TOWNSON ROAD PRECINCT COLEBEE, NSW

Water Quality Modelling and WSUD Assessment for Rezoning Application

Hyder Consulting Pty Ltd
ABN 76 104 485 289
Level 5, 141 Walker Street
Locked Bag 6503
North Sydney NSW 2060
Australia
Tel: +61 2 8907 9000
Fax: +61 2 8907 9001
www.hyderconsulting.com

MECONE PTY LTD

TOWNSON ROAD PRECINCT, COLEBEE NSW

Civil Engineering

Water Quality Modelling and WSUD Assessment for Rezoning Application

Author	Eric Ruiz
Checker	Simon Kinsey
Approver	Greg Ives
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DOCUMENT CONTROL SHEET

Issue Rev.	Amendment	Prepared By & Date	Checked By and Date	Approved By and Date
A	First Issue	ER (15-08-2013)	SK (15-08-2013)	GI (15-08-2013)
B	Rainwater tanks added, SEI Assessment	ER (20-02-2014)	SK (20-02-2014)	GI (20-02-2014)
C	Updated MUSIC model to match latest subdivision layout	ER (07-03-2014)	SK (07-03-2014)	GI (07-03-2014)

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1 INTRODUCTION

Hyder Consulting Pty Ltd was engaged by Mecone Pty Ltd, on behalf of the Townson Road Precinct Land Owner Group, to undertake a water quality modelling / Water Sensitive Urban Design (WSDU) assessment and Stream Erosion Index (SEI) determination in support of a land rezoning application for the Townson Road Precinct (Lots 5-9 DP 27536 & Lot 48 DP 117513) in Colebee, NSW where a residential development is proposed.

The site is located to the south east of the Townson Road and Richmond Road intersection, as indicated in Figure 1. It currently has a 'General Rural' zoning classification within the Blacktown Local Government Area (LGA).

The proposed residential development is within the Blacktown City Council (BCC) Growth Centre Precinct and hence is subject to the BCC Growth Centre Precincts Development Control Plan 2010.

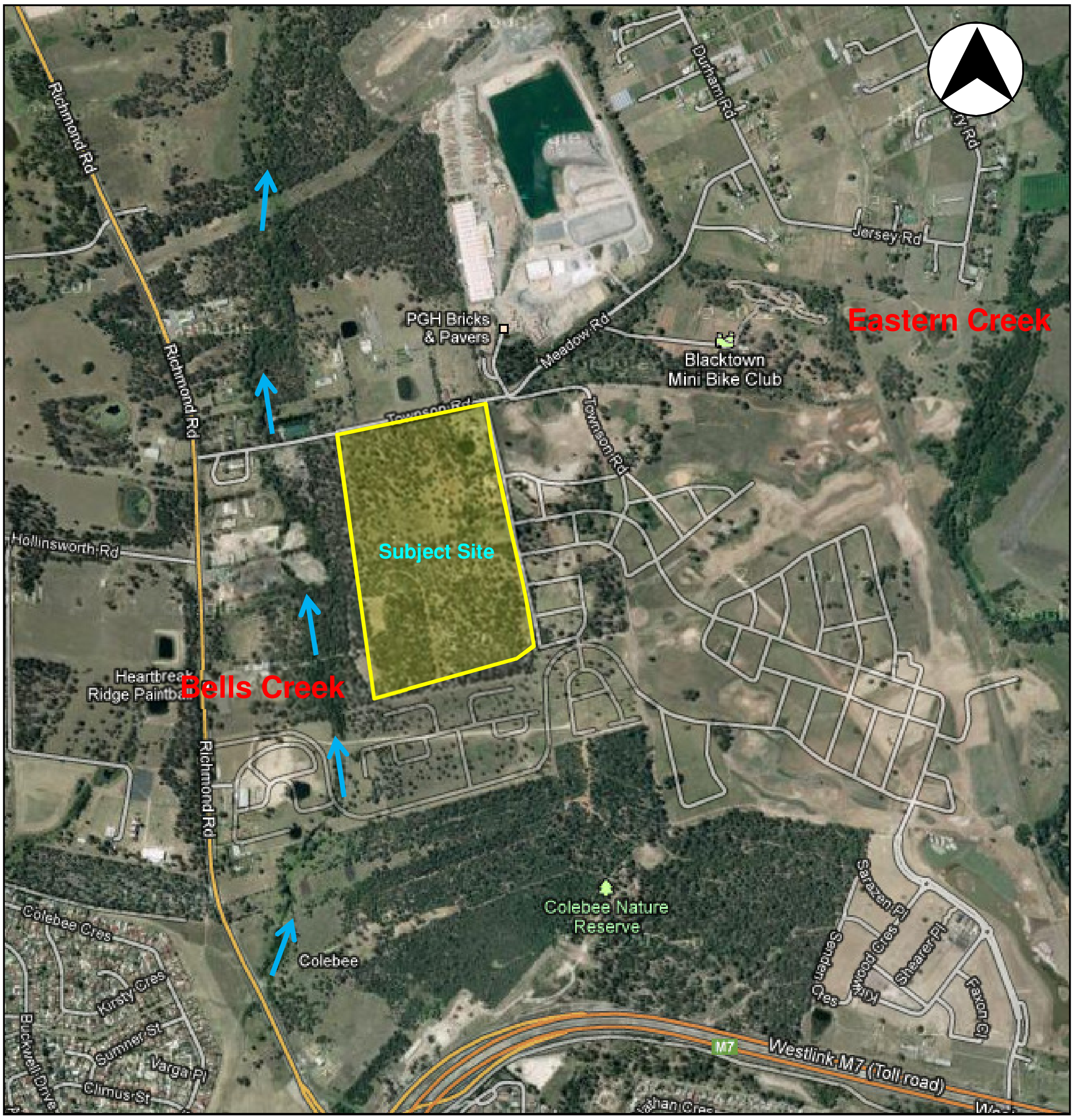

Figure 1 Site location *(Source: Google)*

In particular, this report presents the details of:

