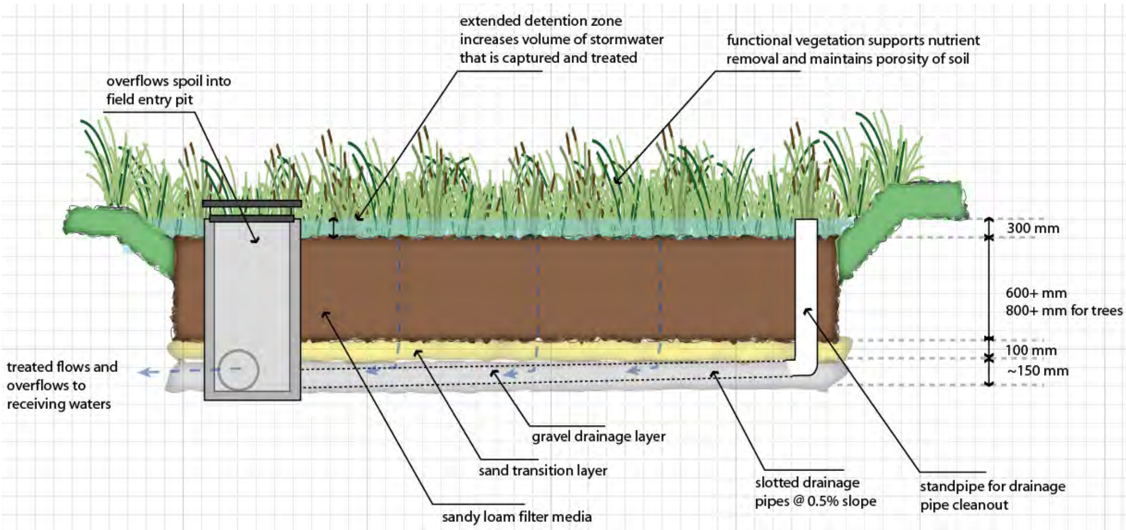


Figure 13 Typical Section through Bioretention Basin

Treatment of the stormwater occurs both on the surface of the bioretention basins and within the filter media. When large storm inflows cause temporary ponding on the surface of the basin, pollutants are removed from the stormwater through sedimentation and particulate adhesion onto the stems and leaves of the vegetation. As stormwater percolates through the filter media, fine particulates and some soluble pollutants are removed through processes such as adhesion on to the surface of the filter media particles, biological transformation of pollutants by biofilms growing on the surface of the filter media particles, and biomass uptake of nutrients and metals through the root systems of the

vegetation growing in the garden.

The nature of the bioretention basins, being planted soil profiles, means there is a reasonable amount of flexibility regarding the size, shape and location of the systems. As such, there are opportunities to integrate the bioretention basins as landscape features within the overall development layout. DesignFlow worked closely with the engineers (Bligh Tanner) and urban planners and landscape architects (DBI) to identify the location, configuration and form of the bioretention basins to integrate and compliment the other landscape and POS functions. The photos above illustrate the typical landscape finish for the bioretention basins.

The location and size of the bioretention basins within the Ella Bay development are presented in Figure 12. The conceptual design of the basins required consideration of the following issues:

- The invert levels of the receiving waterways to ensure there is enough level different between proposed earthworks, drainage pipe level and receiving waterways to support bioretention basins.
- Proposed catchment and drainage pipe configurations.
- Proposed urban design and road locations.
- Proposed public open space precincts (i.e. ensure appropriate space for active open space and bioretention basins).

For the purposes of this stormwater strategy we have not provided detailed concepts and sections for all the bioretention basins but DesignFlow has confirmed the bioretention basins are able to function in the context of the proposal earthworks (i.e. sufficient area and level difference is available to deliver proposed bioretention systems with proper landscape integration).

Key bioretention parameters for the Ella Bay Northern Precinct Bioretention basins:

- Standard bioretention profile (i.e. no saturated zone)
- Filter media
  - FAWB specifications (FAWB, 2009)
  - 600 mm deep
- Transition (coarse sand) layer 100mm deep – constant depth
- Drainage layer 150-200 mm deep (min 50mm cover over slotted PVC pipes)
- Base grades at 0.5% towards pit with impervious/pervious liner as required

4.2.3 Constructed Wetlands

Constructed wetlands remove pollutants from stormwater through a range of physical, chemical and biological processes that occur in the plants, water column and in the sediments. The location and size of the bioretention basins within the Ella Bay development are presented in Figure 12. Constructed wetlands comprise a number of elements that protect and enable function but their design also needs to consider some of site-specific issues such as interactions with groundwater, high flows and landscape.

Protection from High Flows and Sediment

Constructed wetlands are very robust systems that can withstand a number of pressures. High flows and sediment can both reduce the effectiveness of and ultimately degrade the system such that restoration will likely be required. In order to operate effectively and be long-lived, the macrophyte zone of a wetland needs to be protected from:

- flows which have not been pre-treated to remove approximately 80-90% of coarse sediment from stormwater and
- high flows which may scour the base and plants within the system

The high flow bypass system will be densely vegetated flat waterways (max 1m deep and 1 in 8 batters or flatter). The vegetation within the waterways will recreate the endemic melaleuca wetland template of the site. Suitable space has been provided in the design for the densely vegetated high flow bypass systems.

Maintenance access

Good wetland design provides upstream coarse sediment management and protection of the macrophyte zone from high flows. In addition, the design of the constructed wetland systems needs to adequately consider access for maintenance. This is proposed through the following measures:

- **Access around perimeter** on bunds. For wetlands in the development footprint, wide gravel tracks around the entire perimeter of the system on top of bunds will be provided for both maintenance and passive recreation purposes. For the wetland in the conservation covenant (wetland NWR5), informal access will be provided into the system to allow inspection and ongoing weed management.

- **Access to inlet ponds**. Access is to be provided at maximum 1 on 6 grade into the base of all inlet zones to allow silt removal. The path into the system is to be reinforced turf or gravel above the water level and concrete to the base.

This allows easy access to and removal of silt which is typically an annual maintenance requirement. The inlet ponds have been located within the golf course or development zones to allow for access 1 in 5 years. No inlet ponds are located within environmental corridors.

- **Access to structures.** Convenient access to all structures that allow maintenance draining / dewatering and also outlet structures (water level control and weirs).

Bathymetry

Seasonal wetting and drying cycles are likely to have an impact upon wetland vegetation if the outlets and bathymetry (earthworks / floor levels) of the wetland are not designed carefully. Wetting and drying spells analysis will be undertaken as part of detailed design which takes into account expected inflows, evaporation, outlet controls and potential interactions with groundwater.

Landscape integration

The conceptual designs for the wetlands have been developed in collaboration with DBI to integrate into the open spaces which are located in and around the golf course and open space areas. The constructed wetlands will dominate the open space in the flat areas adjacent to the natural wetland and have been carefully considered to relate with and protect these ecosystems. In addition, careful selection of plants will be required to ensure integration with the existing wetlands and success of wetland plants.

Permanent water

All the constructed wetlands in Ella Bay will hold water permanently. This will be achieved by sealing the base of the wetland across the permanent water width.

Having a permanent water will also mean the wetland will provide a source of water to the local Cassowaries. The proposed wetlands are ideally located adjacent to and within existing vegetation corridors for this purpose. Collaboration with ecologist will occur as part of the wetland design to ensure the wetland permanent water can be readily access by Cassowaries.

Mosquito management

A Vector Management Plan (VMP) was prepared for the Ella Bay development by McGinn (2010). The VMP included a mosquito risk assessment, and identified issues to be addressed within the development design and general strategies for mosquito control.

The VMP identified three habitat types considered relevant to the presence of mosquitoes at Ella Bay: rainforest, freshwater wetland and mangrove wetland. The construction of stormwater treatment systems within the Ella Bay development will increase the abundance of freshwater wetland habitat within the site; however the total area associated with treatment wetlands is minor in comparison to the surrounding natural freshwater wetland habitats.

The mosquito risk assessment identified the presence of freshwater habitats during the wet season as likely to provide suitable breeding habitat for mosquito species such as *Culex annulirostris* (commonly found throughout northern Queensland) and *Anopheles farauti* (a potential vector of malaria).

Aedes aegypti (vector for Dengue fever) is also known to breed in freshwater habitats, however this species breeds almost exclusively within urban environments with artificial water bodies such as garden accouchements and building fittings, and its presence is unlikely to be influenced by the presence of stormwater treatment systems.