- The water quality modelling undertaken using MUSIC for the site;
- A conceptual sizing of the water quality devices (i.e. raingardens) required to achieve required pollutant reduction targets; and
- The Stream Erosion Index (SEI) assessment.

2 SITE DESCRIPTION

2.1 EXISTING SITE

The existing site (see Figure 2) is a largely undeveloped rural land dominated by grasses and trees and generally slopes to the west towards Bells Creek at a grade of about 2 to 10%.

Figure 2 Existing site conditions *(Source: Google)*

2.2 PROPOSED DEVELOPMENT

The proposed development covers an area of approximately 26 hectares. Assuming a typical lot size of about 440 m^2, the site can accommodate about 353 lots. A preliminary development layout is shown in Figure 3.

An area of about 2.7 ha from a proposed development in the adjoining land to the east of the site (areas 4 and 5 in Figure 3) will be draining into the Precinct. The proposed stormwater strategy for water quantity and water quality for the Precinct will consider these external catchments.

Two raingardens are proposed for the Precinct, one to service the northern section (areas 1 and 4) and the other to service the southern section (area 2 and 5). The south eastern corner of the Precinct (area 3) and the external catchment area 6 will not drain into the southern raingarden but have been included in the design of the raingarden within Stage 2 of the 799 Richmond Road development south of the site (also by the same owner of the Precinct).

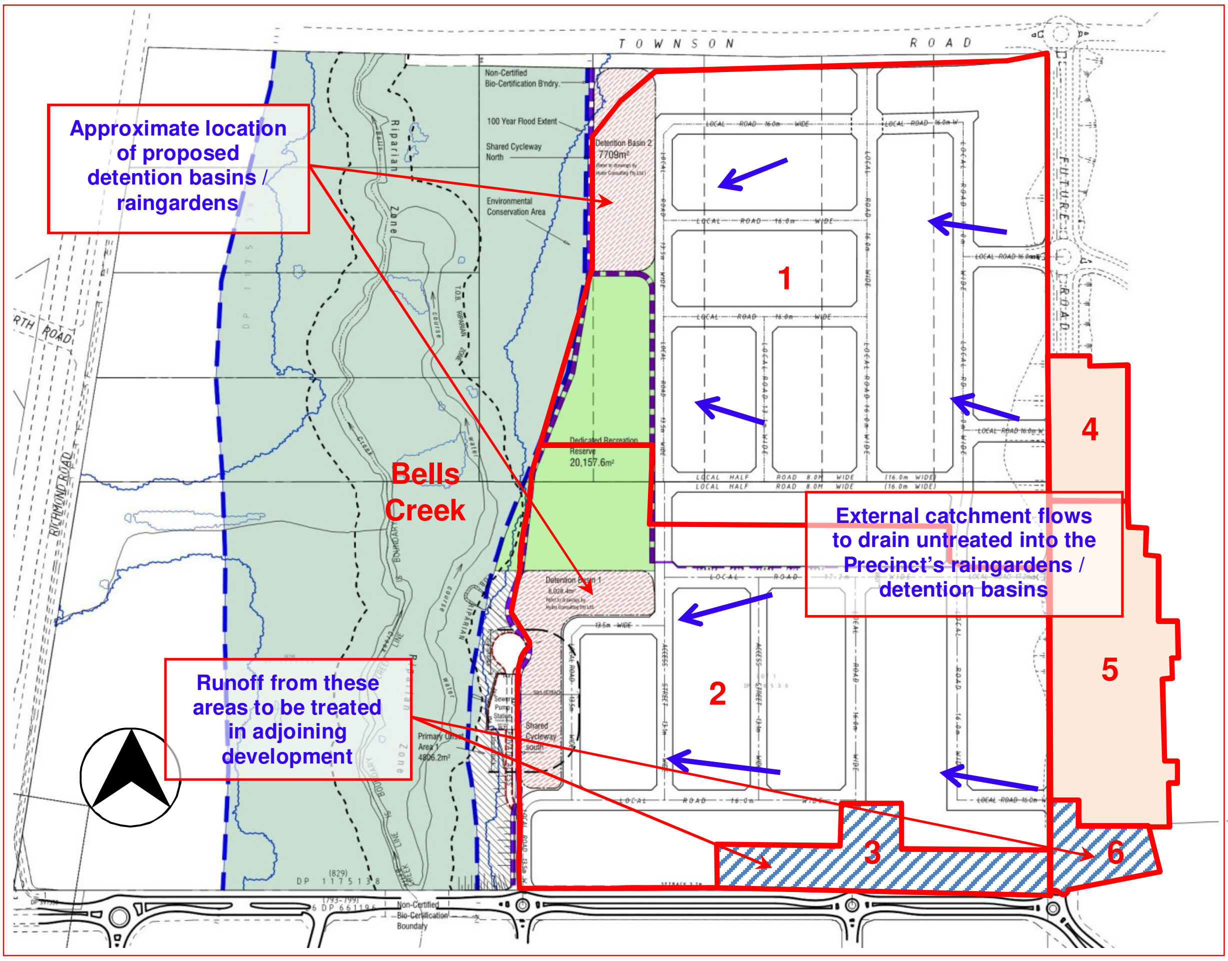

Figure 3 Indicative proposed development Master Plan & drainage configuration

3 WATER QUALITY MODELLING

A detailed water quality analysis has been undertaken by Hyder to develop the WSUD strategy for the Townson Road Precinct with site-specific opportunities and constraints identified to allow the rezoning of the Precinct while achieving and meeting the required water quality targets.