The VMP identified a number of design features that will reduce opportunities for mosquitoes to breed in the stormwater treatment systems:

- Provision of steep batters to minimize shallow water suited to mosquito breeding.
- A minimum water depth of 500 mm except for the margins.
- Basin margins to be unvegetated (no shrubs or trees) to improve opportunities for wind action to keep the water surface disturbed to reduce availability to mosquito larvae.
- Aquatic macrophytes to be planted in no more than 60% of the shallow water (<500 mm depth) around the margin.
- Macrophytes should be clumped with separations of open water allowing wind disturbance on the water surface.
- Detention basins and swales to be empty of surface water in less than seven days to prevent completion of mosquito breeding cycles.
- Stormwater traps and sumps should be free draining without holding water.

Mosquitoes and constructed wetlands

There is little information available within the scientific literature concerning the presence of mosquitoes within constructed wetlands (see review - Willott, 2004).

Greenway et al., (2003) investigated constructed wetlands in tropical Australia and found that wetlands with the greatest biodiversity of macrophytes (type, species and cover) and macroinvertebrates had the least number of mosquito larvae. They suggested that the presence of mosquito larvae within wetlands can be minimized by increasing macroinvertebrate biodiversity by planting a variety of macrophyte species, excluding aggressive plant species, and maintaining at least 30% open water. Similar linkages between vegetation heterogeneity and increased diversity and abundance of macroinvertebrate predators have also been noted by Carlson et al. (2004), Culler and Lamp (2009), Langellotto and Denno (2004) and Mogi (2007).

The natural suppression of mosquitoes within the treatment wetlands at Ella Bay will be facilitated by providing habitat conditions that favor diverse and abundant macroinvertebrate predator populations. The key elements of the wetland designs adopted for the development will include:

- Structural complexity – provision of a broad range of depth regimes, and vegetated and open water areas.
- Increased macrophyte diversity - establishment of diverse emergent and submerged macrophyte populations.

4.2.4 Note on Gross Pollutant Traps

It is not considered necessary to provide gross pollutant traps within any of the drainage at Ella Bay. The reasoning for this is twofold:

- Monitoring undertaken by Brisbane City Council of GPTs receiving runoff from residential catchments has found that generally less than 5% by weight of gross pollutants captured within GPTs is anthropogenic (i.e. plastic, paper). The vast majority of the captured material is organics (i.e. leaf litter) or coarse sediment. This indicates the development density associated with residential allotments, coupled with the high level of general house and yard keeping by individual householders is resulting in only a low generation of anthropogenic litter.

- The BCC monitoring and observations noted in Hunter indicates that when this organic material is captured in wet vault type GPTs there is a tendency for this material to transform under anaerobic conditions to more bioavailable forms of nutrients. This can result in a net export of nutrients in a form that is more deleterious to downstream ecosystems. Hunter concludes that stormwater management needs to target the various forms of gross litter using appropriate management responses. Removal of gross litter from residential catchments, which contain a high proportion of organics, should only occur through aerobic systems.

In response, the stormwater Strategy for Ella Bay does not adopt GPTs but rather applies the following approaches for capturing gross litter and coarse sediment from the residential catchments:

- Gross litter, which is predominantly organic, is to be captured in aerobic conditions within the vegetated swales, bioretention basins and inlet ponds to wetlands. This effectively precludes the discharge of anthropogenic litter to downstream environs. Any accumulation of litter will be removed by hand as part of general landscape maintenance.

5 ASSESSMENT OF WSUD & STORMWATER STRATEGY PERFORMANCE

5.1 STORMWATER QUALITY

The performance of the WSUD stormwater strategy described in Section 4 has been assessed using Version 4 of the MUSIC model developed by eWater. The assessment focused on the stormwater quality elements of the WSUD Strategy in relation to the WSUD objectives listed in Section 3. MUSIC model parameters were adopted according to the *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2010). The results below (Table 5) demonstrate that the proposed stormwater strategy achieves the objectives set for the site.

A comprehensive summary of the approach and results is provided in Appendix A.

Table 5– Results from MUSIC Modelling

Catchment	Catchment Area (ha)	Bio ID	Filter media Area (m^2)	Wetland ID	Macrophyte zone area (m2)	TSS Load Reduction	TP Load Reduction	TN Load Reduction
Northern Resort	5.4	-	0	Resort Wetland	4235	93.3	70.4	39.3
RR6	4.19							
RR1	4.35	-	0	NWR Wetland 5	10825	90.5	71.4	36.3
RR2	0.74	-	0					
NWR5	10.02	NWR5	75					
RR3	0.41	Bio RR3	65	-	0	81.8	65.8	36.5
RR4	0.93	Bio RR4	150	-	0	78.9	63.3	35.6
RR5	0.96	Bio RR5	180	-	0	84.8	66.1	37.1
NWR1	5.84	-		NWR Wetland 1	4300	81.7	65.4	32.1
NWR2	6.42	Bio NWR2	75	NWR Wetland 2	4500	76.5	58.8	25.7
NWR3	1.93	Bio NWR3	300	-	0	93.3	70.4	39.3
NWR4	3.18	Bio NWR4	450	-	0	79.7	64.6	36.1
NWR6	1.51	Bio NWR6	260	-	0	81.8	65.7	37
NWR7	3.31	-	0	NWR Wetland 3	2200	57.4	49.6	24.7
Total*	**49.19**	-	**1555**	-	**26060**	**85**	**66.1**	**35**
				Load Reduction Objective		**75**	**60**	**35**

Comparison objectives

While it is generally not appropriate to use concentration-based objectives for receiving waters as a discharge objective (Section 3), it is useful to compare the discharge concentrations of key pollutants from the developed site with several possible existing case scenarios. The water quality objectives for the site have been taken from the *Queensland Water Quality Guidelines 2009* (DERM, 2009) regional values for freshwater lowland streams and wetlands. MUSIC models were set up with the same catchment areas as the developed situation described above with rural, agricultural and forest landuses. As shown in Tables 6 and 7 below, the results of the modelling show that runoff from a forested catchment typically generates pollutant runoff concentrations that are generally within the guideline receiving water quality objectives. Rural, agricultural and developed catchments exceed these concentrations, however pollutant runoff concentrations from the developed catchments whilst above the guideline receiving water quality objective, are typically more than forested but less than agricultural catchments of the same area.

Table 6 Comparison of 50%ile concentrations (50^{th} %ile of the daily flow weighted mean)

		TSS (mg/L)	TP (mg/L)	TN (mg/L)
Rural	North wetland	4.10	0.046	0.48
	East	4.11	0.046	0.48
	Site	4.06	0.045	0.47
Agriculture	North wetland	10.72	0.074	0.74
	East	10.72	0.074	0.74
	Site	10.47	0.074	0.74
Forest	North wetland	3.99	0.020	0.29
	East	4.22	0.021	0.29
	Site	3.99	0.020	0.29
Developed (and mitigated)	North wetland	8.91	0.085	1.17
	East	4.41	0.051	0.959
	Site	4.88	0.053	0.964
Objectives	**Water Quality Objectives (for wetlands)**	**15***	**0.01 – 0.05**	**0.35 – 1.20**
	Water Quality Objectives (for freshwater lowland streams)	**15***	**0.01**	**0.24**

*note that no data for SS is available in the QWQG for the wet tropics

Table 7 Comparison of 90%ile concentrations (90% of the daily flow weighted mean)

		TSS (mg/L)	TP (mg/L)	TN (mg/L)
Rural	North wetland	317	0.325	2.52
	East	332	0.329	2.56
	Site	332	0.329	2.56
Agriculture	North wetland	363	0.383	2.23
	East	369	0.388	2.26
	Site	370	0.389	2.26
Forest	North wetland	4.27	0.021	0.308
	East	4.22	0.021	0.306
	Site	4.19	0.021	0.304
Developed (and mitigated)	North wetland	12.8	0.098	1.40
	East	15.3	0.103	1.33
	Site	15.4	0.103	1.33
Objectives	Water Quality Objectives (for wetlands)	15*	0.01 – 0.05	0.35 – 1.20
	Water Quality Objectives (for freshwater lowland streams)	15*	0.01	0.24

*note that no data for SS is available in the QWQG for the wet tropics

Pollutant load comparisons using the model as described above demonstrate that pollutant loads from the developed site are less than forest (80%) for TSS, but approximately double the pollutant loads for TP and TN (Table 8). The load comparison also shows that the developed site generates approx. 13%, 40% and 70% of the TSS, TP and TN loads generated by rural and agricultural catchments.