3.1 MUSIC MODELLING SETUP

The water quality analysis for this study was undertaken using the industry standard software model MUSIC (Model for Urban Stormwater Improvement Conceptualisation) Version 5.1 (Build 16). This water quality modelling software was first released in July 2002, and was developed by the Cooperative Research Centre (CRC) for Catchment Hydrology (CRC for Catchment Hydrology, 2005), which is based at Monash University in Melbourne, Australia.

The model provides a number of features relevant for the Precinct:

- It is capable to model the potential nutrient reduction benefits of gross pollutant traps and bioretention systems;
- It provides mechanisms to evaluate the attainment of water quality objectives; and
- It allows the calculation of mean annual flows for the determination of the SEI (see Section 4).

The catchments considered in the water quality analysis are the Townson Road Precinct (areas 1, 2 and 3 in Figure 3) and the adjoining external catchments (areas 4, 5, and 6 in Figure 3) with a combined area of approximately 28.5 ha. About 4.2 ha of the Precinct bypass the two raingardens. The bypassing areas include the Recreation Reserve, the detention basin areas not draining into the raingarden and the lots and roads located near the southeast corner of the catchment (area 3 in Figure 3).

The runoff from areas in the southeast corner of the catchment (i.e. areas 3 and 6) gets treated in the adjoining development south of the Precinct. These had been included in the previous water quality modelling undertaken for Stages 2, 3 and 4 of the 799 Richmond Road, Colebee Development Application.

Two raingardens to the east of Bells Creek are proposed for the Precinct. Gross pollutant traps (GPT) will be provided immediately upstream of these raingardens.

To facilitate the MUSIC modelling, the entire catchment was subdivided into the following subcatchments:

- Northern Subcatchment – areas that drain into the northern raingarden (areas 1 and 4 in Figure 3);
- Southern Subcatchment – areas that drain into the southern raingarden (areas 2 and 5 in Figure 3); and
- Bypass Areas – areas that do not drain into the two proposed raingardens (areas 3 and 6, the Recreation Reserve and the non-raingarden areas of the detention basins).

The boundary of the areas comprising the above subcatchments is as shown in Figure 3.

MUSIC modelling was undertaken to estimate the stormwater runoff pollutant loads within the site before and after the inclusion of the stormwater treatment strategy. The analysis enables the determination of the annual pollutant loads attributed to the proposed development as well as the resultant pollutant loads discharged into Bells Creek after flows go through the treatment train proposed for the development.

3.2 MODELLING DATA & PARAMETERS

3.2.1 RAINFALL DATA

Rainfall records for the area were provided by Blacktown City Council. The nearest rainfall station to the site with a reasonable period of 6 minute rainfall data for a suitably representative period of rainfall for the site nominated by Council is Liverpool. Rainfall data used in the MUSIC model is summarised in Table 1 and graphed in Figure 4.

Table 1 Rainfall data used in the Townson Road Precinct MUSIC model

Station No.	Location	Years of Record	Type of Data
67033	Liverpool	1967-1976	6 minute

It is understood that Blacktown Council have modified the data supplied by the Bureau of Meteorology (BOM) for the Liverpool site to rectify a significant amount of missing data from 1974 to 1976. The mean annual rainfall in the data set supplied by Council is 857mm, while the mean annual rainfall available from the BOM's long term data for the station closest to Colebee is 915mm (Seven Hills).

3.2.2 EVAPOTRANSPIRATION DATA

Monthly average potential evapotranspiration (PET) data was used in the MUSIC model. These PET values for Sydney are shown in Table 2 and plotted in Figure 4.

Table 2 Monthly potential evapotranspiration (PET) values for Sydney

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PET (mm)	180	135	128	85	58	43	43	58	88	127	152	163

3.3 SOIL / GROUNDWATER PARAMETERS AND POLLUTANT LOADING RATES

The adopted MUSIC rainfall-runoff parameters have been derived for the Western Sydney region from model calibration studies. The soil and groundwater parameters are summarised in Table 3.

The recommended event mean concentration values (EMC) for TSS, TP and TN for both dry and wet weather are summarised in Table 4. We note that base or dry-weather flows are generated from pervious areas only. Hence pollutant EMC values for impervious areas during dry weather are irrelevant and are left blank in Table 4.

We note that the soil/groundwater parameters and pollutant loading rates adopted for the MUSIC model are consistent with the values recommended by BCC's *Handbook Part 4: [MUSIC] Modelling Guide Draft June 2013*).