Table 8 Comparison of loads

		TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Rural	North wetland	227000	214	1660
	East	124000	116	916
	Site	351000	330	2580
Agriculture	North wetland	241000	251	1450
	East	133000	139	800
	Site	374000	390	2250
Forest	North wetland	37500	41.5	461
	East	20400	22.8	255
	Site	57900	64.2	716
Developed (& mitigated)	North wetland	20500	54.6	522
	East	25600	84.5	1130
	Site	46100	139	1650

5.2 HYDROLOGY (NORTHERN WETLAND)

Performance assessment of the stormwater strategy in terms of meeting the hydrologic objectives to the Northern Wetland was undertaken using the MUSIC models setup for water quality assessment. Model assumptions were based on *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2010).

As outlined in Section 2.2.2, the Ella Bay development catchment of 31.8ha draining to the Northern Wetland represents only a small portion of the overall catchment of 836ha. Therefore, any change in hydrology on Ella Bay will be insignificant in relation to the larger catchment hydrology to the Northern Wetland. Regardless of this, significant effort has been made to ensure the local hydrology leaving the Ella Bay to the Northern Wetland is managed.

The following scenarios were assessed:

1. Local Catchment to Northern Wetland (31.8ha) – Simulate the hydrology of the local Ella Bay catchment to the wetland.

    i. Pre development catchment – 31.78ha draining to the wetland assumed to be rural landuse.

    ii. Post development catchment – 14.19ha assumed to be urban landuse with rural ground level parameters (to simulate high loading from recycled water irrigation). The remaining 17.59ha is diverted through stormwater treatment to Farm Creek.

2. Whole Catchment to Northern Wetland – Simulate the hydrology of the whole catchment to wetland (836ha):

    i. Pre development catchment – 31.78ha draining to the wetland assumed to be rural landuse with the remaining 804ha assumed to be forest landuse.

    ii. Post development catchment – As per scenario 1. ii) plus the additional 804ha assumed to be forest.

The results of the modeling were post processed to generate the relevant flow duration curves and low flow spells curves.

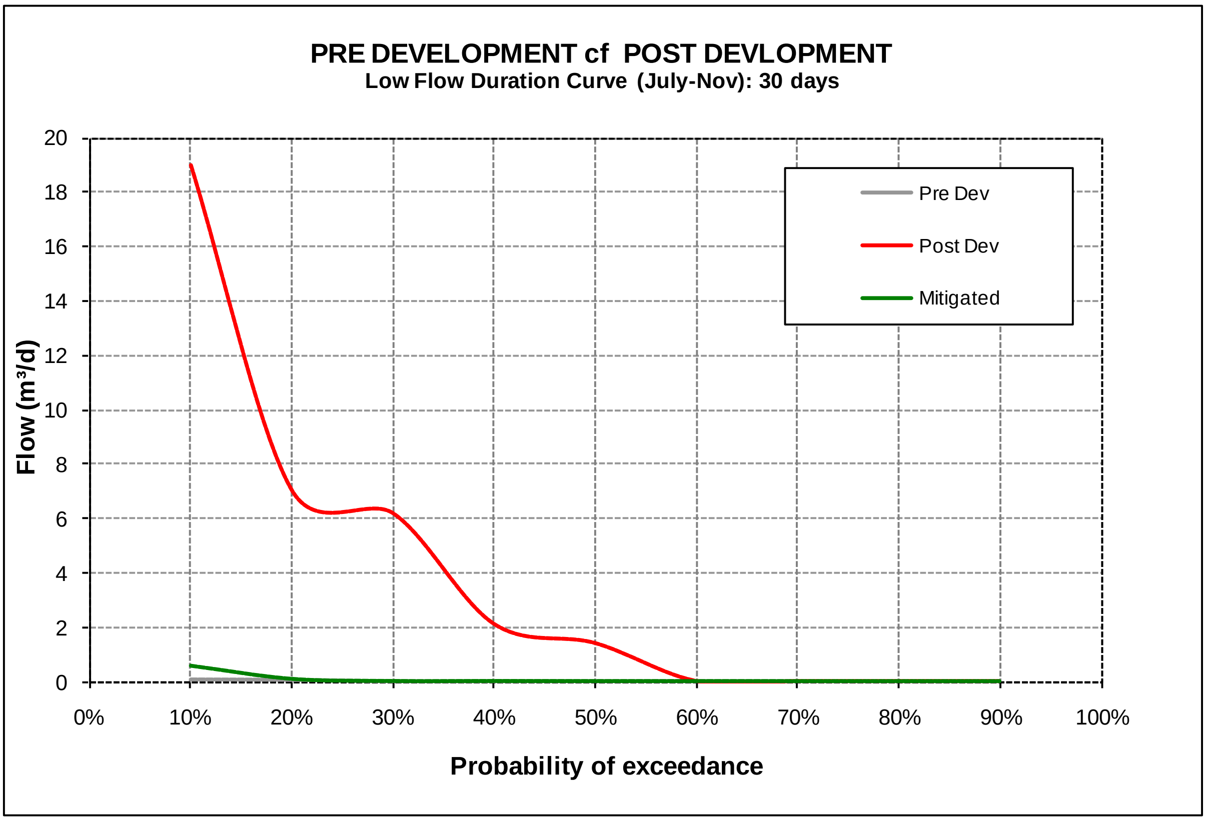
Local Catchment to Northern Wetland

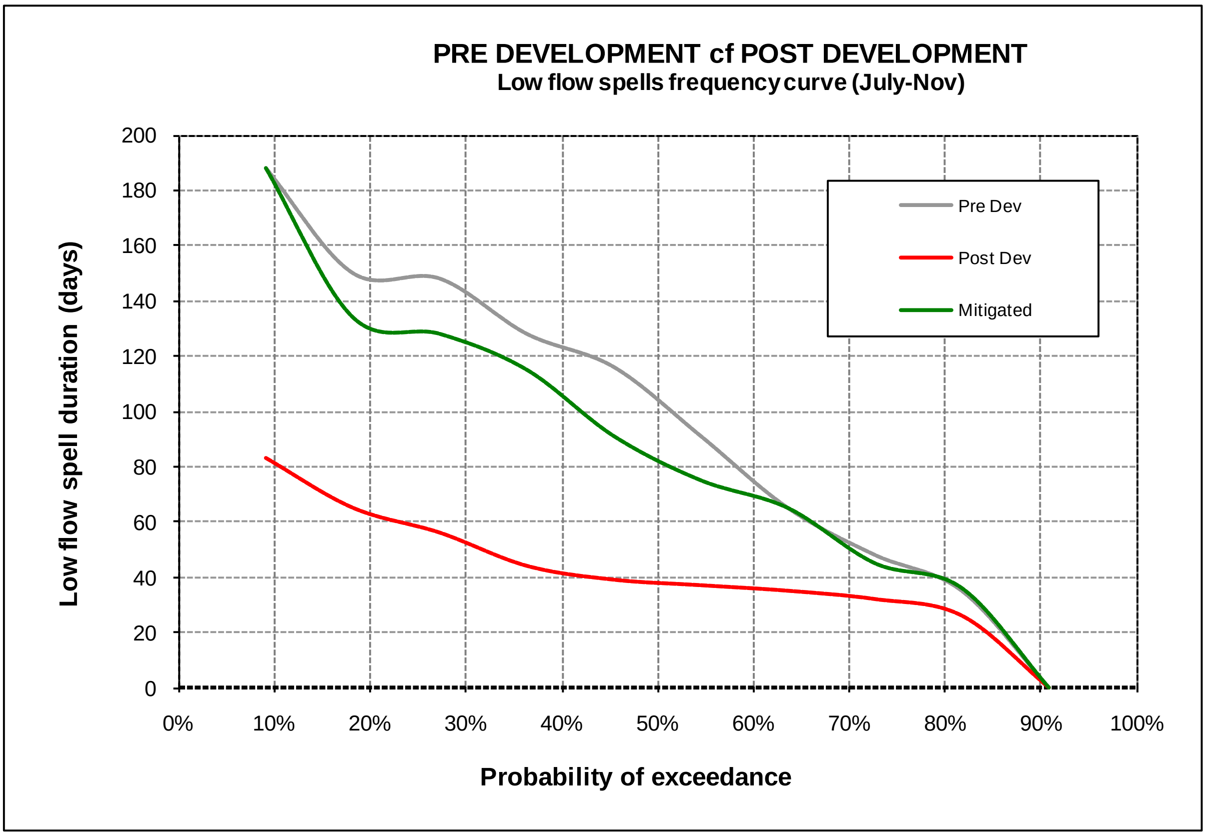
Results of the local catchment modelling (31.8ha) modelling are presented in the three plots below. The following conclusions can be drawn from the results:

- If left un-mitigated, runoff from Ella Bay will result in wetter conditions and shorter dry periods during the dry season (i.e. changed dry season conditions). However, dryer conditions will occur during the wet season. The reason for the dryer conditions in the wet season is the reduction in the catchment drain to the northern wetland from 31.78ha to 14.19ha.

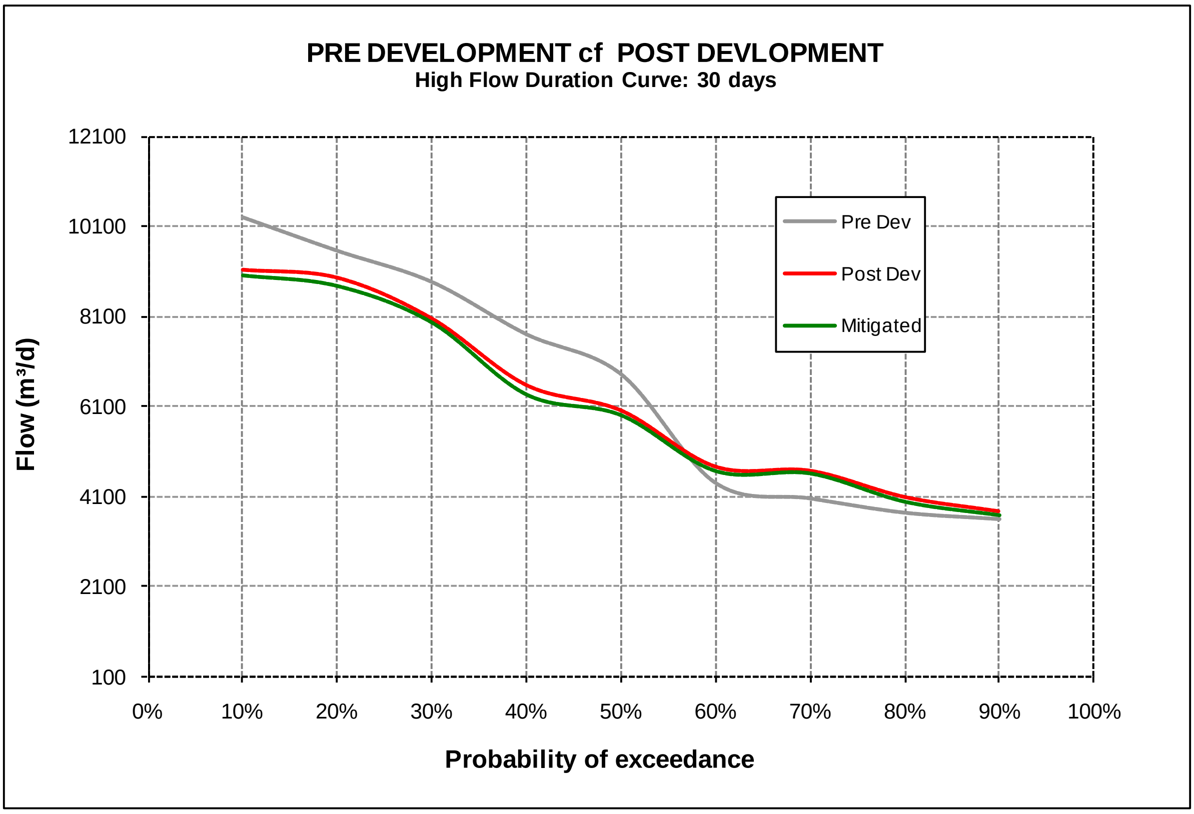
- Introduction of the stormwater strategy ensures the dry season duration and low flow spells (dry periods) are essentially preserved thus meeting the objectives. However, dryer conditions will occur during the wet season for the same reason explained above. Given the very wet conditions during the wet season and the small nature of this catchment in the contact of the large 836ha, these slightly dryer conditions from the local are not expected to impact the Northern Wetland.

- If required a diversion strategy can be implemented within the stormwater strategy to deliver more stormwater to the northern wetland during the wet season.





PRE DEVELOPMENT cf POST DEVELOPMENT
Low flow spells frequency curve (July-Nov)
Low flow spell duration (days)
200
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of exceedance
Pre Dev
Post Dev
Mitigated



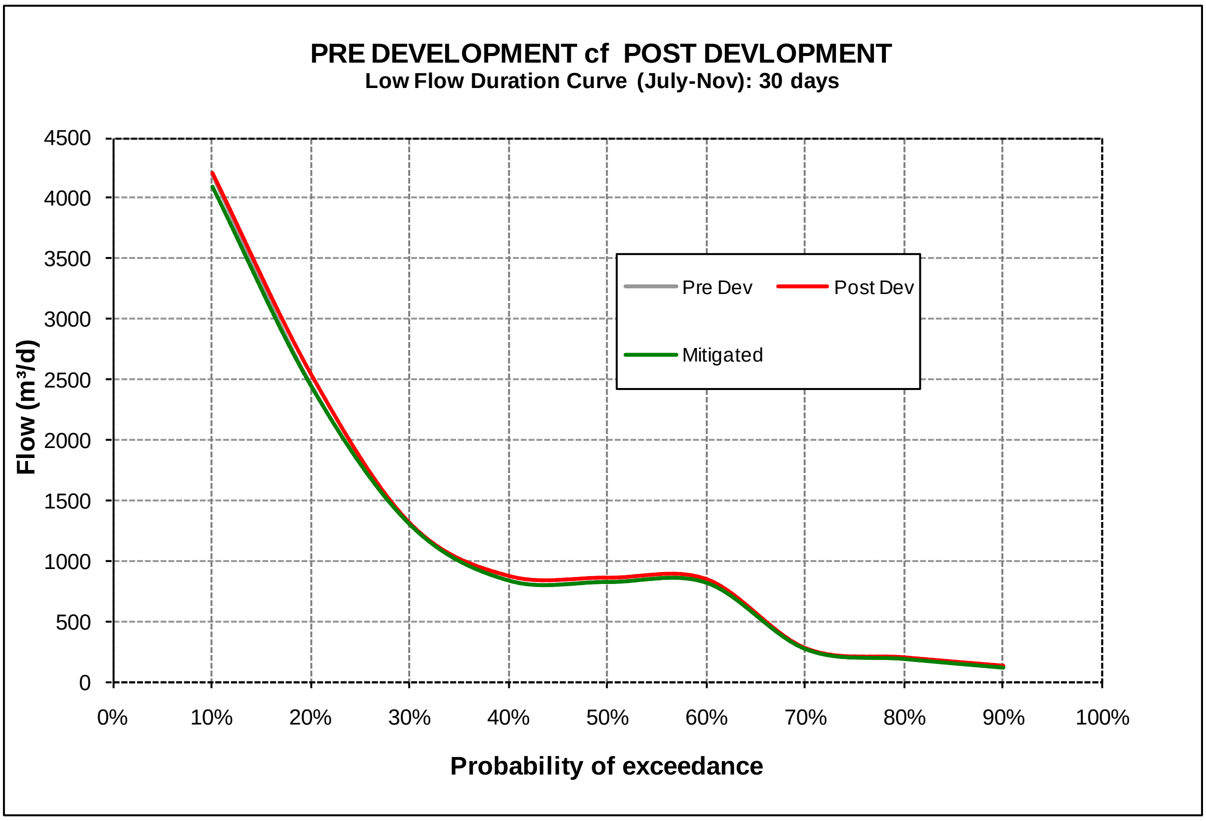
PRE DEVELOPMENT cf POST DEVLOPMENT
High Flow Duration Curve: 30 days
Flow (m³/d)
12100
10100
8100
6100
4100
2100
100
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of exceedance
Pre Dev
Post Dev
Mitigated