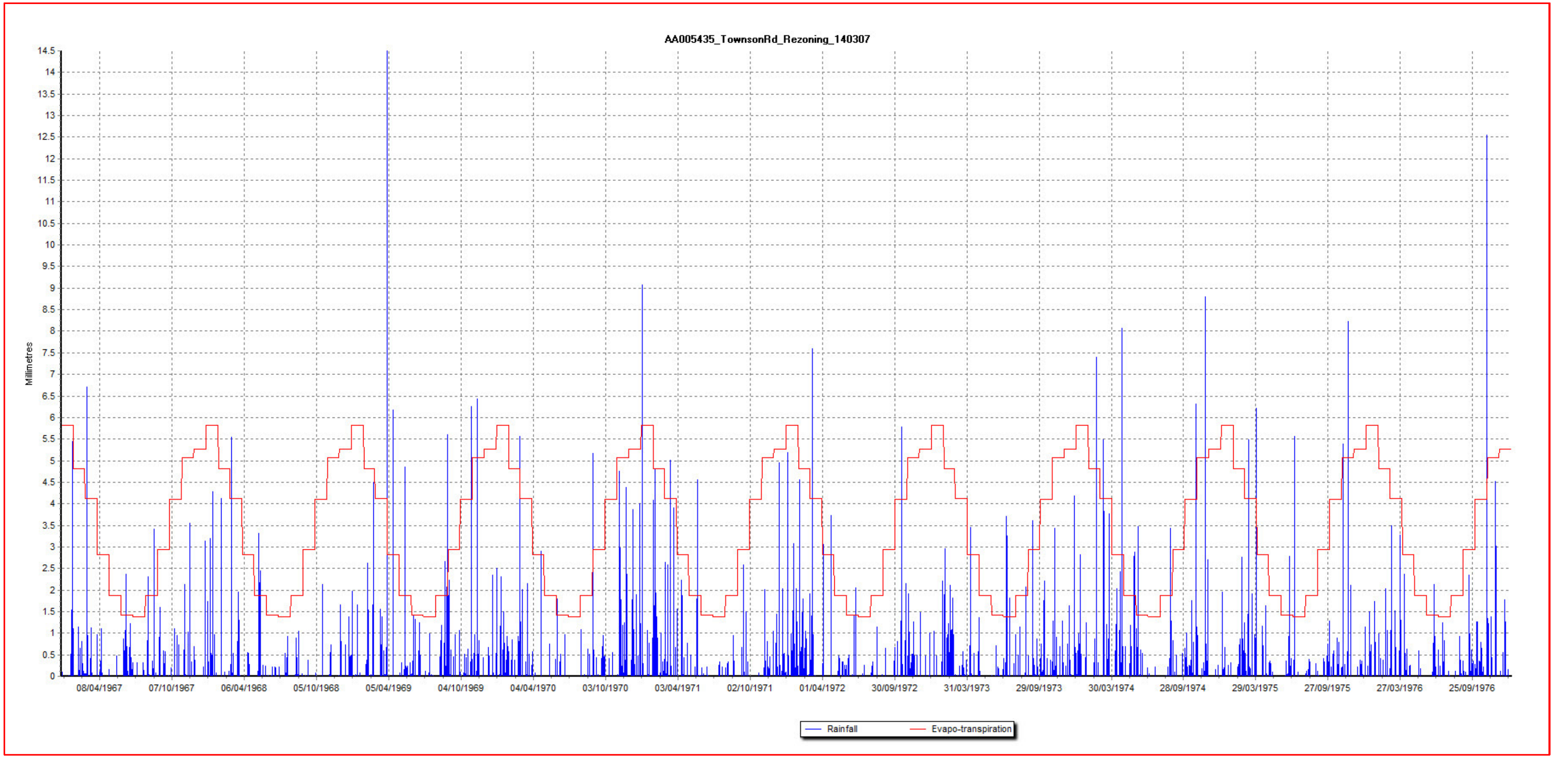

Figure 4 Rainfall and potential evapotranspiration data used in MUSIC for the 1967-1976 period

Table 3 Adopted soil and groundwater properties for the site *(Source: BCC)*

Parameter	Units	Urban
Impervious Areas		
Rainfall Threshold	mm	1.4
Pervious Areas		
Soil Storage Capacity	mm	170
Initial Storage	% of Storage Capacity	30
Field Capacity	mm	70
Infiltration Capacity Coefficient – a	-	210
Infiltration Capacity Coefficient – b	-	4.7
Groundwater Properties		
Initial Depth	mm	10
Daily Recharge Rate	%	50
Daily Baseflow Rate	%	4
Daily Deep Seepage Rate	%	0

Table 4 Adopted pollutant event mean concentrations for impervious areas *(Source: BCC)*

Pollutant	Pollutant Concentration (mg/L)							
	Roads / Carparks		Roofs		General Urban		General Pervious	
	Wet Weather	Dry Weather	Wet Weather	Dry Weather	Wet Weather	Dry Weather	Wet Weather	Dry Weather
TSS	269	-	20	-	141	-	141	15.8
TP	0.501	-	0.13	-	0.251	-	0.25	0.141
TN	2.19	-	2	-	2	-	2	1.29

3.4 WATER QUALITY TREATMENT TARGETS

In terms of water quality, the following requirement formed the basis in developing the Stormwater Quality Management Strategy for the Townson Road Precinct.

3.4.1 BLACKTOWN CITY COUNCIL DRAFT WATER CYCLE MANAGEMENT DCP

Blacktown City Council's *Draft Integrated Water Cycle Management Development Control Plan (March 2009)* recommended the following pollution retention criteria for new developments in the Blacktown LGA:

- **90%** reduction in the post development average annual gross pollutant load;
- **85%** reduction in the post development average annual TSS load;
- **65%** reduction in the post development average annual TP load; and
- **45%** reduction in the post development average annual TN load.

3.4.2 NSW PLANNING & INFRASTRUCTURE BCC GROWTH CENTRE PRECINCTS DCP 2010

The above BCC water quality targets are adopted in the NSW Planning & Infrastructure's *Development Control Plan 2010 for Blacktown City Council's Growth Centre Precincts*.

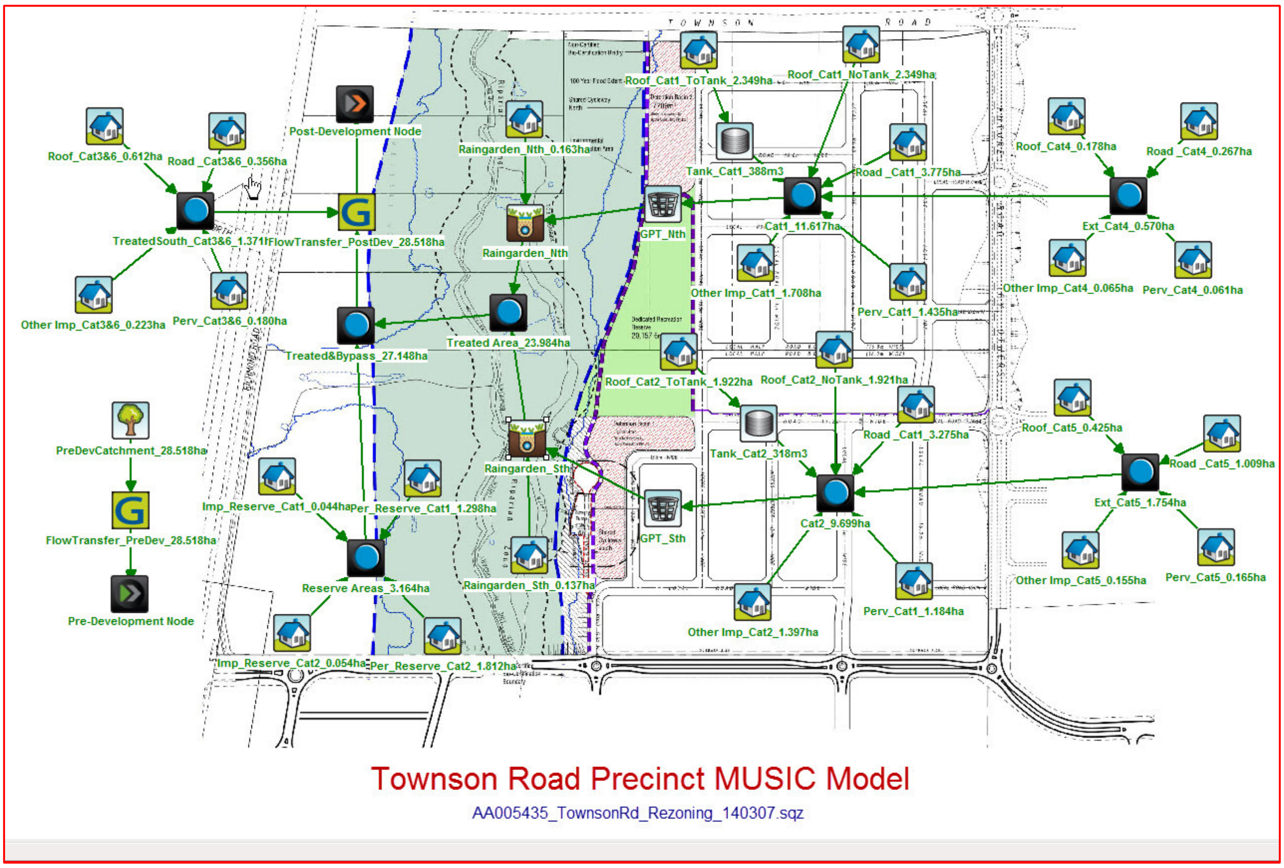

Figure 5 MUSIC model layout for the Townson Road Precinct

3.5 MUSIC MODEL & ASSUMPTIONS

A MUSIC model (see Figure 5) was developed to represent the stormwater quality management strategy proposed for the Townson Road Precinct.

3.5.1 ASSUMPTIONS

The MUSIC model for the site was developed with the following assumptions taken into consideration:

- Average lot size is 440 m^2;
- Rainwater tanks with a 2.5 m^3 volume are provided in all 353 lots (194 lots for the northern section and 159 lots for the southern section);
- Only 50% of roof areas drain into rainwater tanks;
- Each rainwater tank is modelled to have a storage volume of 2.0 m^3 and a surface area of 1.7 m^2 (as per BCC's *MUSIC Modelling Guide*);
- Rainwater reuse (internal use) rate is 0.1 kL/day per lot;
- PET-Rain is 50 kL/year per lot;
- Two raingardens are provided, one for the northern section and the other for the southern section of the Precinct;
- Areas at the south eastern corner of the site bypass the raingardens;
- The Recreation Reserve and portions of the detention basins bypass the raingardens;
- CDS-type gross pollutant traps (GPT) are provided upstream of the raingardens;
- Roads are 95% impervious;
- Lots are 80% impervious;
- All impervious areas are 100% impervious; and
- All pervious areas are 100% pervious.