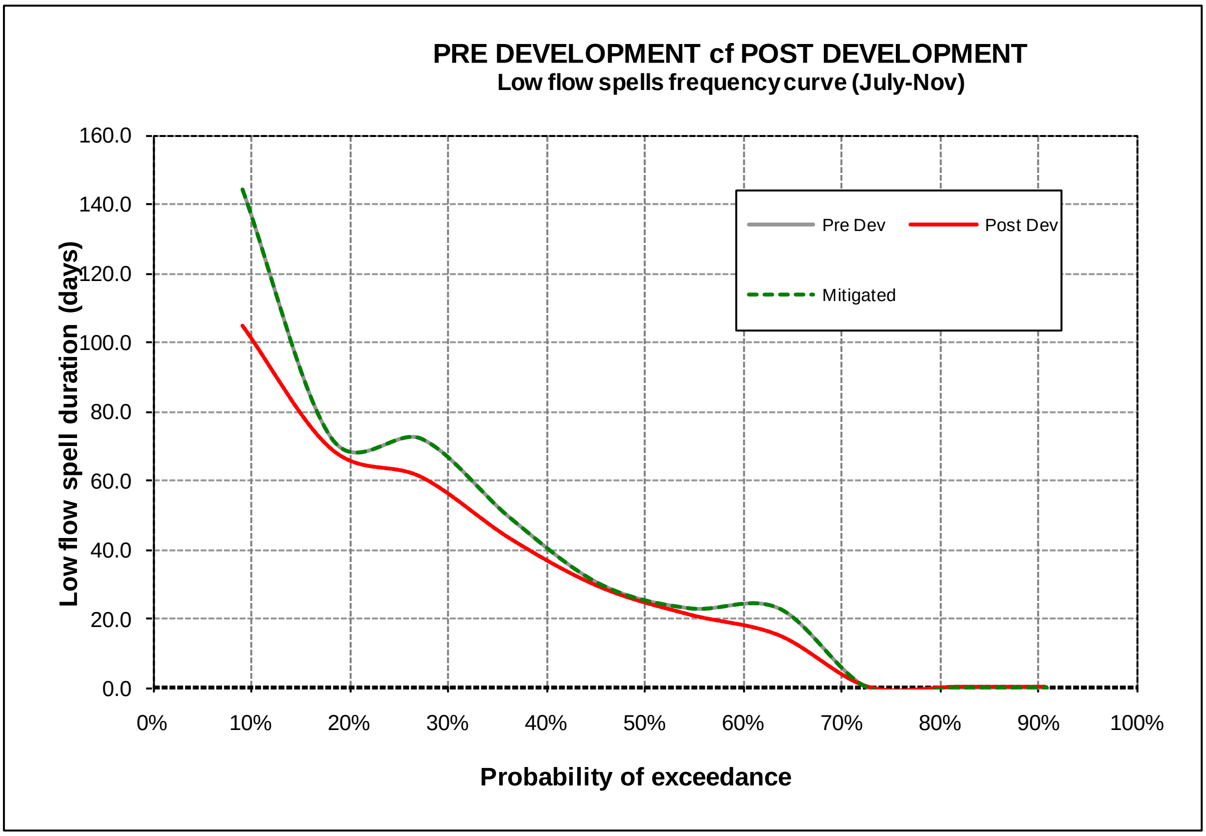
Whole Catchment to Northern Wetland

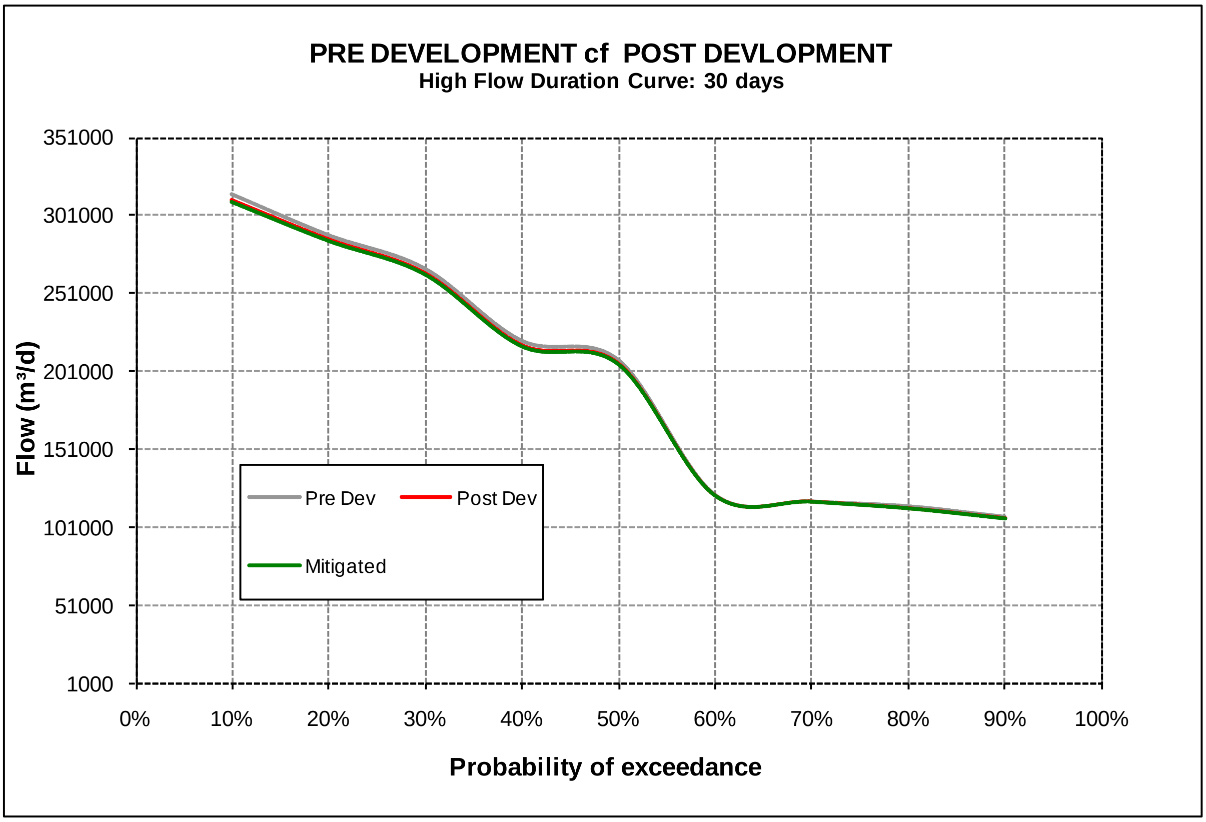
Results of the whole catchment modelling (836ha) modelling are presented in the three plots below. The following conclusions can be drawn from the results:

- If left un-mitigated, runoff from Ella Bay will produce very little change to the overall hydrology of the wetland. The major change will be the reduction in dry spells as indicated into the low flow spells curve. This indicated the surface flows from impervious area within Ella Bay would create runoff which would otherwise not have runoff under pre-developed conditions.

- Introduction of the stormwater strategy ensures the overall hydrology associated with the whole catchment is preserved. All of the flow duration and low flow spells curve characteristics are matched. thus meeting the objectives.




PRE DEVELOPMENT cf POST DEVELOPMENT
Low flow spells frequency curve (July-Nov)
Low flow spell duration (days)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of exceedance
Pre Dev
Post Dev
Mitigated


PRE DEVELOPMENT cf POST DEVLOPMENT
High Flow Duration Curve: 30 days
Flow (m³/d)
351000
301000
251000
201000
151000
101000
51000
1000
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of exceedance
Pre Dev
Post Dev
Mitigated

6 CONSTRUCTION, ESTABLISHMENT & MAINTENANCE

6.1 CONSTRUCTION & ESTABLISHMENT

Experience gained from other development sites across Queensland has resulted in a comprehensive understanding of the methods required for the successful construction and establishment of WSUD systems. A detailed Construction and Establishment Method for the Ella Bay WSUD Systems will be documented as part of the detailed design process and will be submitted to Council with the applications for Operational Works Approval. The construction and establishment approach will be consistent with the guidance provided in *Construction and Establishment Guidelines – Swales, Bioretention Systems and Wetlands* (Water by Design, 2010).

6.2 MAINTENANCE

WSUD infrastructure such as bioretention basins require ongoing inspection and maintenance to ensure they establish and operate in accordance with the design intent. Potential problems associated with WSUD as a result of poor maintenance include:

- Decreased aesthetic amenity;
- Reduced functional performance;
- Public health and safety risks; and
- Decreased habitat diversity (dominance of exotic weeds).