3.5.2 PERCENTAGE IMPERVIOUSNESS

The various land use components (i.e. roofs, roads, pervious and other impervious areas) of the catchments that drain into the two raingardens were determined using the latest available preliminary layout plan. The areas of the different land uses that comprise the internal catchments draining into the northern and southern raingardens are summarised in Tables 5 and 6 respectively. External catchments are not included in the areas shown in these tables.

Impervious areas include the following components of the proposed development:

- Roads;
- Roofs;
- Footpaths;
- Raingardens; and
- All hardstand and paved areas.

Table 5 Pervious & impervious areas in the Precinct draining into the northern raingarden

Subcatchment	Component Areas (ha)		% Impervious
	Pervious	Impervious	
Roof	-	4.876	**100%**
Road	-	4.042	**100%**
General Impervious	-	1.936	**100%**
Pervious	1.496	-	**0%**
Entire Catchment	**1.496**	**10.854**	**88%**

Table 6 Pervious & impervious areas in the Precinct draining into the southern raingarden

Subcatchment	Component Areas (ha)		% Impervious
	Pervious	Impervious	
Roof	-	4.268	**100%**
Road	-	4.284	**100%**
General Impervious	-	1.689	**100%**
Pervious	1.349	-	**0%**
Entire Catchment	**1.349**	**10.241**	**88%**

3.6 STORMWATER MANAGEMENT CONCEPT

It is envisaged that the Townson Road Precinct development, when completed, will demonstrate how the management of the urban water cycle can be seamlessly integrated with urban planning and design. It will demonstrate how the adoption of Water Sensitive Urban Design (WSUD) principles not only serves to reduce pollutant export but also integrates well with the urban landscape.

In addition to working with the various opportunities and constraints inherent in the proposed development, the Stormwater Management Strategy proposed for Townson Road development was prepared with consideration of the requirements and guidelines listed in Section 3-4 of this report.

The stormwater management strategy proposed for the site focuses on minimising the impacts of the development on the total water cycle, and maximising the environmental, social and economic benefits achievable by utilising responsible and sustainable stormwater management practices.

The WSUD devices selected for Townson Road Precinct, namely rainwater tanks, GPTs and raingardens, are applied as part of a treatment train. The “treatment train” approach is proposed where various types of pollutants are removed by a number of devices acting in series.

3.6.1 SALIENT FEATURES OF THE STORMWATER QUALITY MANAGEMENT STRATEGY

The stormwater management strategy proposed for the Precinct utilises the latest technology for water quality management is functional, delivers the required technical performance, avoids environmental degradation and pressure on downstream ecosystems and infrastructure, and provides for a sustainable solution for stormwater management within the site. In particular, the key features of the proposed strategy are as follows:

Social

- Enhanced visual amenity through underground placement of GPTs and aesthetics provided by raingardens;

Environmental

- Limited downstream discharge peaks and velocities;
- Provision of GPTs and raingardens to achieve water quality;

Economic

- Integration with other land uses consistent with the achievement of environmental and social objectives; and
- Proposed water quality improvement measures that keep recurrent maintenance tasks and costs to a minimum.

The Stormwater Quality Management Strategy proposed for the Precinct development consists of the elements set out below.

3.6.2 ROOF RUNOFF REUSE

Re-use of roof water associated with the provision of a minimum 2500 litre rainwater tank for each lot complies with the BASIX requirements (as per BCC’s *MUSIC Modelling Guidelines*). The tanks which are plumbed into the residence for toilet flushing and on-lot irrigation will assist in the reduction of pollutant loads discharging into Bells Creek.

We note that each rainwater tank is represented in the MUSIC model to have a storage volume of 2000 litres and a surface area of 1.7 m^2. These values are consistent with BCC’s *MUSIC Modelling Guidelines*.

3.6.3 GROSS POLLUTANTS REMOVAL

CDS-type gross pollutant traps (GPT) are designed to capture and retain gross pollutants, litter, grit, sediments and associated oils (see Figure 6). They utilise continuous deflection separation (CDS) technology to isolate the pollutants from the incoming flows.

The CDS units are sized and designed by taking into account the catchment’s characteristics, pollution load, hydraulic site constraints and opportunities, system capacities, velocity, backwater, as well as the location of the services and access for cleaning. Cleaning of the CDS unit will be undertaken using a small vacuum truck. The cleaning frequency depends on the catchment type, size and expected pollutant loading.

Figure 6 A typical gross pollutant trap *(Source: ROCLA)*

3.6.4 BIORETENTION SYSTEMS

A stormwater bioretention system is a widely accepted WSUD concept that improves the quality of stormwater by filtering water through a biologically influenced media. A typical bioretention system, also known as raingarden (see Figure 7), consists of a vegetated surface overlaying a porous filter medium with a drainage pipe at the bottom. Stormwater is directed into the bioretention system flows through dense vegetation and temporarily ponds on the surface before slowly filtering down through the filter media. Depending on the design, treated flows are either infiltrated to underlying soils, or collected in the underdrain system for conveyance to downstream waterways or storages.

Figure 7 A typical raingarden

The two raingardens proposed for the Precinct will be constructed as second generation raingarden. The raingardens capture and treat stormwater flows from the upstream urban catchments before they enter Bells Creek. The vegetated top layer filters sediment and gross pollutants (including plastics, bottles and wrappers) before water gets filtered through a series of layered media (e.g. soil, sand). Together with the plants' root system, the layered media treats the flows to remove nitrogen, phosphorus, sediment, grease and oils before outflows discharge into Bells Creek.