Detailed maintenance schedules will be developed for the Ella Bay Bioretention Systems during construction. These maintenance schedules will be refined as part of Operational Works to establish Maintenance Plans for each of the WSUD elements in collaboration with Council assets and maintenance departments to ensure the structure and frequency of maintenance is consistent with current Council procedures. This will also provide an opportunity for transfer of knowledge in this regard to allow Council to effectively operate the WSUD infrastructure. Maintenance guidance will be produced that is consistent with the upcoming *Maintenance Guideline for WSUD Assets* (Water by Design, to be released early 2011).

It should be noted that once established, bioretention systems and wetlands will require relatively low levels of maintenance. The predominant maintenance activity in these systems is weed management and sediment removal from inlet areas such as coarse sediment forebays and inlet ponds)

7 CONCLUDING REMARKS

A WSUD and stormwater management strategy has been developed for Ella Bay that delivers the objectives for urban stormwater quality improvement set in Section 3. After considering several approaches to stormwater management, this strategy is the best outcome for the site given the key constraints of climate and flat topography. By using an approach that harnesses the synergies between the objectives of potable water conservation, stormwater quality, waterway stability management and landscape design, this WSUD strategy delivers innovative solutions that provide a combination of allotment potable water conservations and precinct-scale management of stormwater integrated into the urban and park landscape.

The measures recommended in this strategy represent current best practice in urban stormwater management, thereby affording appropriate protection to Farm Creek, the natural wetlands on site in addition to Ella Bay and ultimately the Great Barrier Reef Marine Park.

Design development and detailed design of the WSUD Strategy will be undertaken in accordance with *Australian Runoff Quality (ARQ, 2005)* and the *South East Queensland WSUD Technical Design Guidelines (2006).* In addition to the landscape and civil drawings the following documentation will be produced as part of the design development and detailed design for Operational Works Application:

- WSUD Design Report OR Detailed Stormwater Management Plan
- A description of key functional elements
- Refined modelling
- Relevant WSUD Specifications and calculations
- Detailed Sediment and Erosion Control Plan
- WSUD Construction and Establishment Methodology
- Monitoring Plan for the Ella Bay site
- WSUD Maintenance Plans for the specific WSUD elements

8 REFERENCES

AECOM (2008) *Queensland Best Practice Environmental Management Guidelines - Urban Stormwater Technical Note: Derivation of Design Objectives*

3D Environmental (2009) *Vegetation Survey Report of the proposed 'Ella Bay Integrated Resort Project'*. A report prepared for Satori Resorts on behalf of Biodiversity Assessment and Management Pty Ltd. February 2009.

Brisbane City Council (BCC) 2003, Guidelines for Pollutant Export Modelling in Brisbane Version 7 – Draft (October 2003)

BMT-WBM (2007) *Ella Bay – Erosion Prone Area Reassessment*. Report prepared for Satori Resorts.

Carlson, J., J. Keating, C.M. Mbogo, S., Hahindi and J.C. Beier (2004) Ecological limitations on aquatic mosquito predator colonization in the urban environment. *Journal of Vector Control*. 29: 331-339.

Culler and Lamp (2009) Selective predation by larval Agabus(Coleoptera: Dytiscidae) on mosquitoes: support for conservation based mosquito suppression in constructed wetlands. *Freshwater Biology*. 54: 2003-2014.

Cooperative Research Centre for Catchment Hydrology (CRCCH) (2005). *Model for Urban Stormwater Improvement Conceptualisation (MUSIC) User Guide*, Version 3.01, CRCCH, Monash University, Victoria

DERM & EDAW (2009) *Technical Note: Derivation of Design Objectives*

DERM (2009a), *State Planning Policy for Healthy Waters*, Department of Environment and Resource Management

DERM (2009b) *Queensland Water Quality Guidelines 2009*, Version 3, September 2009. Department of Environment and Resource Management

DesignFlow (2009) *Ella Bat Stormwatrer Management Objectives*

Ecological Engineering (2005), *Feasibility Assessment for Proposed Stormwater Management 'Design Objectives' (CCI WSD: Task 9303)*. A report for the Moreton Bay Waterways and Catchments Partnership.

Ecological Engineering (2007a) Water Sensitive Urban Design Solutions for Catchments above Wetlands: Appendix A: Wetlands Classification Scheme. Prepared for the Hunter Central Coast Regional Environmental Management Strategy.

Ecological Engineering (2007b) Water Sensitive Urban Design Solutions for Catchments above Wetlands: Appendix B: Catchment Hydrologic Indices and Urban Water Management Performance Objectives. Prepared for the Hunter Central Coast Regional Environmental Management Strategy.

Ella Bay Developments (2009) *Ella Bay Cassowary Water Survey*. October 2009.

Engineers Australia (2005), *Australian Runoff Quality*, Wong, T.H.F. (ed).

Environmental Protection Agency (2008-2009) *Draft State Planning Policy for Healthy Waters*

Greenway, M., P. Dale and H. Chapman (2003) An assessment of mosquito breeding and control in 4 surface flow wetlands in tropical-subtropical Australia. *Water Science and Technology*. 48: 249-256.

Healthy Waterways (August 2006), WSUD Technical Design Guidelines for South East Queensland

Hunter, Geoffrey, Stormwater Quality Improvement Devices - Issues for consideration

Langellotto, G.A and R.F.Denno (2004) Responses of invertebrate natural enemies to complex-structured habitats: a meta-analytical synthesis. *Oecologia*. 139: 1-10.

Mackay Regional Council (2009) *Stormwater Quality Performance Curves and Stormwater Quality Objectives for Mackay* (April 2009). A report for Mackay Regional Council by DesignFlow.

McGinn (2010) Vector Management Plan: Ella Bay Development. Mosquito Consulting Services Pty Ltd.

Mogi, M. (2007) Insects and other invertebrate predators. *Journal of the American Mosquito Control Association*. 23: 93-109.

Queensland Wetlands Programme (2009a) Wetland Management Profiles – An overview. Report prepared for the Queensland Environmental Protection Agency.

South East Queensland Healthy Waterways Partnership (SEQ HWP 2007), *WSUD: Developing Design Objectives for Water Sensitive Developments in South East Queensland – Version 2, 8th November 2007*

Townsville City Council (2008) *Draft Dry Tropics WSUD Guideline for WSUD Systems*, for WSUD06 Conference

Water by Design (2010) *MUSIC Modelling Guidelines for South-East Queensland*. Healthy Waterways Partnership 2010.

Water by Design (2009) *South East Queensland WSUD Technical Design Guidelines* (2006), and the *Construction and Establishment Guidelines – Swales, Bioretention Systems and Wetlands*

Water by Design (Draft for release 2011) *Maintenance Guideline for WSUD Assets*

Willott, E. (2004) Restoring Nature, Without Mosquitoes? *Restoration Ecology*. 12: 147-153.

APPENDIX A – PERFORMANCE ASSESSMENT

The meteorological data used in modelling is shown in Table A1.

Table A1 – Meteorological and rainfall runoff data used in MUSIC modelling

Input	Data used in modelling
Rainfall Station	32037 South Johnstone Exp Station
Time Step	6-minute
Modelling period	1/1/1996- 31/12/2005
Mean Annual Rainfall (mm)	3167
Evapotranspiration (mm)	1647
Rainfall runoff parameters*	Residential Rural Residential for ground level and roads
Pollutant export parameters*	Residential Rural Residential for ground level and roads

* *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2009).

CATCHMENTS

Source nodes

Source nodes have been split as per the *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2009) with the following areas adopted for the Northern Precinct of the Ella Bay development site. Rural residential parameters have been adopted for ground level and also roads as this type of node better represents the landuse. The following assumptions were made in the calculation of the areas used in MUSIC modelling (Table A2):

Table A2 - Catchment definition reporting

Sub-catchment	Total Area (ha)	Land use	Total % Impervious
Northern Resort	5.40	Residential	22%
RR1	4.35	Residential	31%
RR2	0.74	Residential	32%
RR3	0.41	Residential	41%
RR4	0.93	Residential / golf	14%
RR5	0.96	Residential / golf	15%
RR6	4.19	Residential / golf	18%
NWR1	5.84	golf	0%
NWR2	6.42	Residential	23%
NWR3	1.93	Residential	32%
NWR4	3.18	Residential	30%
NWR5	10.02	Residential/ golf	23%
NWR6	1.51	Residential / golf	26%
NWR7	3.31	Golf	0%
TOTAL	49.19		20%

Catchment split

Catchments are described below with a summary provided in Table A3.

- Roof size was estimated at 200-250 m^2
- Road reserves were measured from the development layout
- Ground level area is estimated as the remainder of the lots

Table A3 - Catchment split

Catchment	Area (ha)			
	Roof	Ground	Road	Total
Northern Resort	1.18	4.22	0	5.4
RR1	0.85	2.70	0.8	4.35
RR2	0.15	0.44	0.15	0.74
RR3	0.02	0.14	0.25	0.41
RR4	0	0.71	0.22	0.93
RR5	0	0.72	0.24	0.96
RR6	0.475	3.265	0.45	4.19
NWR1	0	5.84	0	5.84
NWR2	0.95	4.63	0.84	6.42
NWR3	0.45	1.2	0.28	1.93
NWR4	0.65	2.03	0.5	3.18
NWR5	1.625	7.345	1.05	10.02
NWR6	0.225	1.015	0.27	1.51
NWR7	0	3.31	0	3.31
TOTAL	**6.575**	**37.565**	**5.05**	**49.19**

TREATMENT NODES

Rainwater tanks

Potable water usage reductions will be provided by reticulated recycled wastewater in addition to rainwater tanks on the individual allotments. Assumptions per allotment are summarised below with assumptions for the development summarised in Table A4:

- Roof drains to 10 kL rainwater tank (resort: 200 m^2 roof, residential 250m^2 roof)

- 224 L/household/day for internal use. This corresponds to laundry, kitchen and bathroom use with toilet flushing to occur using recycled wastewater

- No outdoor re-use from the rainwater tanks is assumed as this demand will be supplied through reticulation of recycled wastewater

Table A4 – Rainwater Tank reporting

Parameter	Catchment													
Rainwater Tank ID	**Northern Resort**	**RR1**	**RR2**	**RR3**	**RR4**	**RR5**	**RR6**	**NWR1**	**NWR2**	**NWR3**	**NWR4**	**NWR5**	**NWR6**	**NWR7**
Number of Allotments	59	34	6	1	0	0	19	0	38	18	26	65	9	0
Catchment Area (ha)[1]	1.18	0.85	0.15	0.02	0	0	0.475	0	0.95	0.45	0.65	1.625	0.225	0
Tank Volume (kL)	590	340	60	10	0	0	190	0	380	180	260	650	90	0
Depth above overflow (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Equivalent pipe diameter (mm)	691	525	220	90	0	0	392	0	555	382	459	726	270	0
Surface area (m^2)	295	170	30	5	0	0	95	0	190	90	130	325	45	0
Daily demand	13.216	7.616	1.344	0.224	0	0	4.256	0	8.512	4.032	5.824	14.56	2.016	N/A
Annual Demand (kL/yr) (scaled to PET-rain)	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1] 50% of the roof area or 150 m^2 per allotment is assumed to drain to the rainwater tanks

2 One 10 kL rainwater tank is provided per allotment

Swale node reporting

Swales will be used in different parts of the Northern Precinct to convey stormwater and treat runoff prior to discharge to wetlands. Key parameters adopted for modelling are shown in Table A5 below. As per the SEQ MUSIC Modelling guidelines, approximately 50% of the length of the swales measured from the concept plans was assumed for the modelling.

Table A5 – Swale node reporting

Swale ID	NWR2	NWR Wetland 2 swale	NWR5 swale	NWR7 swales	Resort Residential Bypass Channel	RR1 Swale	RR6 Swale	Northern Resort Bypass Channel	Resort Swales
Length (m)	150	100	150	100	200	50	100	200	100
Bed slope (%)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Base width (m)	1	4	1	0.5	10	0.5	3	10	0.5
Top width (m)	5	8	5	3	16	3	5	16	3
Depth (m)	0.5	0.5	0.5	0.3	0.5	0.3	0.3	0.5	0.3
Vegetation height (m)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Exfiltration rate (mm/hr)	0	0	0	0	0	0	0	0	0
Bioretention filter area (if applicable) (m^2)	75	0	75	0	0	0	0	0	0
Low flow bypass (m^3/s)	0.004	0	0.004	0	0.031	0	0	0.012	0

Bioretention

The Version 4 bioretention node has not been used in MUSIC modelling. Following the release of Version 4 of MUSIC, eWater released an updated bioretention node which is based on the Version 3 node (http://waterbydesign.com.au/interimnode/). This 'interim' node is recommended for use by Water by Design until the Version 4 node is further investigated and has been used in the assessment of the stormwater management strategy for the Northern Precinct of Ella Bay. A summary of the modelling parameters used for the bioretention basins at the Northern Precinct of Ella Bay and the overall MUSIC model is provided in Table A6 and Figure A1. **Note that for assessment purposes the node should not be 'upgraded' to a Version 4 node when loading the model.**

Table A6 – Bioretention node reporting

Bioretention Basin ID	Bio NWR3	Bio NWR4	Bio NWR6	Bio RR3	Bio RR4	Bio RR5
Catchment Area (ha)	1.93	3.18	1.51	0.41	0.93	0.96
Filter Area (m^2)	300	450	260	65	150	180
Surface Area (m^2)	300	450	260	65	150	180
Check that appropriately sized (% Catchment area)	1.55%	1.42%	1.72%	1.59%	1.61%	1.88%
Extended detention Depth (m)	0.3	0.3	0.3	0.3	0.3	0.3
Saturated hydraulic conductivity (mm / hr)*	200	200	200	200	200	200
Filter depth (m)	0.6	0.6	0.6	0.6	0.6	0.6
Overflow weir width (m)	30	45	30	20	20	20

Inlet ponds (Sediment Basins)

Inlet ponds have been provided for the constructed wetlands where protection of the wetlands is required from coarse sediment. The wetland node in the MUSIC model includes an allowance for inlet ponds, but because of the complex relationship between catchments and inlet zones, these have been modelled separately. Details of the adopted parameters are shown in Table A7 below.

Table A7 –Sediment pond reporting

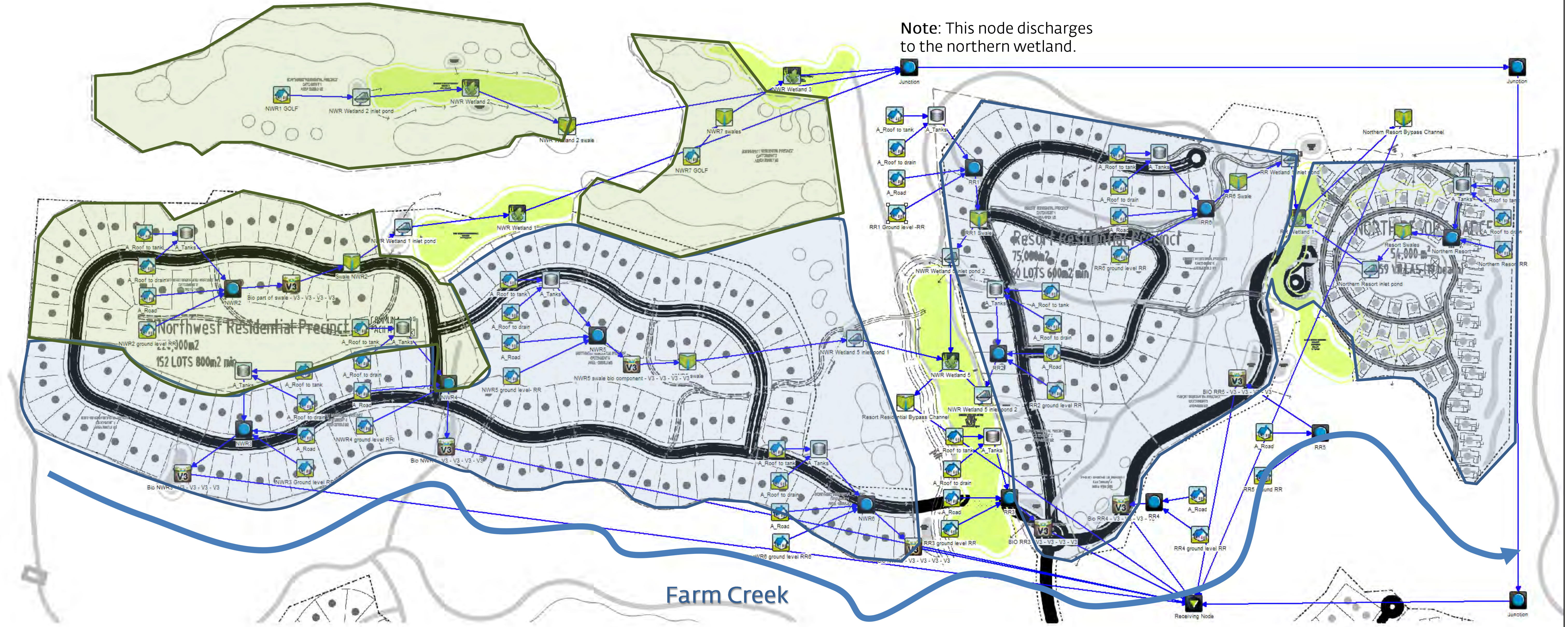
INLET POND ID	NWR Wetland 1 inlet pond	NWR Wetland 2 inlet pond	NWR Wetland 5 inlet pond 1	NWR Wetland 5 inlet pond 2	RR Wetland 1 inlet pond	NWR Wetland 5 inlet pond 3	Northern Resort inlet pond
Surface Area (m^2)	475	360	1000	333	350	137	4000
Check that appropriately sized (capture 80% fine sand)	475	360	650	200	350	75	400
Extended detention Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Permanent Pool Volume (m^3)	600	500	1500	450	500	200	4000
Exfiltration rate (mm/hr)	0	0	0	0	0	0	0
Evaporative Loss (% PET)	100	100	100	100	100	100	100
Equivalent Pipe Diameter (m)	100	100	150	80	80	50	250
Overflow weir width (m)	50	40	100	40	35	15	400
Notional detention time (h)	4	3	3.75	4.4	4.1	4.6	4.2
Number of CSTR Cells	2	2	2	2	2	2	2
Default K and C* values	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Constructed wetlands