The properties adopted for the filter media in the two raingardens are summarised in Table 7. These values are generally consistent with the values recommended in BCC's *MUSIC Modelling Guidelines*.

Table 7 Adopted properties for the northern and southern raingardens

Property	Value
Northern Raingarden	
Filter Area (m^2)	1080
Extended Detention Volume (m^3)	373
Saturated Hydraulic Conductivity (mm/hr)	100
Filter Depth (m)	0.5
TN Content of Filter Media (mg/kg)	800
Orthophosphate Content of Filter Media (mg/kg)	40
Overflow Weir Width	4.8
Southern Raingarden	
Filter Area (m^2)	1060
Extended Detention Volume (m^3)	366
Saturated Hydraulic Conductivity (mm/hr)	100
Filter Depth (m)	0.5
TN Content of Filter Media (mg/kg)	800
Orthophosphate Content of Filter Media (mg/kg)	40
Overflow Weir Width	4.8

3.7 POLLUTANT LOAD ESTIMATES

Total annual pollutant load estimates were derived using MUSIC for the Townson Road Precinct incorporating the proposed water quality treatment systems. The estimated annual pollutant loads and reductions for these subcatchments, using the MUSIC reference node "Treated&Bypass_27.148ha", are presented in Table 8.

Table 8 Summary of estimated mean annual pollutant loads and reductions for the Precinct *(Reference node: "Treated&Bypass_27.148ha")*

Criteria	Pollutant			
	Gross Pollutants	TSS	TP	TN
Total Development Source Loads (kg/yr)	4040	29100	56.6	374
Target Reduction Required (%)	**90%**	**85%**	**65%**	**45%**
Target Reduction Required (kg/yr)	3636	24735	36.8	168
Total Residual Load to Bells Creek (kg/yr)	19	4340	18.3	182
Total Reduction Modelled (kg/yr)	4021	24760	38.3	192
Total Reduction Modelled (%)	**99.5%**	**85.1%**	**67.7%**	**51.3%**

3.8 DISCUSSION OF MODELLING

The MUSIC modelling for the Proposed Development Treated Scenario has demonstrated that the proposed water quality management strategy in the Precinct will result in lower levels of Gross Pollutants, Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) compared to values resulting from the Base Scenario.

The Stormwater Quality Management Strategy proposed for the Townson Road Precinct development consists of the following elements:

- **Two raingardens** – with a combined filter media area of **2140 m^2**; and
- **Two gross pollutant traps** (e.g. CDS) – one for each raingarden placed immediately upstream.

The performance of the proposed water quality management strategy for the proposed Townson Road Precinct development obtained from the MUSIC model, as summarised in Table 8 shows that:

- In order to achieve the objective 90% reduction in **Gross Pollutants** from the proposed Townson Road Precinct development, the minimum Gross Pollutants reduction is **3,636 kg/yr**. The MUSIC modelling predicts that Gross Pollutants are reduced by **4,021 kg/yr**. The water quality management strategy therefore achieves the target reduction for Gross Pollutants.

- In order to achieve the objective 80% reduction in **TSS** from the proposed Townson Road Precinct development, the minimum TSS reduction is **24,735 kg/yr**. The MUSIC modelling predicts that TSS is reduced by **24,760 kg/yr**. The water quality management strategy therefore achieves the objective reduction for TSS.
- In order to achieve the objective 45% reduction in **TP** from the proposed Townson Road Precinct development, the minimum TP reduction is **36.8 kg/yr**. The MUSIC modelling predicts that TP is reduced by **38.3 kg/yr**. The water quality management strategy therefore achieves the objective reduction for TP.
- In order to achieve the objective of a 45% reduction in **TN** from the proposed Townson Road Precinct development, the minimum TN reduction is **168 kg/yr**. The MUSIC modelling predicts that TN is reduced by **192 kg/yr.** The water quality management strategy therefore achieves the objective reduction for TN.

The combination of rainwater tanks, gross pollutant traps and raingardens as elements of the Stormwater Quality Management Strategy for the proposed Townson Road Precinct development achieves the pollution reduction targets for Gross Pollutants, Total Suspended Solids, Total Phosphorus and Total Nitrogen recommended by Blacktown City Council.

4 WATERWAY STABILITY MANAGEMENT AND STREAM EROSION INDEX

4.1 INTRODUCTION

Blacktown City Council, the NSW Planning & Infrastructure and the Sydney Metropolitan Catchment Management Authority (CMA) have released guidelines to address the risk of stream erosion from the urbanisation of catchments. The guidelines aim toward minimal impact caused by the development on the built and natural environment downstream.

Stream erosion is assessed using a measure of the increase in the relative frequency in flows from the site greater than the identified "stream forming flow" resulting from urbanisation of the catchment. This measure is referred to as the Stream Erosion Index (SEI). The SEI assessment is considered to be an appropriate means of assessing and addressing the impacts of urbanisation on the frequency of regular flows to the riparian corridor.

The stream erosion index is defined as the post development duration of flows greater than the 'stream forming flow' or critical flow divided by natural duration of flows greater than the 'stream forming flow'. BCC defines the critical flow as the flow threshold below which no erosion is expected to occur within the waterway. For Blacktown where dispersive clay soil is prevalent, the critical flow is taken as 25% of the pre-development two year ARI peak flow at the location in question.