A summary of the modelling parameters adopted for constructed wetlands is provided in Table A8.

Table A8 – Constructed wetland node reporting

Constructed Wetland ID	NWR1	NWR2	NWR3	NWR5	Resort	Total
Catchment area (ha)	6.42	5.84	3.31	14.77	9.73	6.42
Macrophyte Zone Area (m^2)	4300	4500	2200	10826	4235	4300
Check that appropriately sized (% Catchment area)	6.7%	7.7%	6.6%	7.3%	4.4%	6.7%
Extended detention Depth (m)	0.5	0.5	0.5	0.5	0.5	0.5
Permanent Pool Volume (m^3)	1300	1350	660	3250	1270	1300
Average Permanent pool depth (m)	0.30	0.30	0.30	0.30	0.30	0.30
Exfiltration rate (mm/hr)	0	0	0	0	0	0
Evaporative loss (% PET)	100	100	100	100	100	100
Equivalent Pipe Diameter	87	90	62	137	86	87
Overflow weir width (m)	430	450	200	1000	400	430
Notional Detention time (h)	48	47	48	49	48	48



Note: The positioning of the receiving node is not intended to be geographically realistic, however allows assessment of the overall strategy for the site in a modelling context.

Project:	Report:	Figure A1:	Date:
Ella Bay Northern Precinct	Ella Bay Northern Precinct Draft Stormwater Quality Management Plan (DesignFlow, 2010)	MUSIC Modelling Layout	30/3/11
			Scale:
			NTS

RESULTS

As discussed in Section 4, there was a need to re-examine the pollutant load reduction objectives as they relate to the Ella Bay development site. The reasons for this change are provided in detail in Section 3 of the report.

Table A9 below summarises the pollutant load reductions predicted by MUSIC for the WSUD Strategy and show that the adopted objectives are achieved for the proposed development.

Table A9 – Stormwater quality treatment performance (load reductions)

Catchment	Catchment Area (ha)	Bio ID	Filter media Area (m^2)	Wetland ID	Macrophyte zone area (m2)	TSS Load Reduction	TP Load Reduction	TN Load Reduction
Northern Resort	5.4	-	0	Resort Wetland	4235	93.3	70.4	39.3
RR6	4.19							
RR1	4.35	-	0	NWR Wetland 5	10825	90.5	71.4	36.3
RR2	0.74	-	0					
NWR5	10.02	NWR5	75					
RR3	0.41	Bio RR3	65	-	0	81.8	65.8	36.5
RR4	0.93	Bio RR4	150	-	0	78.9	63.3	35.6
RR5	0.96	Bio RR5	180	-	0	84.8	66.1	37.1
NWR1	5.84	-		NWR Wetland 1	4300	81.7	65.4	32.1
NWR2	6.42	Bio NWR2	75	NWR Wetland 2	4500	76.5	58.8	25.7
NWR3	1.93	Bio NWR3	300	-	0	93.3	70.4	39.3
NWR4	3.18	Bio NWR4	450	-	0	79.7	64.6	36.1
NWR6	1.51	Bio NWR6	260	-	0	81.8	65.7	37
NWR7	3.31	-	0	NWR Wetland 3	2200	57.4	49.6	24.7
Total*	**49.19**	-	**1555**	-	**26060**	**85**	**66.1**	**35**
				Load Reduction Objective		75	60	35

Comparison objectives

As discussed in Section 3 of the report, while it is generally not appropriate to use concentration-based objectives for receiving waters as a discharge objective, it is useful to compare the discharge concentrations of key pollutants from the developed site sith several possible existing case scenarios. The water quality objectives for the site have been taken from the *Queensland Water Quality Guidelines 2009* (DERM, 2009) regional values for freshwater lowland streams and wetlands. MUSIC models were set up with the same catchment areas as the developed situation described above with rural, agricultural and forest landuses. As shown in Tables A10 and A11 below, the results of the modelling show that runoff from a forested catchment typically generates pollutant runoff concentrations that are below the guideline receiving water quality objectives. Rural, agricultural and developed catchments exceed these concentrations, however pollutant runoff concentrations from the developed catchments whilst above the guideline receiving water quality objective, are typically more than forested but less than agricultural catchments of the same area.

Table A10 Comparison of 50%ile concentrations (50th %ile of the daily flow weighted mean)

Scenario	Part of site	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Rural	North wetland	4.12	0.05	0.49
	East	4.09	0.04	0.48
	Site	4.06	0.04	0.47
Agriculture	North wetland	10.72	0.07	0.75
	East	10.72	0.07	0.74
	Site	10.47	0.07	0.74
Forest	North wetland	3.99	0.02	0.29
	East	4.19	0.02	0.29
	Site	3.99	0.02	0.29
Developed	North wetland	8.91	0.09	1.17
	East	4.41	0.05	0.96
	Site	6.89	0.07	1.03
Objectives	Water Quality Objectives (for wetlands)	15	0.01 – 0.05	0.35 – 1.20
	Water Quality Objectives (for freshwater lowland streams)	15	0.01	0.24

*note that no data for SS is available in the QWQG for the wet tropics

Table A11 Comparison of 90%ile concentrations (90% of the daily flow weighted mean)

Scenario	Part of site	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Rural	North wetland	307	0.33	2.50
	East	332	0.33	2.58
	Site	328	0.33	2.56
Agriculture	North wetland	365	0.38	2.19
	East	372	0.39	2.26
	Site	372	0.39	2.24
Forest	North wetland	4.31	0.02	0.31
	East	4.19	0.02	0.30
	Site	4.18	0.02	0.30
Developed	North wetland	12.8	0.10	1.40
	East	15.3	0.10	1.33
	Site	15.4	0.10	1.33
Objectives	Water Quality Objectives (for wetlands)	15.00	0.01 – 0.05	0.35 – 1.20
	Water Quality Objectives (for freshwater lowland streams)	15.00	0.01	0.24

*note that no data for SS is available in the QWQG for the wet tropics

Pollutant load comparisons using the model as described above demonstrate that pollutant loads from the developed site are less than forest (80%) for TSS, but approximately double the pollutant loads for TP and TN (Table A12). The load comparison also shows that the developed site generates approx. 13%, 40% and 70% of the TSS, TP and TN loads generated by rural and agricultural catchments.

Table A12 Comparison of loads

Scenario	Part of site	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Rural	North wetland	178000	175	1340
	East	166000	156	1230
	Site	345000	331	2570
Agriculture	North wetland	195000	204	1170
	East	178000	188	1080
	Site	373000	392	2250
Forest	North wetland	30300	34	375
	East	27800	31	344
	Site	58100	64	719
Developed	North wetland	20500	55	522
	East	25600	85	1130
	Site	46100	139	1650