4.2 MODELLING

The Townson Road Precinct MUSIC model described in Section 3 was also used to determine the SEI. The procedure adopted in calculating the SEI is consistent with Council's *MUSIC modelling guidelines* as well as Sydney Metropolitan CMA's *Draft NSW MUSIC Modelling Guidelines*.

The proposed detention basins have been conservatively excluded from the SEI modelling. The pre and post development scenarios were modelled in MUSIC as it allows a continuous simulation assessment and easy extraction of the flows and durations.

A Forest node with 0% impervious was adopted to represent the pre-development case. Urban nodes representing the roofs draining to rainwater tanks, the roads and parking areas and the remaining urban areas were used to represent the post development scenario, with a total impervious area of 88%. Bioretention nodes were included to represent the raingardens that treat the runoff from the internal and external catchments. The general arrangement of the MUSIC model used for the assessment is shown in Figure 5.

A 'Generic' node was added to both the pre-development and post-development MUSIC models just upstream of the 'End' nodes. The flow transfer function in these nodes was defined to allow the calculation of the annual volume of flow above the critical flow. All inflows that are equal or less than the critical flow are converted as zero outflows. Inflows greater than the critical flow are reduced by the critical flow once they pass the generic node.

4.3 SEI TARGET

To limit erosion in the receiving waterway, the SEI for the site needs to comply with the value set by the following guidelines:

4.3.1 BLACKTOWN CITY COUNCIL DRAFT WATER CYCLE MANAGEMENT DCP & MUSIC GUIDELINES

Blacktown City Council's *Draft Integrated Water Cycle Management Development Control Plan (March 2009)* recommended that "the post-development duration of stream forming flows shall be no greater than 3.5 times the pre-developed duration of stream forming flows.

BCC's *Handbook Part 4: MUSIC Modelling Guide (Draft)* also mentioned that "the SEI has to be less than 3.5 with a stretch target of 1."

4.3.2 NSW PLANNING & INFRASTRUCTURE BCC GROWTH CENTRE PRECINCTS DCP 2010

The NSW Planning & Infrastructure's *Development Control Plan 2010 for Blacktown City Council's Growth Centre Precincts* recommends the SEI to be minimised to limit stream erosion to the minimum practicable. The DCP recommends the SEI should be within the 3.5 to 5.0 range and that development proposals should be designed to achieve an SEI as close to 1.0 as practicable.

4.4 STREAM FORMING FLOW

The 2 year ARI flow for the site was determined using the Probabilistic Rational Method. The stream forming flow was determined to be **0.403 m^3/sec**, which is 25% of the 2 year ARI peak flow. The calculation of the critical flow is summarised in Table 9.

The ten year six minute rainfall data described in Section 3.2 was adopted for the assessment. The results of the SEI assessment are summarised in Table 10 below.

Table 9 Estimation of the pre-development stream forming flow (critical flow)

JOB NO: AA005435
JOB NAME: TOWNSON RD., COLEBEE NSW

DISCHARGE POINT(S):		1		*Assume one discharge point for two detention basins*
TRIBUTARY CATCHMENT:				
	Internal Catchments	25.85	ha	
	External Catchments	2.668	ha	
	Total Catchment Area	28.518	ha	
	Total Catchment Area	0.285	km^2	
PRE-DEVELOPMENT CRITICAL FLOW				
	Time of Concentration	0.472	hr	*Probabilistic Rational Method*
	Time of Concentration	28	min	
	Rainfall Intensity (I_2)	45.8	mm/hr	*From BCC's Engineering Guide for Development*
	Runoff Coefficient (C_2)	0.444		*Provided in BCC MUSIC Guidelines*
	Peak 2 year ARI flow (Q_2)	1.612	m^3/s	
	Critical Flow ($Q_{critical}$)	0.403	m^3/s	*25% of 2 year ARI flow*

Table 10 Stream Erosion Index calculation

Catchment Condition	Mean Annual Outflow (ML/yr)	SEI
Pre-Development	10.3	**2.3**
Post-Development	23.9	

4.5 DISCUSSION OF MODELLING

The results of the modelling as summarised in Table 10 shows that:

- For the pre-development case, the Mean Annual Outflow volume in excess of the 'critical flow' volume is **10.3 ML/year** for the 10 years of rainfall data assessed.
- For the post-development case, even with the provision of the WSUD elements, the urbanisation of the catchment will result in the Mean Annual Outflow volume in excess of the 'critical flow' volume to be **23.9 ML/year** for the 10 years of rainfall data assessed.
- Dividing the post-development Mean Annual Outflow by the pre-development Mean Annual Outflow results in a **Stream Erosion Index of 2.3** which is less the value of 3.5 required by Council. We note that the resulting SEI is a conservative estimate in consideration of the two detention basins being excluded from the assessment.
- The provision of WSUD elements (i.e. rainwater tanks, GPTs and raingardens) within the development will assist in minimising the impact of urbanisation on the waterway stability of Bells Creek.

5 REFERENCES

1. CRC for Catchment Hydrology (2005). MUSIC Model for Urban Stormwater Improvement Conceptualisation – User Guide Version 3.

2. Blacktown City Council (2009). Draft Integrated Water Cycle Management Development Control Plan.

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5. Sydney Metropolitan Catchment Management Authority (2010). Draft NSW MUSIC Modelling Guidelines.